FOURTH EDITION

You Be The Chemist®

ACTIVITY GUIDE:
Lesson Plans for Making Chemistry Fun

GRADES 5–8

You Be The Chemist®

ACTIVITY GUIDE:

Lesson Plans for Making Chemistry Fun

Presented by the contributors of the Chemical Educational Foundation®,
dedicated to fostering a greater understanding of the science and value of chemistry.

GRADES 5–8

FOURTH EDITION

CHEMICAL
EDUCATIONAL
FOUNDATION®

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THANK YOU!

In addition to all of those named above, CEF would like to extend a special thank-you to the Foundation's corporate and individual contributors, as well as to the countless volunteers who work tirelessly to implement CEF programs in their communities. Without your support, the Activity Guides would not be possible!

We would also like to thank the following groups for their insight, direction, and support in the development of all CEF programs:

- *CEF's Board of Trustees*
- *CEF's Program,* You Be The Chemist® *Development, Communications, and Funding & Investment Committees*
- *The Board of Directors and staff of the National Association of Chemical Distributors*

LETTER from the Executive Director

Dear Friend,

The Chemical Educational Foundation® (CEF) welcomes you to the *You Be The Chemist®* Activity Guide: Lesson Plans for Making Chemistry Fun! Whether you are an educator, an after-school instructor, a parent, or just a fan of science, we hope that these activities will help you impart an important message to young people everywhere—science is fun, and chemistry and chemicals play an important role in all of our lives!

The Activity Guide program was originally launched in 1997 and is now in its fourth edition. With each revision, our goal has been to expand the educational content, keep in step with changing educational trends and standards, and provide meaningful connections to chemistry in our everyday lives. In this edition, enhancements include modifications and extensions for performing the experiments, more real-world applications that students can relate to their lives and to industry, in-depth activity sheets for students with answer keys for educators to test what students are learning, and tools for differentiation in the classroom.

The information included in the Activity Guide supports the framework of the National Science Education Standards (created by the National Science Academies) and is intended to make teaching science, specifically chemistry, more engaging for educators and students. Chemistry is the central science, and its concepts often extend into many other subjects as well—and not just within the traditional sciences! This guide helps students make real-world connections through hands-on activities and gives educators tools to create lifelong learners who appreciate and understand the benefits of science.

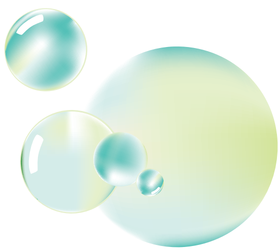
CEF extends gratitude to the many people who have played a role in the development of this Activity Guide. We acknowledge the major participants on the left of this page; however, there are many more partners not named individually. We simply don't have the space! Most notably, we would like to recognize and thank our valuable contributors and program volunteers. All of CEF's activities are only possible through their generous and loyal support.

We would also like to thank you; if you've taken the time to read this letter and review our Activity Guide, you are no doubt a champion of science education. You understand that knowledge and enjoyment are gained from the study of science. Together, we can make sure the next generation does as well!

We hope you enjoy.

Sincerely,

John M. Rice
Executive Director
Chemical Educational Foundation



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OVERVIEW

LESSON PLANS

The *You Be The Chemist*® Activity Guide: Lesson Plans for Making Chemistry Fun for grades 5–8 offers 33 classroom lessons that engage students in the exploration of chemistry through hands-on experiments. Experiment materials are nontoxic, everyday household items, and no special lab equipment is necessary. However, appropriate safety gear should be worn for each experiment.

Also included in the guide are suggested lesson modifications and extensions that offer students additional fun and interactive ways to learn about chemistry.

ACTIVITY SHEETS

Following each lesson is a corresponding activity sheet that students can complete as they perform the experiment. These activity sheets help to reinforce the concepts covered in the lesson and assess student learning. An educator's answer key with sample answers is also provided as a reference, although data may vary and other answers may be acceptable in certain cases.

RESOURCE GUIDE

This portion of the Activity Guide contains information about the Chemical Educational Foundation® and its programs. It also provides information to better assist educators, especially those with a limited chemistry background, as they present the science of chemistry to students.

The sections of the ***Resource Guide*** include ...

- ***Tips for Teaching Science, Technology, Engineering, and Math (STEM)***
- ***Safety First***
- ***Content Topics Index***
- ***Lesson Plan Vocabulary***
- ***Review Game Suggestions & Content***
- ***Sample Review Game Board***
- ***Notable Chemists***

The Importance of MEASUREMENT

Scientists use many skills as they investigate the world around them. They make observations by gathering information with their senses. Some observations are simple. For example, a simple observation would be figuring out the color or texture of an object. However, if scientists want to know more about a substance, they may need to take measurements.

Measurement is perhaps one of the most fundamental concepts in science. Without the ability to measure, it would be difficult for scientists to conduct experiments or form theories. Not only is measurement important in science and the chemical industry, it is also essential in farming, engineering, construction, manufacturing, commerce, and numerous other occupations and activities.

The word "measurement" comes from the Greek word "metron," which means "limited proportion." **Measurement** is a technique in which properties of an object are determined by comparing them to a standard.

Measurements require tools and provide scientists with a quantity. A **quantity** describes how much of something there is or how many there are. A good example of measurement is using a ruler to find the length of an object. The object is whatever you are measuring, the property you are trying to determine is the object's length, and the standard you are comparing the object's length to is the ruler.

In general, scientists use a system of measurement still commonly referred to as the "metric system." The metric system was developed in France in the 1790s and was the first standardized system of measurement. Before that time, people used a variety of measurement systems.

In 1960, the metric system was revised, simplified, and renamed the Système International d'Unites (International System of Units) or **SI system** (meters, kilograms, etc.). This system is the standard form of measurement in almost every country around the world, except for the United States, which uses the U.S. customary units system (inches, quarts, etc.). The SI system is, however, the standard system used by scientists worldwide, including those in the United States.

There are several properties of matter that scientists need to measure, but the most common properties are length and mass. **Length** is a measure of how long an object is, and **mass** is a measure of how much matter is in an object. Mass and length are classified as base units, meaning that they are independent of all other units. In the SI system, each unit of measure has a base unit.

The Importance of MEASUREMENT

The seven base units of the SI system are listed in the table below.

Measure	Base Unit
Length	**Meter (m)**
Mass	**Kilogram (kg)**
Time	**Second (s)**
Temperature	**Kelvin (K)**
Amount of substance	**Mole (mol)**
Electric current	**Ampere (A)**
Luminous intensity	**Candela (cd)**

Other SI units have been derived from the seven base units.
The table below lists some common derived units.

Measure	Derived Unit	Symbol	Base Units
Volume	**Liter**	**L**	$10^{-3} \times m^3$
Force	**Newton**	**N**	$kg \times m/s^3$
Energy, work	**Joule**	**J**	$N \times m$
Pressure	**Pascal**	**Pa**	N / m^3
Frequency	**Hertz**	**Hz**	**1 / s**

The Importance of MEASUREMENT

Some things scientists want to measure may be very large or very small. The SI, or metric, system is based on the principle that all quantities of a measured property have the same units, allowing scientists to easily convert large and small numbers. To work with such large or small numbers, scientists use metric prefixes. Prefixes can be added to base units and make the value of the unit larger or smaller. For example, all masses are measured in grams, but adding prefixes, such as milli- or kilo-, alters the amount. Measuring a human's mass in grams would not make much sense because the measurement would be such a large number. Instead, scientists use kilograms because it is easier to write and say that a human has a mass of 90 kilograms than a mass of 90,000 grams. Likewise, one kilometer is 1,000 meters, while one millimeter is 0.001 meters. The table below lists some common prefixes and the quantities they represent.

Prefix	Symbol	Numerical Value
tera	T	10^{12} (1,000,000,000,000)
giga	G	10^{9} (1,000,000,000)
mega	M	10^{6} (1,000,000)
kilo	k	10^{3} (1,000)
hecto	h	10^{2} (100)
deca	da	10^{1} (10)
NO PREFIX	--	10^{0} (1)
deci	d	10^{-1} (0.1)
centi	c	10^{-2} (0.01)
milli	m	10^{-3} (0.001)
micro	µ	10^{-6} (0.000001)
nano	n	10^{-9} (0.000000001)
pico	p	10^{-12} (0.000000000001)

New scientific instruments have allowed scientists to measure even smaller and larger amounts. Therefore, additional prefixes have been added over the years, such as femto- (10^{-15}) and exa- (10^{18}).

When scientists take measurements, they generally have two goals—accuracy and precision. **Accuracy** means to get as close as possible to the true measurement (true value) of something. **Precision** means to be able to take the same measurement and get the same result repeatedly.

Unfortunately, measurement is never 100% precise or accurate, so the true value measure of something is never exactly known. This uncertainty is a result of error. **Error** is a concept that is naturally associated with measuring because measurement is always a comparison to a standard. Manually measuring something always involves uncertainty because it is based on judgment. If two people use a ruler to measure how tall a plant is, it may look like 20 cm to one person and 18 cm to the other.

To increase the accuracy of a measurement, and therefore reduce error, an object should always be measured more than once. Taking multiple measurements and then determining the average measurement increases the likelihood that you have the exact measurement. For example, when measuring an object, you determine its length to be 10.50 cm; when you measure it again, you get a measurement of 10.70 cm. If you average these measurements, you get 10.60 cm. The length of the object is *most likely* closer to 10.60 cm than it is to either 10.50 cm or 10.70 cm.

There are two main types of error—random error and systematic error. **Random error** is not controllable. As the name suggests, the occurrence of random errors is random and due to chance. Alternatively, **systematic errors** are controllable and have a known cause. A systematic error can result from many things, such as instrument error, method error, or human error. Systematic errors can usually be identified and reduced or even eliminated.

The Importance of MEASUREMENT

PRACTICE MEASUREMENT!

Using the background information provided previously, introduce students to measurement with the easy activity below.

1. Have students (in groups or individually) measure the length, width, and height of their textbook. (Make sure students are measuring the same textbook.)
2. As the students take their measurements, have them record the numbers—with units!—e.g., 28.1 centimeters. Then have the students report their measurements to the class by writing their findings on a whiteboard or chalkboard.
3. After pooling all of their measurements, the students should notice that their recordings vary. Explain the reasons why there are differing measurements based on the information on error included on page 10.
4. After discussing error in measurement, the students (or teacher) should calculate the average measurement for the length, width, and height of the textbook. Discuss accuracy and precision with the class. (You can also have all the students take their measurements three times to test their own precision.)
5. With these measurement averages, teach them how to calculate the volume of the book. **Volume** is defined as the amount of space an object occupies. The volume of a rectangular solid can be calculated by measuring the length, width, and height of an object and then multiplying those measurements together (volume = length × width × height).

MODIFICATION/EXTENSION

1. Have 3 or 4 students volunteer to use a plastic container to collect water from a water fountain for 5 seconds each. (Measure time using a stopwatch.)
2. Then, have each volunteer pour that water into separate graduated cylinders to determine how much water they have collected. (Measure volume and record the measurements).
3. Write down each volume on the board and ask all the students to calculate the average volume of water used. (Discuss what may account for the differences. Answers may include human error in measuring time or volume, etc.)
4. Ask the students to multiply this number by the number of students in the classroom to figure out how much water would have been used if all the students collected the water.
5. Finally, have the students convert that number into liters.

EXPANDED MODIFICATION/EXTENSION TO DISCUSS WATER CONSERVATION

1. Place a rectangular plastic container under the water fountain faucet so that it covers the drain. Then, have 3 or 4 volunteers drink from the fountain for 5 seconds each. (Make sure the water that the students aren't consuming is being collected in the container.)
2. Then, have the students pour the water from the container into a graduated cylinder to determine how much water was not consumed. Divide that volume by the number of volunteers to determine the average amount of water not consumed, or lost, by each student.
3. Ask the students to multiply the average amount of water lost per student by the number of students in the classroom to figure out how much water would have been lost if they all drank from the fountain.
4. Multiply the answer from step 3 by the total number of classrooms in the school. (Discuss estimating with the students.)
5. Next, multiply that number by the number of days per year that school is in session—usually 180 days.
6. Finally, have the students convert their answer in step 5 to liters to figure out how many liters of water would be lost each school year if every student in the school drank from the fountain for 5 seconds each day. (To help them visualize the amount of water, divide the number by 2 to illustrate the number of 2-liter soda pop bottles that amount of water would fill.)

Challenge the students to explain how this relates to leaving the faucet on when brushing their teeth versus turning the faucet off.

The Importance of MEASUREMENT

CONVERTING METRIC UNITS

To work with objects that can vary drastically in size, scientists need to be able to convert between large and small measurements quickly. The SI system makes conversion simple because prefixes are based on groups of ten.

For example, a newborn baby and a large professional football player are placed onto separate balances. One has a mass of 4,000 grams, and the other has a mass of 90 kilograms. Which mass belongs to the football player? Which mass is the baby's? To figure it out, you can convert the measures into the same units:

$$4{,}000\ \cancel{g} \times \frac{0.001\ kg}{1\ \cancel{g}} = 4\ kg$$

From this conversion, we can conclude that the mass of 4,000 g (4 kg) is the baby's mass because it is much smaller than the mass of 90 kg.

QUICK CONVERSION TRICK!

To change from one prefix to another, look at the exponents for those prefixes on page 10.

1. Subtract the exponent for the first prefix from the exponent for the second prefix.
2. Then, move the decimal point that number of places to the right or left, as appropriate. (Move right to go from larger to smaller numbers. Move left to go from smaller to larger numbers.)
3. Finally, fill in with zeros, if necessary.

For example, to change centimeters (10^{-2}) to millimeters (10^{-3}), the difference between the exponents is one. Therefore, you'll move the decimal one place to the right to go from the larger centimeter to the smaller millimeter (1.0 cm = 10.0 mm). Likewise, to change millimeters to centimeters, the difference is still one, but this time you will move the decimal one place to the left to go from the smaller unit to the larger one (1.0 mm = 0.10 cm).

PRACTICE CONVERSION!

Using the background information provided on pages 8–12, introduce students to the process of converting measurements with the activity below.

1. Instruct students to use the average length measurement determined from the previous activity, Practice Measurement!, and convert the length into micrometers, millimeters, meters, and kilometers.
2. Have them do the same for the width and height measurements.
3. Review the correct answers as a class.

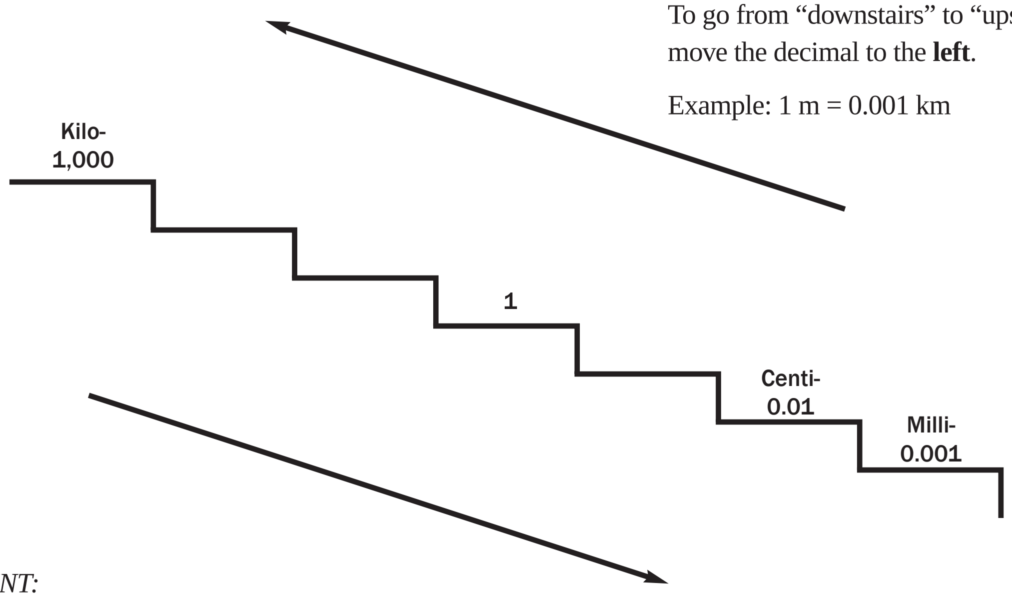
You can also provide students with the following illustration to help them visualize the process as they practice conversion.

METRIC CONVERSIONS "STAIR CHART"

HINT:

To go from "downstairs" to "upstairs," move the decimal to the **left**.

Example: 1 m = 0.001 km



HINT:

To go from "upstairs" to "downstairs," move the decimal to the **right**.

Example: 1 km = 1,000 m

SCIENTIFIC INQUIRY

Nobel Prize-winning chemist Sir Cyril Norman Hinshelwood described science as "an imaginative adventure of the mind seeking truth in a world of mystery." The different ways that scientists explore or seek truth in the world can be collectively described as scientific inquiry. The most traditional model for conducting scientific inquiry is known as the scientific method.

THE SCIENTIFIC METHOD

The scientific method is used by scientists to conduct experiments and research and record their findings. These recordings allow others to interpret and build upon their work. Because there is more than one way to explore science, different books, websites, and documents describe the scientific method in various ways. Some sources describe the scientific method in four steps. Others describe it in five steps. No matter how it is presented, the scientific method generally includes the same basic concepts, which are described in the following pages. It is important to remember that when conducting scientific inquiry, scientists may go through the process in different ways. For example, sometimes you may make a new observation after conducting research.

OBSERVATION

Scientists generally begin by making an observation. They explore and collect information with their senses (smell, sight, sound, touch, and taste), and ask a question that they would like to answer. This question will guide scientists in conducting research and experiments.

Example: Observation

- When I turn on a flashlight using the on/off switch, light comes out of one end.

Example: Question

- What makes light come out of a flashlight when I turn it on?

RESEARCH

Once scientists ask a question, they generally do research. Scientists have been asking questions for thousands of years, so there is a good chance that someone has made the same observation and asked a similar question. Therefore, after asking the question, scientists spend time reading papers and books on past research to prepare for their own research. Your students should do the same! When studying prior research, it is important that the information is from a credible source, meaning that the information and the source of the information are believable and trustworthy. Conducting research helps scientists better understand their observations or questions before they conduct experiments (and will help you and your students, too!).

Example: Research

- Look in the flashlight's instruction manual for tips, or conduct an online search on how flashlights work using the manufacturer's website. You can even analyze information and past experiments or discoveries regarding the relationship between energy and light.

HYPOTHESIS

With a question in mind, scientists decide on what they want to test. (The question may have changed as a result of research.) Scientists will clearly state what they expect to find out during the experiment. They'll develop an informed statement that could answer the question or explain the observation. This statement is called a **hypothesis**. A hypothesis guides the experiment and must be testable.

Example: Hypothesis

- The batteries inside a flashlight give it energy to produce light when the flashlight is turned on.

SCIENTIFIC INQUIRY

EXPERIMENTATION

Design and conduct an experiment that tests the hypothesis. Remember, a hypothesis is only a possible explanation, so it cannot be considered valid until an experiment verifies that it is valid.

Example:* *Experimental Procedure

1. Remove the batteries from the flashlight, and try to turn it on using the on/off switch.
   Result: The flashlight does not produce light.
2. Reinsert the batteries into the flashlight, and try to turn it on using the on/off switch.
   Result: The flashlight does produce light.
3. Write down these results.

In general, it is important to design an experiment to measure only one thing at a time. This way, you know your results are directly related to the one thing that you changed. If you do not design the experiment carefully, your results may be confusing and will not tell you anything about your hypothesis.

The things that change in an experiment are known as variables. In an experiment, scientists use two types of variables. The **independent variable** (manipulated variable) is the variable you are going to change in the experiment. The **dependent variable** (responding or outcome variable) is the variable you observe when the independent variable is changed. These variables are used to show how changes in the independent variable affect the dependent variable.

A constant or **control** is something that does not change throughout an experiment. Controls are used to make sure your comparisons are meaningful. Without controls you may not be able to tell why you got the results that you did. Often an experiment may have two or more different setups. An experimental setup is one part or one arrangement of materials in the overall experimental design. In a controlled experiment, one setup may not be changed in any way. This setup is considered the control. The control helps you to know what happens when you don't make any changes (when the setup is left alone). In the other setups, the independent variable is changed.

After your experiment, you can compare the data from the different setups. (For example, if testing the effects of different fertilizers on plant growth, a plant that receives no fertilizer would be the control setup. In the other setups, the type of fertilizer used changes.) Likewise, **controlled variables** are used to make sure you are only testing one thing. They are things that should not change during an experiment. Experiments often have many controlled variables.

Example:* *Designing an Experiment

- Independent variable: Whether or not batteries are used.
- Dependent variable: Whether or not light is produced.
- Controlled variables: The same flashlight is used each time. The on/off switch is moved into the same positions each time.

Another important principle of experimentation is that the experiment should be repeatable and give the same results every time. If experimental results cannot be repeated, this may be because of unwanted changes in controlled variables or errors. (Did you use two different flashlights? If so, there might be something else besides the battery that is making the difference.)

Through experimentation, scientists collect data. **Data** are pieces of information collected before, during, or after an experiment. To collect data, scientists read the measuring instruments carefully. Scientists usually record their data in notebooks, journals, or on a computer.

SCIENTIFIC INQUIRY

ANALYSIS

Once the experiment is complete, the data is then analyzed to determine the results. In addition, performing an experiment multiple times can be helpful in determining the credibility of your data.

Fun Fact
Although it is not common, even well-established theories and laws can be invalidated by new data.

Example:* *Analysis
- Record the results of the experiment in a table.
- Review the results that you have written down.

CONCLUSION

If the hypothesis was testable and the experiment provided clear data, scientists can make a statement telling whether or not the hypothesis was correct. This statement is known as a **conclusion**. Conclusions must always be backed up by data. Therefore, scientists rely heavily on data so they can make an accurate conclusion.

- If the data support the hypothesis, then the hypothesis is considered correct or *valid*.
- If the data do not support the hypothesis, then the hypothesis is considered incorrect or *invalid*.

Example:* *Valid Hypothesis
- The flashlight did not produce light without batteries. The flashlight did produce light when batteries were inserted. Therefore, the hypothesis that batteries give the flashlight energy to produce light is valid, given that no changes are made to the flashlight during the experiment.

Example:* *Invalid Hypothesis
- What if the flashlight did NOT produce light when the batteries were inserted? Then, the hypothesis would have to be modified to say something such as, "The batteries inside a flashlight give it energy to produce light when the batteries are in the correct orientation and when the flashlight is turned on." Then, another experiment would be conducted to test the new hypothesis.

An invalid hypothesis is not a bad thing! Scientists learn something from both valid and invalid hypotheses. If a hypothesis is invalid, it must be rejected or modified. This gives scientists an opportunity to look at the initial observation in a new way. They may start over with a new hypothesis and conduct a new experiment. Doing so is simply the process of scientific learning.

COMMUNICATION

Scientists generally tell others what they have learned. Communication is a very important component of scientific progress! It gives other people a chance to learn more and improve their own experiments. Many scientists' greatest breakthroughs would not have been possible without published communications from previous experimentation.

Every experiment yields new findings and conclusions. By documenting both the successes and failures of scientific inquiry in journals, speeches, or other public documents, scientists are contributing information that will serve as a basis for future research. Therefore, communication is an important step in future scientific discovery.

Example:* *Communication
- Write your findings in an article and share it with others, or present your findings to a group of people. Your work may guide someone else's research on creating alternative energy sources to generate light, additional uses for battery power, etc.

LESSON 1: Goofy Putty

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** 5–10 minutes

DESCRIPTION

Create a new "goofy" substance by mixing a borax solution with glue.

OBJECTIVE

This lesson demonstrates the results of a chemical reaction and compares and contrasts the properties of mixtures and solutions. By making goofy putty, students learn about measurement, mixtures, solutions, physical changes, and chemical reactions. This lesson can be extended to introduce polymers.

CONTENT TOPICS

Scientific inquiry; measurement; properties of matter; chemical reactions; mixtures (solutions); polymers

MATERIALS

- ❑ White school glue
- ❑ Borax (found in the laundry detergent aisle)
- ❑ Measuring spoons
- ❑ Clear bowls, Ziploc® bags, or small cups
- ❑ Spoons
- ❑ Water

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 20 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Most of the things around us are mixtures, like the air, the ocean, lemonade, and pizza! A **mixture** is made of two or more substances that are combined physically. When you combine glue with water, a glue-water mixture is formed. Combining borax and water creates a borax solution.

A solution is a specific type of mixture. A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). However, the mixture of glue and water is not a solution, because the glue will not quite dissolve in the water.

Scientists sort matter by its physical and chemical properties. **Physical properties** can be observed by using our senses and taking measurements. Some examples of physical properties are color, shape, boiling point, melting point, and density. **Chemical properties** can be identified by observing how a chemical reacts with other substances. Some examples of chemical properties include acidity, toxicity, and flammability. During the experiment, students can observe the different physical (and chemical) properties of the substances.

LESSON 1: Goofy Putty

When the glue mixture and borax solution are combined, a change occurs. Matter often changes, and these changes can be either physical or chemical. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s).

By adding the borax solution to the glue mixture, you start a chemical reaction. The glue molecules and the borax molecules react with each other to create a stretchy, bouncy new substance.

FORMULAS & EQUATIONS

Hydrous sodium borate (or sodium tetraborate decahydrate) is commonly known as borax.

The chemical formula for borax is $\mathbf{Na_2B_4O_7 \cdot 10H_2O}$ or $\mathbf{Na_2B_4O_5(OH)_4 \cdot 8(H_2O)}$.

The structure of this formula means that each sodium borate molecule has multiple water molecules attached to it.

White glue is primarily a mixture of water and polyvinyl acetate (PVAc).

Water has the formula $\mathbf{H_2O}$.

The formula for PVAc is $\mathbf{(C_4H_6O_2)_n}$. *The* n *stands for any number of molecules.*

Because there are various PVAc molecules and because different types of white glue have slightly different compositions, it is difficult to provide the exact chemical equation for the reaction of the borax solution and glue mixture. Essentially during the reaction, borate ions from the hydrous sodium borate cause the vinyl molecules in the glue to form cross-linked bonds. The formation of cross-linked bonds results in the creation of a new substance made up of a long, flexible chain of molecules.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures, physical and chemical properties, and chemical reactions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on solutions can be found in the Chemicals by Volume— Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

▶Mixing white school glue and borax will create a new substance that has different properties than the original substances.

Fun Fact

Initially, Silly Putty® was a novelty item marketed toward adults. In 1955, the market for the item changed, and Silly Putty® became a popular toy among kids between the ages of 6 and 12.

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 20, but focus the lesson on describing and classifying matter. Discuss physical properties in more detail and the different uses of different substances.

Another option is to spend more time on the concepts of mixtures, solutions, and chemical reactions. Use pictures and have students write down or state their answers of whether a certain substance is a solution or simply a mixture. For example, show a picture of apple juice—solution. Show a picture of chicken noodle soup—mixture. After students complete this exercise, be sure to remind them that solutions are a type of mixture. Therefore, apple juice is a mixture *and* a solution.

Likewise, use the same method to go over physical and chemical changes in more detail. For example, show a picture of a pencil. Then show a picture of the pencil broken—that's a physical change. Next, show a picture of cake batter and then a baked cake—that's a chemical change!

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Create a polymer by mixing a borax solution with glue.

OBJECTIVE

This lesson demonstrates the results of a chemical reaction, compares and contrasts the properties of mixtures and solutions, and introduces polymers. By making goofy putty, students learn about measurement, mixtures, solutions, physical changes, and chemical reactions, as well as polymers.

OBSERVATION & RESEARCH

A **molecule** is the smallest particle of an element or compound that maintains the chemical properties of that element or compound. It is composed of two or more atoms chemically bonded together by an exchange or sharing of electrons. At the beginning of the 20th century, chemists learned how to create special molecules by combining many smaller molecules in a regular pattern. These large molecules are called polymers. **Polymers** are long, chain-like molecules that are formed by connecting many repeating units (monomer units). The most common polymers are made of long chains of carbon atoms. A **monomer** is a single molecule capable of combining with other similar molecules.

When you combine the glue and the borax solution, you start a chemical reaction. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). When combined, the glue molecules and the borax molecules react with each other and bond together to make a tangled structure of long, flexible, cross-linked chains. This giant molecule, a polymer, is made up of thousands of smaller molecules. Like the goofy putty created in this lesson, nylon and plastics are also polymers.

Borate ions, provided by the borax (hydrous sodium borate), cause the vinyl molecules in the glue to form cross-linked bonds. The process of **cross-linking** continues to alter the physical properties of the polymer. As more and more bonds are formed, the characteristics of the polymer change. The polymer will eventually become brittle as additional cross-linked bonds are formed.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on polymers can be found in the Industrial Applications of Chemistry section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action.*

LESSON 1: Goofy Putty

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the amount of borax added to the glue and water mixture changes, do the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Put one teaspoon of water into your cup or bowl. Add one teaspoon of white glue and mix well. (This may be a good time to discuss mixtures.)
2. In another cup or bowl, create your borax solution. Mix one teaspoon of borax with four teaspoons of water. Stir well. The solution will become saturated, so all of the borax will not dissolve. (This may be a good time to discuss the difference between solutions and mixtures. You may also choose to discuss saturation.)
3. Add one teaspoon of the borax solution to your original cup of glue and water. Stir for 60 seconds.
4. Remove the substance and knead it with your hands for one to two minutes.

During this experiment, you will be measuring and mixing substances. If the measurements are not exact, the experiment will not work correctly. If goofy putty doesn't form, see if the students can guess why and then come up with a way to correct the problem, such as adding more borax, adding more glue, or just starting over.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. For example, what measurements did they use? What physical properties did they observe? You can use the table and Venn diagram provided in the activity sheet (or similar charts of your own) for students to record their data.

NOTES

LESSON 1: Goofy Putty

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the importance of measuring the correct quantities to obtain desired results.
- Compare and contrast mixtures and solutions.
- Identify the physical properties of the substances before and after the experiment.
- Define and identify chemical reactions.
- Differentiate between monomers and polymers (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples or have a discussion to generate other ideas as a class.

- Add some color to your lesson! Students can make their goofy putty different colors by adding food coloring. They'll simply add one drop of food coloring to the glue mixture and stir until the color seems to be spread throughout. Then, when they add the borax solution to their colored glue mixture, their goofy putty will turn out colorful as well! You can also have some students add color after the goofy putty has formed and they have shaped it into a ball. Then, cut open one goofy putty ball that had color added to the glue and water mixture, and cut open another goofy putty ball that had color added once the goofy putty ball was formed. The color added later in the process is not absorbed all the way into the ball. (You may want to have students use plastic bags or gloves when adding color to avoid getting the dye all over their hands.)
- Challenge your students with the question: Is goofy putty a solid or liquid? Let them discuss why they think one way or the other. Then you can explain that it is actually a viscoelastic liquid, which is a material that demonstrates viscous (resistance to flow) and elastic (solid) properties.

REAL-WORLD APPLICATIONS

- If done correctly, the goofy putty should resemble Silly Putty®. Have your students explore the history of Silly Putty®, which was created when engineer James Wright was attempting to create a synthetic rubber for truck tires. Use this example to explain that when doing experiments, scientists do not always get the result they want, but they still may discover something unique!
- Chemical reactions are everywhere and so are polymers! Polymers, like synthetic rubber, plastics, Teflon® (a nonstick coating used for cooking products), and Kevlar® (a synthetic fiber used in bullet-resistant products) have been produced through chemical reactions in laboratories.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 1 ACTIVITY SHEET: Goofy Putty

OBSERVE & RESEARCH

1. Write down the materials you observe.

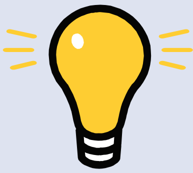
2. Predict how these materials may be used.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Solution		
Physical property		
Chemical property		
Physical change		
Chemical reaction		

4. Consider what will happen if white school glue, water, and borax are combined and why.

▶ **Write your hypothesis.**



LESSON 1 ACTIVITY SHEET: Goofy Putty

PERFORM YOUR EXPERIMENT

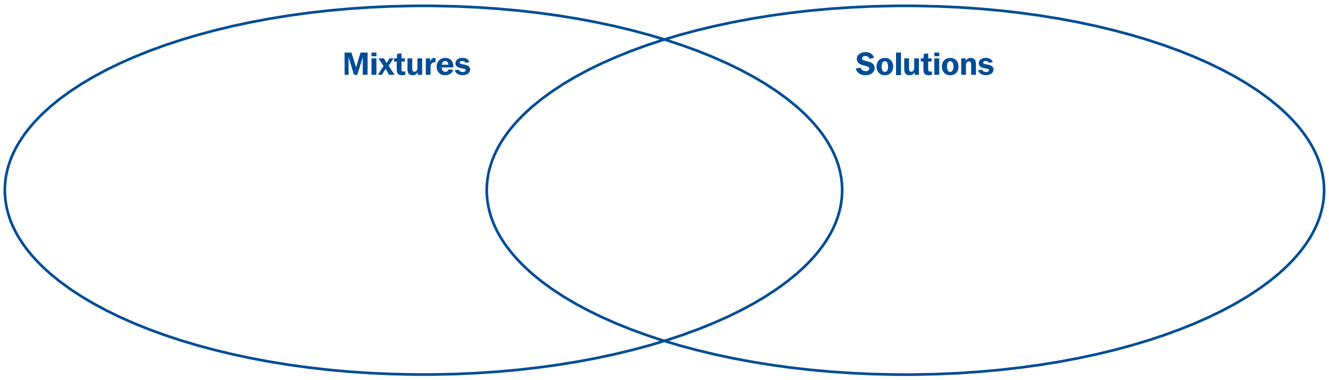
1. Put one teaspoon of water into your cup or bowl. Add one teaspoon of white glue, and mix well.
2. In another cup or bowl, create your borax solution. Mix one teaspoon of borax with four teaspoons of water. Stir well.
3. Add one teaspoon of the borax solution to your original cup of glue and water. Stir for 60 seconds.
4. Remove the substance, and knead it with your hands for one to two minutes.

ANALYZE & CONCLUDE

1. List the physical properties of each substance in the table below.

Glue	Borax	Goofy Putty
White...		

2. Compare and contrast mixtures and solutions.



3. What happens when you combine the borax solution and glue mixture? Explain how you know.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

LESSON 1 ACTIVITY SHEET: Goofy Putty

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Molecule		
Monomer		
Polymer		

2. List other substances that are polymers or are made of polymers. ______________________________

____

____

LESSON 1 ACTIVITY SHEET: Goofy Putty

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

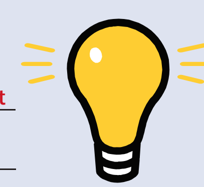
1. Write down the materials you observe. Glue, borax, water, measuring spoons ...

2. Predict how these materials may be used. Glue may be used to hold things together. Borax may be used to clean things. Water may be used for drinking, cleaning, and many other things. The different materials may be combined to create something new.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Physical property	A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance.	
Chemical property	A property of a substance that can be revealed by the way the substance interacts with other substances; describes an object's "potential" to undergo some chemical change or reaction due to its composition.	
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a chemical change.	

4. Consider what will happen if white school glue, water, and borax are combined and why.



▶ **Write your hypothesis.** Mixing white school glue, water, and borax will create a new substance that has different properties than the original substances.

LESSON 1 ACTIVITY SHEET: Goofy Putty

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

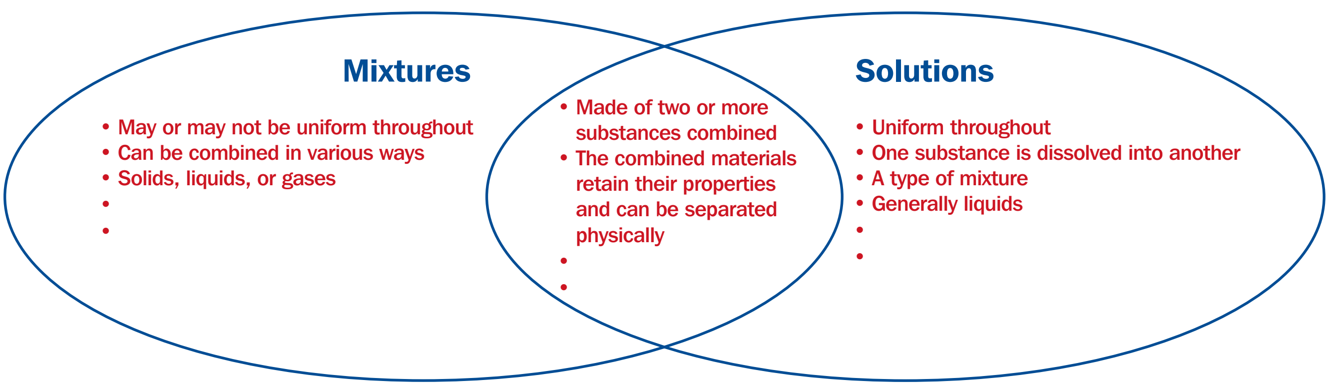
1. Put one teaspoon of water into your cup or bowl. Add one teaspoon of white glue, and mix well.
2. In another cup or bowl, create your borax solution. Mix one teaspoon of borax with four teaspoons of water. Stir well.
3. Add one teaspoon of the borax solution to your original cup of glue and water. Stir for 60 seconds.
4. Remove the substance, and knead it with your hands for one to two minutes.

ANALYZE & CONCLUDE

1. List the physical properties of each substance in the table below.

Glue	Borax	Goofy Putty
• White • Sticky • Viscous—it flows slowly • •	• White • Powdery • Granular—grainy • •	• White (unless food coloring is added) • Stretchy • Can be molded into different shapes • •

2. Compare and contrast mixtures and solutions.



3. What happens when you combine the borax solution and glue mixture? Explain how you know. A chemical reaction occurs. The resulting substance (the goofy putty) has different properties than the original substances.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 1 ACTIVITY SHEET: Goofy Putty

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Molecule	The simplest structural unit of an element or compound that is made up of atoms held together by chemical bonds and maintains the chemical properties of the element or compound.	
Monomer	A single molecule capable of combining with other similar molecules to form a polymer.	
Polymer	A large molecule formed by combining many smaller molecules (monomers) in a regular pattern.	

2. List other substances that are polymers or are made of polymers. Plastic bottles, rubber bands, tires, polyester clothing, nylon (tights), DNA, proteins …

LESSON 2: "Ageless" Apples

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** The effects can be observed over a 24-hour time period.

• DESCRIPTION

Place apple slices into solutions with different levels of acidity to change the rate at which the apples turn brown.

• OBJECTIVE

This lesson introduces acids, bases, and the pH scale as a measure of acidity. Students apply solutions with different levels of acidity to apple slices to determine what level of acidity works best to keep the apple slices from browning. This lesson can be extended to introduce proteins, amino acids, and enzymes.

• CONTENT TOPICS

Scientific inquiry; properties of matter; chemical reactions; acids and bases; food chemistry; chemistry in the human body

• MATERIALS

- ❑ Lemon juice
- ❑ Baking soda
- ❑ Water (preferably distilled)
- ❑ Apples
- ❑ Plastic sandwich bags with a snap or zip closure (or small bowls with lids)
- ❑ Permanent markers
- ❑ Measuring cups and spoons
- ❑ Knife or apple slicer

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 31 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

To describe certain chemical compounds, chemists may use the terms "acid" and "base." In general, a solution that contains a concentration of hydrogen ions (H^+) greater than the concentration in pure water is called an **acid**. Common household acids include lemon juice, vinegar, soda pop, and orange juice. Likewise, a solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than that of pure water is called a **base**. Common household bases include ammonia, baking soda, milk of magnesia, borax, and bleach. Solutions containing an H^+ concentration equal to that of pure water are **neutral**.

Fun Fact

Bases can be used to neutralize acids and vice versa.

The concentration of hydrogen ions in acids and bases are measured on the **pH scale**. The higher the concentration of H^+, the lower the pH will be. A substance with a pH

LESSON 2: "Ageless" Apples

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on acids and bases can be found in the Acids, Bases, and pH section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on food chemistry and preservation can be found in the Applications of Chemistry in Everyday Life section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

lower than 7 is considered to be acidic. The lower the concentration of H^+, the higher the pH will be. A substance with a pH higher than 7 is considered to be basic. Most substances range from 0 to14 on the pH scale, with 0 being the most acidic, 7 being neutral, and 14 being the most basic. Pure water is a neutral substance with a pH of 7.

Apples (and apple juice) are acidic. They are also perishable, which means that they will eventually go bad or decay. When apple slices are exposed to oxygen, certain organic substances in the apple, called enzymes, cause the exposed flesh of the apple to turn brown. The rate at which this browning process occurs can be slowed down by making the enzymes less active. The enzymes become less active at lower pH levels. Therefore, applying an acid to the surface of the apple slice slows the activity of the enzymes and keeps the apple from browning. However, basic solutions, such as a baking soda solution, will not lower the pH level on the surface of the apple slices.

Lemon juice is often used to keep fruit from browning because lemon juice has a very low pH. Applying lemon juice to the surface of sliced apples increases the acidity on the surface to a pH level below 2. This low pH reduces the activity of the enzymes in the apple and slows down the browning process.

FORMULAS & EQUATIONS

Lemon juice gets its acidity from citric acid.

The chemical formula for citric acid is $\mathbf{C_6H_8O_7}$.

Ascorbic acid, commonly known as vitamin C, is also found in many fruits.

The chemical formula for ascorbic acid is $\mathbf{C_6H_8O_6}$.

The vitamin C and citric acid found in citrus fruits, such as lemons, oranges, and limes, all help to prevent browning.

Sodium bicarbonate is commonly known as baking soda.

The chemical formula for sodium bicarbonate is $\mathbf{NaHCO_3}$.

The baking soda solution used in this lesson has a higher concentration of hydroxide ions and a pH level of about 9.0.

Distilled water (pure water) is neutral. It has a pH level of 7.0 and is, therefore, neither acidic nor basic.

The chemical formula for pure water is $\mathbf{H_2O}$.

Regular tap water may be slightly acidic. If you use regular tap water, you may want to discuss the difference between tap water and distilled water with your students.

HYPOTHESIS

▶ Acids and bases will have different effects on the rate at which apple slices turn brown because of the differences in their pH levels.

LESSON 2: "Ageless" Apples

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 31, but spend more time on acids, bases, and physical and chemical properties. Discuss other properties of acids—a sour taste (be sure to remind them that they should never taste an unknown substance to determine what it is!) and corrosive. Discuss other properties of bases—slippery to the touch (again, remind students they should never touch an unknown substance without proper protection, like gloves). Then, use pictures and have students write down or state their answers of whether a certain substance is an acid or base. For example, show a picture of orange juice —an acid. Show a picture of laundry detergent—a base.

Likewise, use the same method to go over chemical reactions in more detail. For example, show a picture of cake batter and then a baked cake. Ask how they know a chemical reaction occurred. Then, show a picture of a rusted nail. Again, ask how they know a chemical reaction occurred.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Use solutions of varying pH levels to affect the enzyme activity in an apple and change the rate at which apple slices turn brown.

OBJECTIVE

This lesson introduces acids, bases, and the pH scale as a measure of acidity. Students apply different solutions to apple slices to determine what pH level works best to keep the apple slices from browning and learn how acidity relates to enzyme activity. This lesson also introduces proteins, amino acids, and catalysts.

OBSERVATION & RESEARCH

Most foods contain proteins. **Proteins** are complex organic compounds that are involved in almost all cell functions. **Enzymes** are proteins that act as a catalyst by increasing the rate of chemical reactions. A **catalyst** is a substance that helps to change the rate of a reaction. During a reaction, a catalyst is not consumed or changed.

Enzymes, like all proteins, are made up of **amino acids**—the building blocks of proteins. Enzymes are formed by stringing together between 100 and 1,000 amino acids in a very specific and unique order. The chain of amino acids then folds into a unique shape that allows the enzyme to carry out specific chemical reactions very quickly.

When apples and many other fruits are cut, they may turn brown quickly. This browning occurs as a result of the exposure to oxygen in air. When a fruit is cut or bruised, its cells become damaged, allowing oxygen in the air to react with a type of chemical compound in the fruit called phenols. The rate of this oxidation reaction is increased by the enzyme polyphenol oxidase (PPO) or tyrosinase, which is also present in the fruit.

To slow down the rate at which a fruit turns brown, chemical compounds are used to control the activity of the enzymes. The activity of enzymes can be reduced by reducing the pH on the surface of the exposed fruit. The most common treatment is to apply ascorbic acid (vitamin C) to the fruit. The increase in the acidity decreases the rate of the chemical reaction between the phenols in the fruit and oxygen in the air (an oxidation reaction). Therefore, the apple slice will remain crisp and white in color for a longer amount of time.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on physical and chemical properties can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions and catalysts can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections.*
- Additional information on proteins and amino acids can be found in the Organic Chemistry section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 2: "Ageless" Apples

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the level of acidity of the solutions changes, will the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Use a marker to label three plastic bags. Label one "lemon juice," the second "baking soda," and the third "water."
2. Pour ¼ cup of lemon juice into the bag labeled "lemon juice."
3. Create a baking soda solution by mixing ¼ cup of water with one tablespoon of baking soda. Pour the baking soda solution into the plastic bag labeled "baking soda."
4. Pour ¼ cup of water into the plastic bag labeled "water."
5. Carefully cut an apple or apples into evenly sliced pieces.

Sharp objects like knives can be dangerous. You may want to cut the apples for the students, and then have them come to the front of the class to get their apple slices once they have prepared their bags.

6. Place two to three apple slices into each of the three bags. Seal the bags tightly. Gently shake each bag to make sure the apple slices are completely coated by the solution in the bag.
7. Take the apples out of the lemon juice bag, and place them on a table on top of the bag. Do the same for the apples in the other bags. Be sure to lay them on top of the right bag so you know which apples were coated with which solution.
8. Observe the apple slices immediately following the treatment. Then, set the apple slices aside for a few hours (or a day or two) and observe the differences in color of the apples as the time passes.

Although common household acids and bases are diluted, they can still pose risks. Proper safety procedures should be followed to protect your eyes, skin, clothing, and work surfaces.

Never use the sense of taste in the lab. Do not allow students to eat the apples or taste the solutions.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. For example, which substances were acids and which were bases? How long did the apple slices take to brown in each bag? You can use the table provided in the activity sheet (or a similar one of your own) for students to record their data.

NOTES

LESSON 2: “Ageless” Apples

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and understand the differences between acids and bases.
- Identify common household acids and bases.
- Understand pH and identify the pH of different solutions.
- Describe the chemical reaction (an oxidation reaction) and how they know a chemical reaction took place (see ***Differentiation in the Classroom***).
- Understand the role of enzymes (a group of catalysts) in chemical reactions (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Consider using different household acids and bases to test their effects on the apple slices. You could bring in various substances, such as lemon juice, vinegar, cola, a baking soda solution, and milk of magnesia. Then, allow students to choose two substances. Once they observe the reactions, have them guess whether the substance is an acid or base.
- Instead of water, use plain apple slices as a control. (Do not put them in any substance. Just cut them and leave them out.) Then discuss the use of controls in experiments.

REAL-WORLD APPLICATIONS

- Chemistry is important in keeping food fresh. Chemicals are added to foods to preserve their freshness, shelf life, and flavor. Challenge your students to look for a list of chemical preservatives on the labels of their favorite foods. Also discuss the importance of certain preservation methods to their health. For example, pasteurization kills bacteria in milk so that it is safer to drink.
- The acidity of foods can also affect your health. Discuss the discovery of citrus fruits as a means of preventing scurvy among explorers, pirates, and other early sailors. Talk about how it is important to consume sources of vitamin C daily.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

Fun Fact

Our stomachs contain gastric acid, which is mainly hydrochloric acid. It has a pH varying from 1 to 3. The high level of acidity is one of the causes of heartburn.

Fun Fact

Antacids are taken to relieve heartburn. It is comprised of basic solutions that neutralize the stomach acids to provide relief.

LESSON 2 ACTIVITY SHEET: “Ageless” Apples

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Acid		
Base		
pH scale		

4. Consider what will happen if apple slices are coated with the different solutions and why.

▶ **Write your hypothesis.** ____

____

____

LESSON 2 ACTIVITY SHEET: “Ageless” Apples

PERFORM YOUR EXPERIMENT

1. Use a marker to label three plastic bags. Label one “lemon juice,” another “baking soda,” and the third “water.”
2. Pour ¼ cup of lemon juice into the bag labeled “lemon juice.”
3. Create a baking soda solution by mixing ¼ cup of water with one tablespoon of baking soda. Pour the baking soda solution into the plastic bag labeled “baking soda.”
4. Pour ¼ cup of water into the plastic bag labeled “water.”
5. Collect the apple slices from your teacher.
6. Place two to three apple slices into each of the three bags. Seal the bags tightly. Gently shake each bag to make sure the apple slices are completely coated by the solution in the bag.
7. Take the apple slices out of the lemon juice bag, and place them on a table on top of the bag. Do the same for the apple slices in the other bags. Be sure to lay them on top of the right bag so you know which apple slices were coated with which solution.
8. Observe the apple slices immediately following the treatment. Then, set the apple slices aside, and observe them later at your teacher’s direction.

ANALYZE & CONCLUDE

1. Record your observations of the reactions in the table below at different time intervals. For example, the first row of the table might read: lemon juice, 30 minutes, white.

Coating Substance	Time Passed	Color of Apple Slices

LESSON 2 ACTIVITY SHEET: "Ageless" Apples

2. What effect did bases have on the apple slices? What effect did acids have? ______________________

____

____

3. List some other household substances that you think are acids. ______________________

____

____

4. List some other household substances that you think are bases. ______________________

____

____

5. Why is it useful for a chemist to know if a chemical is an acid or a base? ______________________

____

____

6. If you have an apple for lunch but don't finish it, what would be the best way to keep it fresh and crisp? ____________

____

____

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________

____

____

LESSON 2 ACTIVITY SHEET: “Ageless” Apples

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Protein		
Amino acid		
Enzyme		
Catalyst		

2. Where are proteins found in the human body? What is their role? ____________________________________

____

____

3. List some chemical reactions in the human body that use enzymes as catalysts. ______________________

____

____

LESSON 2 ACTIVITY SHEET: "Ageless" Apples

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

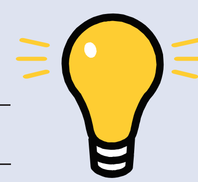
1. Write down the materials you observe. Lemon juice, baking soda, water, apples ...

2. Predict how these materials may be used. Lemon juice and baking soda may be used for cooking. Water is used for drinking, cleaning, and many other things. Apples are a healthy food to eat. The different materials may be combined, so the browning of apples (a chemical reaction) occurs at different rates.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Acid	A solution that contains an excess of hydrogen ions (H^+); acids have a higher concentration of hydrogen ions than pure water.	
Base	A solution that has an excess of hydroxide ions (OH^-); bases have a lower concentration of hydrogen ions than pure water.	
pH scale	A scale that is used to measure the acidity of (concentration of hydrogen ions in) a solution; the pH scale generally ranges from 0 to 14.	

4. Consider what will happen if apple slices are coated with the different solutions and why.



▶ **Write your hypothesis.** Acids and bases will have different effects on the rate at which apple slices turn brown because of the differences in their pH levels.

LESSON 2 ACTIVITY SHEET: "Ageless" Apples

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Use a marker to label three plastic bags. Label one "lemon juice," another "baking soda," and the third "water."
2. Pour ¼ cup of lemon juice into the bag labeled "lemon juice."
3. Create a baking soda solution by mixing ¼ cup of water with one tablespoon of baking soda. Pour the baking soda solution into the plastic bag labeled "baking soda."
4. Pour ¼ cup of water into the plastic bag labeled "water."
5. Collect the apple slices from your teacher.
6. Place two to three apple slices into each of the three bags. Seal the bags tightly. Gently shake each bag to make sure the apple slices are completely coated by the solution in the bag.
7. Take the apple slices out of the lemon juice bag, and place them on a table on top of the bag. Do the same for the apple slices in the other bags. Be sure to lay them on top of the right bag so you know which apple slices were coated with which solution.
8. Observe the apple slices immediately following the treatment. Then, set the apple slices aside, and observe them later at your teacher's direction.

ANALYZE & CONCLUDE

1. Record your observations of the reactions in the table below at different time intervals. For example, the first row of the table might read: lemon juice, 30 minutes, white.

Coating Substance	Time Passed	Color of Apple Slices
Lemon juice	30 minutes	White
Baking soda solution	30 minutes	Slightly brown
Water	30 minutes	Slightly brown
Lemon juice	1 day	White or slightly brown
Baking soda solution	1 day	Completely brown (or dark brown)
Water	1 day	Completely brown (or dark brown)

LESSON 2 ACTIVITY SHEET: "Ageless" Apples

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. What effect did bases have on the apple slices? What effect did acids have? The bases did not have any effect on the browning reaction of the apple slices, so the apples still turned brown quickly. The acids slowed the rate at which the apples turned brown, so they stayed white and crisp longer.

3. List some other household substances that you think are acids. Soda pop, vinegar, orange juice, milk, coffee ...

4. List some other household substances that you think are bases. Ammonia, bleach, milk of magnesia, antacids (such as Tums®) ...

5. Why is it useful for a chemist to know if a chemical is an acid or a base? Acids and bases react differently with other substances and can be dangerous if handled incorrectly. Acids and bases should also never be stored together because they can react violently. Determining the pH of a substance is important to lab safety.

6. If you have an apple for lunch but don't finish it, what would be the best way to keep it fresh and crisp? To keep the apple crisp, add some lemon juice or another edible acid to the apple.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 2 ACTIVITY SHEET: "Ageless" Apples

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Protein	A type of complex organic compound made up of amino acids and involved in various cell functions; proteins help the body to grow and repair damage.	
Amino acid	A substance that makes up proteins; amino acids are the building blocks of proteins.	
Enzyme	A type of protein found in living cells that acts as a catalyst by increasing the rate of a chemical reaction in living organisms.	
Catalyst	A substance that helps to change the rate of a reaction but is not consumed or changed during the reaction.	

2. Where are proteins found in the human body? What is their role? Proteins can be found in human hair, nails, organs, muscles, ligaments, skin, etc. They help the body to grow and to repair damage.

3. List some chemical reactions in the human body that use enzymes as catalysts. Enzymes help with digestion and metabolism, as well as cellular respiration.

LESSON 3: Rusting Wool

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** Allow 48 hours to observe the results.

DESCRIPTION

Place steel wool in a jar, and then invert the jar over water to observe an oxidation reaction.

OBJECTIVE

This lesson provides students with an understanding of oxidation and how rust is formed. It also allows them to gain a deeper understanding of the composition of air and the earth's atmosphere. Students use steel wool (which contains iron) to observe the reaction between iron and oxygen. The lesson can be extended to explain the importance of oxidation reactions in the body and how the process of photosynthesis releases oxygen into the atmosphere.

CONTENT TOPICS

Scientific inquiry; properties of matter; elements and compounds; molecules; chemical reactions (oxidation); metals

MATERIALS

- ❑ Shallow bowl
- ❑ Steel wool (size 0000, soap free)
- ❑ Wax crayon or dry erase marker
- ❑ 2–3 equally sized bottle caps
- ❑ Tall, slender glass or graduated cylinder (clear plastic will also work)
- ❑ Bendable drinking straw or rubber tube

⚠ Do not use steel wool pads that contain soap or cleaners. Use 0000 steel wool. If you cannot find it in an all-purpose store, it can generally be found in hardware and paint stores.

⚠ Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 45 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- LS1.A: Structure and Function (see ***Differentiation in the Classroom***)
- LS1.B: Growth and Development of Organisms (see ***Differentiation in the Classroom***)
- LS2.A: Interdependent Relationships in Ecosystems (see ***Differentiation in the Classroom***)
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

⚠ The reaction will take approximately 48 hours, so you should plan on setting up the experiment on one day and allotting time (two to three days) to make observations.

LESSON 3: Rusting Wool

OBSERVATION & RESEARCH

BACKGROUND

Steel wool is made up of very fine soft steel filaments; it is used to polish wood or metal products and for cleaning certain types of household cookware. Steel is an alloy made of the metal iron and the nonmetal element carbon. (An **alloy** is a uniform mixture made up of two or more metals or a metal and a nonmetal.) Steel wool is made from low-carbon steel, meaning that the iron content is very high, and iron is known to undergo a certain chemical reaction when exposed to moist air.

Air is composed of approximately 78% nitrogen and 21% oxygen; the rest is composed of trace gases (small amounts of other gases, such as carbon dioxide, argon, and water vapor). Most of the oxygen in our atmosphere is in the form of a **diatomic molecule**—two atoms of oxygen bound together forming a molecule of O_2. Some of the oxygen in our upper atmosphere is **triatomic**—three atoms of oxygen bound together to form a molecule of O_3. The triatomic form of oxygen is commonly called ozone, which forms the ozone layer.

Fun Fact

Oxygen is what allows a fire to burn. With no oxygen, there can be no fire.

When oxygen interacts with other substances, an oxidation reaction often occurs. **Oxidation** is defined as the loss of at least one electron when two or more substances interact. Those substances may or may not include oxygen. The process of oxidation can be seen all around you. It causes fruit to spoil, it reacts with glucose in the body to produce energy, and it causes iron objects to rust. **Rust** is a common name for iron oxide, the brittle reddish-brown substance that will form on the metal.

In this experiment, the water level in the jar should rise as the oxygen inside combines with the iron in the steel wool. That oxygen does not disappear; it simply becomes part of the compound iron oxide. The consumption of the oxygen gas by the iron creates a slight vacuum in the jar.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and chemical reactions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on elements and molecules can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on oxidation and chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

As a result, water will rise up in the jar to take the place of the missing oxygen gas. Air pressure outside of the jar pushes water up into the jar as the oxygen is consumed. The volume of gas in the jar should decrease by approximately 20%, which corresponds to the approximate percent of oxygen in the atmosphere. This volume change will be represented by the amount the water rises.

LESSON 3: Rusting Wool

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Place steel wool in a glass and then invert the glass over water to observe a chemical reaction.

OBJECTIVE

This lesson demonstrates the results of a chemical reaction and compares and contrasts the properties of different substances. It also allows students to gain a deeper understanding of solids, liquids, and gases. Students use steel wool (which contains iron) to observe the reaction between iron (a solid metal) and oxygen gas.

OBSERVATION & RESEARCH

Scientists sort matter by its physical and chemical properties. **Physical properties** can be observed by using our senses and taking measurements. Some examples of physical properties are color, shape, boiling point, melting point, and density. **Chemical properties** can be identified by observing how a chemical reacts with other substances. Some examples of chemical properties include acidity, toxicity, and flammability. During the experiment, students can observe the different physical (and chemical) properties of the substances.

Steel wool is made mostly of the element iron. When iron interacts with oxygen in moist air, a change occurs. Matter often changes, and these changes can be either physical or chemical. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). By placing the steel wool in a jar with plenty of oxygen and water, you start a chemical reaction. The iron and the oxygen react to form a new reddish-brown substance, called iron oxide or rust.

In this experiment, the water level in the glass should rise as the oxygen inside combines with the iron in the steel wool. That oxygen does not disappear; it simply becomes part of the compound iron oxide. The consumption of the oxygen gas by the iron creates a slight vacuum in the glass. As a result, water will rise up in the glass to take the place of the missing oxygen gas. This process is called displacement. **Displacement** occurs when one substance takes the place of another. The water takes the place of the consumed oxygen. Therefore, the water level in the glass will rise.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on physical and chemical properties and physical and chemical changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*
- Additional information on displacement can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 3: Rusting Wool

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Use the experiment to further explore the process of oxidation in the body, as well as the release of oxygen in the atmosphere through photosynthesis. Oxygen is a naturally abundant gas that makes up approximately 21% of the air on the earth. Oxygen also makes up most of the mass in a water molecule. Since water makes up a significant part of the human body, the majority of the human body's mass comes from oxygen. It is about 65% of a human's mass.

Oxygen is an essential element for all living things. Humans and other animals breathe in oxygen gas from the air. Oxygen is used in the body's cells in the process of respiration. **Respiration** is a set of reactions that take place inside the cells to convert energy from nutrients into a type of stored energy that can be used by the body. **Aerobic respiration** is the oxidation of food molecules, like glucose, to release energy, carbon dioxide, and water.

The process is represented by the following chemical equation:

$$C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + \text{energy}$$

Alternately, oxygen is released in the atmosphere through the process of photosynthesis. **Photosynthesis** is the chemical reaction that occurs within a plant when it uses light energy to convert carbon dioxide and water that it absorbs from the atmosphere into glucose. The process of photosynthesis produces oxygen as a byproduct.

The chemical equation for photosynthesis is:

$$6CO_2 + 12H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Chlorophyll is a key molecule for photosynthesis. It is found in the chloroplasts in a plant's cells. Chlorophyll gives plants their green color and is how plants absorb sunlight.

FORMULAS & EQUATIONS

Iron oxides are a group of chemical compounds formed between oxygen and iron. One of the most common iron oxides is iron (III) oxide, known as rust.

The chemical formula for rust is $\mathbf{Fe_2O_3}$.

Rust is formed when iron reacts with oxygen in moist air.

The following chemical equation represents the reaction: $4Fe + 3O_2 \rightarrow 2Fe_2O_3$.

Water is necessary for the oxidation reaction to occur and to facilitate transport of the electrons. Since there are water droplets in the air, iron will rust over time when exposed to the air.

HYPOTHESIS

▶ Steel wool placed in a glass that is inverted over water will react with oxygen to form rust, causing the water level in the glass to rise.

LESSON 3: Rusting Wool

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the iron oxidizes, will the water level in the bowl change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

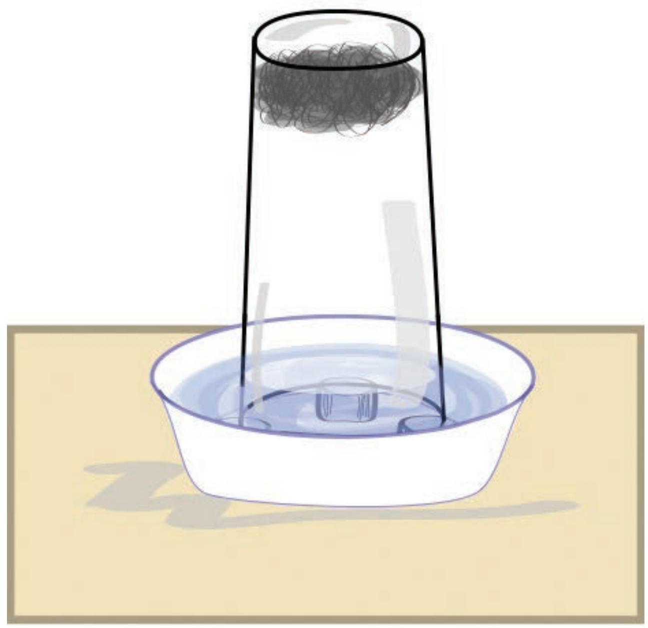
EXPERIMENTAL PROCEDURE

1. Partially spread apart the fibers of the steel wool pad.
2. Moisten the steel wool pad with tap water and shake off any excess water.
3. Gently push the pad to the bottom of the graduated cylinder or glass. Do not squeeze the fibers of the steel wool pad together.
4. Invert the glass. The pad should remain near the bottom (now the top) of the glass.
5. Fill the shallow bowl with water. Place the bottle caps on the bottom of the bowl to lift the glass off the bottom. Then, place the inverted mouth of the glass on top of the bottle caps in the water, but keep the lip of the glass submerged in the water. (If using a graduated cylinder, it is easiest to make sure the water level reaches the 100 mL mark on the cylinder.)
6. The water level in the glass should align with the water level in the bowl. If it does not, use a straw or rubber tube to remove or add air to the interior of the inverted glass. Remove the tube or straw once the water levels are equalized.
7. Use the marker or crayon to indicate the initial water level by marking a line on the exterior of the glass. (If using the graduated cylinder, observe the water level change using the markings already on the cylinder.)
8. Check and mark the water level in the glass for the next couple of days.

If you do not want to make marks directly on the glass, put a piece of tape vertically along the glass and make the marks on the tape.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. For example, what changes occurred in the glass? What happened to the water level? You can use the table provided in the activity sheet (or a similar one of your own) for students to record their data.



LESSON 3: Rusting Wool

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and identify chemical reactions.
- Understand the composition of air.
- Differentiate between the molecular forms of oxygen.
- Understand the process of oxidation, specifically the formation of rust.
- Explain why the water level inside the glass is rising and how it relates to displacement.
- Describe the processes of photosynthesis and respiration (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Discuss the composition of air with your students. Ask them if air is a pure substance or a mixture and how they know. Discuss the importance of oxygen to living organisms and how it is replenished in our atmosphere. You can also discuss photosynthesis and why plants are important to humans and the world. See the ***Differentiation in the Classroom*** section for more information.
- Try leaving the steel wool on a ledge near the window and observe it over the semester. Do you notice any changes? Does the chemical change occur faster or slower than the reaction in the jar? Challenge students to explain why they think this is the case.

REAL-WORLD APPLICATIONS

- Chemical reactions that involve oxidation occur all around us. Along with the important oxidation processes that occur in the human body, all combustion (burning) reactions involve oxidation.
- Iron and steel are used to make a variety of products, especially those used in the construction and auto industries. Many large buildings and structures, like stadiums and bridges, are supported by steel supports. Likewise, car bodies are often constructed of steel. In addition, steel products are used in major home appliances, like refrigerators and dishwashers, and in surgical equipment. Why use steel in environments with so much water and oxygen? The type of steel used in these products is known as stainless steel. Stainless steels and surgical stainless steels contain chromium and/or nickel to make them resistant to rusting.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 3 ACTIVITY SHEET: Rusting Wool

OBSERVE & RESEARCH

1. Write down the materials you observe. ____________________

____

____

2. Predict how these materials may be used. ____________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical change		
Chemical reaction		
Alloy		
Diatomic molecule		
Triatomic molecule		
Oxidation		

4. Consider what will happen when the steel wool interacts with oxygen and water in the air and why.

▶ **Write your hypothesis.** ____________________

____

____

LESSON 3 ACTIVITY SHEET: Rusting Wool

PERFORM YOUR EXPERIMENT

1. Partially spread apart the fibers of the steel wool pad.
2. Moisten the steel wool pad with tap water, and carefully shake off any excess water.
3. Gently push the pad to the bottom of the glass. Do not squeeze the fibers of the steel wool pad together.
4. Turn the glass upside down. The steel wool pad should remain lodged near the bottom (now the top) of the glass.
5. Fill the shallow bowl with water. Place the bottle caps on the bottom of the bowl to lift the glass off the bottom. Then, place the inverted mouth of the glass on top of the bottle caps in the water, but keep the lip of the glass submerged in the water. (If using a graduated cylinder, make sure the water level is at the 100 mL mark on the cylinder.)
6. The water level in the glass must match the water level in the bowl. If it does not, use a straw or rubber tube to remove or add air to the inside of the glass. Remove the tube or straw once the water levels are equal.
7. Draw a line with a crayon or marker on the exterior of the glass to mark the initial water level. Check and mark the water level in the glass for the next couple of days and make observations. (If using the graduated cylinder, record the water level change using the markings already on the cylinder.)

ANALYZE & CONCLUDE

1. Record your observations of the water level at different time intervals. (Measure the height of the mark on the glass in centimeters using a ruler or using the markings on the graduated cylinder.)

Time	Water Level (height in cm)

LESSON 3 ACTIVITY SHEET: Rusting Wool

2. Graph the data on graph paper. Do you notice a relationship? ____

3. Is the water level inside the glass rising or falling? ____

4. What is causing the water level to change inside the glass? ____

5. Write down any other changes you noticed inside the glass. What do you think caused the change? ________________

6. What substance forms when iron and oxygen interact in moist air? (What is its chemical name? What is its common name?) ____

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

LESSON 3 ACTIVITY SHEET: Rusting Wool

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Respiration		
Aerobic respiration		
Photosynthesis		

2. What are the two main gases that make up the air? ______________________________

____

3. List some other gases that make up the air. ______________________________

____

4. Write the chemical equations for respiration and photosynthesis. What do you notice about these equations?

____

____

____

____

____

LESSON 3 ACTIVITY SHEET: Rusting Wool

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

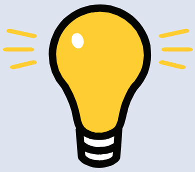
1. Write down the materials you observe. Steel wool, water, drinking straws, bottle caps, tall slender glass …

2. Predict how these materials may be used. Steel wool may be used in cleaning dishes. Water is used for drinking, cleaning, and many other things. Drinking straws are used to drink different liquids like water or juice. These materials may be used to demonstrate the oxidation of the iron in the steel wool.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances.	
Alloy	A uniform mixture made up of two or more metals or of a metal and a nonmetal.	
Diatomic molecule	A molecule consisting of two atoms bound together, such as diatomic oxygen gas (O_2).	
Triatomic molecule	A molecule consisting of three atoms bound together, such as ozone (O_3).	
Oxidation	The loss of at least one electron when two or more substances interact, which may or may not involve oxygen.	

4. Consider what will happen when the steel wool interacts with oxygen and water in the air and why.



▶**Write your hypothesis.** Steel wool placed in a glass that is inverted over water will react with oxygen to form rust, causing the water level in the glass to rise, as it replaces the consumed oxygen gas.

LESSON 3 ACTIVITY SHEET: Rusting Wool

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Partially spread apart the fibers of the steel wool pad.
2. Moisten the steel wool pad with tap water, and carefully shake off any excess water.
3. Gently push the pad to the bottom of the glass. Do not squeeze the fibers of the steel wool pad together.
4. Turn the glass upside down. The steel wool pad should remain lodged near the bottom (now the top) of the glass.
5. Fill the shallow bowl with water. Place the bottle caps on the bottom of the bowl to lift the glass off the bottom. Then, place the inverted mouth of the glass on top of the bottle caps in the water, but keep the lip of the glass submerged in the water. (If using a graduated cylinder, make sure the water level is at the 100 mL mark on the cylinder.)
6. The water level in the glass must match the water level in the bowl. If it does not, use a straw or rubber tube to remove or add air to the inside of the glass. Remove the tube or straw once the water levels are equal.
7. Draw a line with a crayon or marker on the exterior of the glass to mark the initial water level. Check and mark the water level in the glass for the next couple of days and make observations. (If using the graduated cylinder, record the water level change using the markings already on the cylinder.)

ANALYZE & CONCLUDE

1. Record your observations of the water level at different time intervals. (Measure the height of the mark on the glass in centimeters using a ruler or using the markings on the graduated cylinder.)

Time	Water Level (height in cm)
For time, measure whenever it is convenient for your class. Recommended intervals are below.	Answers will vary depending on the diameter of the glass and time intervals used.
6 hours	
12 hours	
24 hours	
48 hours	

LESSON 3 ACTIVITY SHEET: Rusting Wool

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. Graph the data on graph paper. Do you notice a relationship? Yes. The water level in the glass rises over time.

3. Is the water level inside the glass rising or falling? The water level inside the glass is rising.

4. What is causing the water level to change inside the glass? The water level inside the glass is changing because as the iron in the steel wool oxidizes, oxygen is removed from the air. The water level rises to take the place of the consumed oxygen gas.

5. Write down any other changes you noticed inside the glass. What do you think caused the change? Inside the glass, the water may appear slightly reddish brown. This color change occurs because the rust from the steel wool falls into the water.

6. What substance forms when iron and oxygen interact in moist air? (What is its chemical name? What is its common name?) Iron (III) oxide, Fe_2O_3, is formed when iron and oxygen interact in moist air. The common name for iron (III) oxide is rust.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 3 ACTIVITY SHEET: Rusting Wool

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Respiration	A set of reactions that take place inside cells to convert the energy stored in food into another type of chemical energy that can be used by the body.	
Aerobic respiration	The chemical process by which food molecules, like glucose, combine with oxygen to release energy, carbon dioxide, and water.	
Photosynthesis	The process by which some living organisms, primarily green plants, convert light energy, carbon dioxide, and water into oxygen gas and sugars that store chemical energy.	

2. What are the two main gases that make up the air? Nitrogen (N_2) and oxygen (O_2) are the two main gases that make up the air.

3. List some other gases that make up the air. Argon, carbon dioxide, neon, helium, methane, krypton, and hydrogen also make up the air.

4. Write the chemical equations for respiration and photosynthesis. What do you notice about these equations?

Aerobic respiration is represented by $C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O$ + energy. Photosynthesis is represented by $6CO_2 + 12H_2O$ + light energy $\rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$. These equations are opposite reactions. Aerobic respiration that occurs inside the bodies of humans or animals produces the chemicals necessary for plants to carry out photosynthesis, and vice versa.

LESSON 4: Buoyant Butter

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 5–10 minutes

• DESCRIPTION

Calculate the density of a stick of butter to determine if it will sink or float in water.

• OBJECTIVE

This lesson teaches students about density, how to calculate it, and how it is related to determining whether an object will sink or float in a certain liquid. Students will measure sticks of butter or margarine to determine whether they will sink or float in water. The lesson can be simplified to reinforce the importance of measurement in a scientific experiment.

• CONTENT TOPICS

Scientific inquiry; measurement; properties of matter (density)

• MATERIALS

- ❑ Stick of butter or margarine (with the wrapper on)
- ❑ Metric ruler
- ❑ Large bowl or container

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 58 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Mass and volume are common units of measure. Mass is a measure of the amount of matter in a substance. (It's the amount of "stuff" in a substance.) Volume is the amount of space an object occupies.

Density is an important concept in chemistry that is defined as the mass of an object per unit volume. Density is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are. The formula used to calculate density is **d = m/v**, where d is the density, m is the mass of the object, and v is the volume of the object.

Scientists use density in different ways. They use it to identify unknown substances and to separate different liquids.

In this experiment, students determine the density of an object and compare it to the density of water. The approximate density of liquid water is 1.0 gram per milliliter (g/mL). This means that one milliliter of water will have a mass of one gram; thus, it will weigh one gram on the earth. In general, a substance that is less dense than water will rest on top of the water, and a substance that is denser than water will sink. Therefore, a copper coin, which has a density of 8.96 g/cm^3 would sink in water. On the other hand, if we have a 10-gram piece of wood with a volume of 20 milliliters, we would first calculate the density of the wood. Using the equation, we know that the density of the wood is 0.5 g/mL. Because this number is less than the density of water (1.0 g/mL), the wood will float.

You can also determine whether the wood will float using another method. Since we know the object weighs 10 grams and the volume is 20 milliliters, we can then determine how much 20 milliliters of water weighs. The answer (using the density equation) is 20 grams, which is more than the piece of wood. Therefore, again, we know that the wood will float.

Density, however, is not the only consideration. Think about a ship made of steel. Although steel has a density greater than water, the shape of the boat spreads the weight of the steel over a larger space. In addition, some of that space is filled with air, which is much less dense than water. Therefore, whether an object sinks or floats also has to do with displacement. **Displacement** occurs when one substance takes the place of another. When an object is placed in water, it will displace some of the water. (Think about sitting in a bathtub. When you sit down, the water will rise, as your body takes the place of some of the water.) In general, if an object weighs more than the water it displaces, the object will sink. If an object weighs less than the water it displaces, it will float. **Buoyancy** is the upward force that a fluid exerts on an object that enables the object to float. The buoyant force on an object is equal to the weight of the fluid displaced by the object.

FORMULAS & EQUATIONS

Certain laboratory equipment can be used to gather different measurements. The mass of an object can be determined by using a balance. The volume of a liquid can be easily determined by pouring the liquid into a graduated cylinder. For solid objects, measuring volume takes a little more effort. You can calculate the volume of rectangular solids with the following equation:

$$v = l \times w \times h$$

where v is the volume, l is the length of the object, w is the width of the object, and h is the height of the object.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on measurement and types of physical measurements can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on displacement can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

The volume of a solid is therefore measured in cubic centimeters (or cubic meters). For solids with an irregular shape, you can use a displacement method.

Once the mass and volume of an object have been determined, the density of that object can be calculated.

Use the following equation: **d = m/v**.

Density is measured in grams per milliliter or grams per cubic centimeters. One cubic centimeter (cm^3 or cc) is equal to one milliliter (mL).

HYPOTHESIS

▶ Density can be calculated using the mass and volume of an object. If the average density of an object is less than the average density of water, it will float.

LESSON 4: Buoyant Butter

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Practice performing different measurements to reinforce the importance of measurement and explain the difference between accuracy and precision. Students will calculate the mass, volume, and density of different sized pieces of butter.

OBJECTIVE

This lesson reinforces the importance of measurement and allows students to practice measuring mass, volume, and density.

OBSERVATION & RESEARCH

Measurement is perhaps one of the most fundamental concepts in science. It is the process of determining the ratio of a physical quantity, such as length or a mass, to a unit of measurement. Without the ability to measure, it would be difficult for scientists to conduct experiments or form theories. Not only is measurement important in science, but it is also essential in industry, farming, engineering, construction, manufacturing, commerce, and numerous other occupations and activities.

A good example of measurement is using a ruler to find the length of an object. The object is whatever you are measuring, the property you are trying to determine is the object's length, and the standard you are comparing the object's length to is the ruler.

Scientists have two goals when they take measurements. They want their measurements to be accurate by getting as close as possible to the true measurement of something. They also want their measurements to be precise so that they can take the same measurement and get the same result over and over. You should strive to achieve **accuracy** and **precision** in your measurements.

Measurement is never 100% accurate, so the true value of a measurement is never exactly known. This uncertainty is a result of error, a concept which is associated with measuring, because measurement is always a comparison to a standard. Manually measuring something always involves uncertainty because it is based on judgment. If two people use a ruler to measure how tall a plant is, it may look like 20 cm to one person and 18 cm to the other.

To increase the accuracy of a measurement, therefore reducing error, an object should always be measured more than once. Taking multiple measurements and then determining the average measurement increases the likelihood that you have the exact measurement.

There are several properties of objects that scientists need to measure, but the most useful and common properties are length and mass. **Length** is a measure of how long an object is, and **mass** is a measure of how much matter is in an object. Mass and length are base units, meaning that they are independent of all other units. Most units of measure, such as volume and density, are derived or calculated from base units.

For example, density is derived from the base measurement units of mass and length. **Density** is an important concept in chemistry, defined as the mass of an object per unit volume. Density is a physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are. The formula used to calculate density is **d = m/v**, where d is the density, m is the mass of the object, and v is the volume of the object.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on measurement can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on measuring mass and volume can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on density can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 4: Buoyant Butter

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described below, but explore the concept of density further. Have students perform different measurements and calculate the density of various objects. Discuss density as it relates to solids, liquids, and gases. Can liquids "float" on top of one another? See the ***Modifications/Extensions*** section for other ideas to reinforce the concept of density.

Another option is to discuss buoyancy in more detail, as well as other forces, such as gravity, friction, and nuclear forces. Explore the differences between those forces.

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the volume of the stick of butter, will it act the same way in water?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

Before the experiment, ask the students if the stick of butter will float or sink in water. Ask them if they know how to figure this out without testing it in water.

1. Determine the mass of the butter or margarine in the stick. This amount (in grams) is printed on the wrapper of the butter. You can also weigh the butter on a balance to find the mass.
2. To determine how much space the butter takes up (volume), measure the length, width, and height of the stick of butter in centimeters (cm).
3. Multiply length × width × height, and record that number in cm^3, which is equal to a milliliter (mL).
4. To determine the approximate density of your stick of butter, divide the mass of the butter (in grams) by its volume (in cm^3).
5. Now compare your calculated density of the butter to that of water (1 g/mL), and determine whether the object will sink or float.
6. Fill the bowl or container with water, and place the stick of butter in the water to observe what happens.

It is best to use a frozen stick of butter.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the measurements for length, width, and height of the stick of butter? What is the mass of the stick of butter? You can use the table provided in the activity sheet (or a similar one of your own) for students to record their data.

NOTES

LESSON 4: Buoyant Butter

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the importance of taking careful measurements.
- Understand density, displacement, and buoyancy as they relate to whether an object will sink or float in a liquid.
- Explain the concept of density and calculate the density of an object if given the mass and volume.
- Understand the importance of accuracy and precision to measurement (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Try using sticks of butter at different temperatures. Ask the students if they think a frozen stick of butter and a room-temperature stick of butter will act the same when placed in water. Then, place each in water to see what happens.
- Try different objects, and ask the students if the objects will sink or float. Ask them what that means about the density of the object in relation to the water. You can also discuss the differences between salt water and freshwater. Ask them to think about whether it is easier to float in the ocean or a freshwater pool. Because salt water is denser than freshwater, people can float much easier in the ocean.
- Explain the concept of density using a visual. For example, use mini-marshmallows in a clear box to show how mass can change in a given volume.

K-4 See **Lesson 12: Density Totem** for another lesson on density.

5-8 See **Lesson 19: Liquid Rainbow** for a more complex density lesson.

REAL-WORLD APPLICATIONS

- Challenge the students by asking them how huge boats made of metal can float. Then, explain that the massive weight of the boat is spread out over a large area. Thus it has a large volume, making it possible to float in water.
- The concepts of density and buoyancy are vital to the development of large ships, such as aircraft carriers, cargo ships, and cruise ships.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

Fun Fact

The Dead Sea, which is located in the Middle East, has a very high concentration of salt. Its density is so great that anyone can float, almost lie, in the water.

LESSON 4 ACTIVITY SHEET: Buoyant Butter

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mass		
Volume		
Density		
Displacement		

4. Consider what will happen when the stick of butter is placed in water and why.

▶**Write your hypothesis.** ______________________________

____

____

LESSON 4 ACTIVITY SHEET: Buoyant Butter

PERFORM YOUR EXPERIMENT

1. Determine the mass of the stick of butter. This amount (in grams) is printed on the wrapper or can be found by placing the stick of butter on a balance.

2. Measure the length, width, and height of the stick of butter in centimeters (cm) to determine the volume.

3. Multiply the length, width, and height (length × width × height). Record that number in cm^3. This amount is the volume.

4. Determine the approximate density of your stick of butter by dividing its mass by its volume.

   $1\ cm^3 = 1$ mL. Use this formula to convert your units from g/cm^3 to g/mL.

5. Compare your calculated density of the butter to the density of water (1 g/mL). Do you think the butter will sink or float?

6. Fill the bowl with water, and place the stick of butter in the water. Observe what happens.

ANALYZE & CONCLUDE

1. Record your measurements and calculations in the following table.

Mass of Butter (g)	
Length (cm)	
Width (cm)	
Height (cm)	
Volume (cm^3)	
Density of Butter (g/cm^3)	
Density of Water (g/mL)	

LESSON 4 ACTIVITY SHEET: Buoyant Butter

2. What is the formula for density? What is the unit of measurement for density? ______________________________

____

____

3. Based on your calculation, is the density of the butter greater or less than the density of water? ________________

____

____

4. Do you think the butter will sink or float? Why? ____

____

____

5. If you place the stick of butter in salt water, do you think it will sink or float? Why? ________________________

____

____

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? __________________________

____

____

LESSON 4 ACTIVITY SHEET: Buoyant Butter

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Measurement		
Accuracy		
Precision		

2. List some objects that you think have a density greater than water. ______________________________

____

____

3. List some objects that you think have a density less than water. ______________________________

____

____

4. If you cut the stick of butter in half, will its density change? Why or why not? ____________________

____

____

LESSON 4 ACTIVITY SHEET: Buoyant Butter

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Stick of butter/margarine, metric ruler, large bowl, water …

2. Predict how these materials may be used. The butter may be used for cooking. The ruler may be used to take measurements. The bowl may be used to hold water or other materials. These materials may be used to identify and compare the physical properties of butter and water.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Density	A physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are; the amount of matter per unit of volume ($d = m/v$).	
Displacement	The act of moving something out of its original position or of one substance taking the place of another.	

4. Consider what will happen when the stick of butter is placed in water and why.

▶**Write your hypothesis.** Density can be calculated using the mass and volume of an object. If an object is denser than the water it displaces, it will sink. If an object is less dense than the water it displaces, it will float.

LESSON 4 ACTIVITY SHEET: Buoyant Butter

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Determine the mass of the stick of butter. This amount (in grams) is printed on the wrapper or can be found by placing the stick of butter on a balance.
2. Measure the length, width, and height of the stick of butter in centimeters (cm) to determine the volume.
3. Multiply the length, width, and height (length × width × height). Record that number in cm^3. This amount is the volume.
4. Determine the approximate density of your stick of butter by dividing its mass by its volume.

$1\ cm^3 = 1\ mL$. Use this formula to convert your units from g/cm^3 to g/mL.

5. Compare your calculated density of the butter to the density of water (1 g/mL). Do you think the butter will sink or float?
6. Fill the bowl with water, and place the stick of butter in the water. Observe what happens.

ANALYZE & CONCLUDE

1. Record your measurements and calculations in the following table.

Mass of Butter (g)	Answers will vary
Length (cm)	Answers will vary
Width (cm)	Answers will vary
Height (cm)	Answers will vary
Volume (cm^3)	Answers will vary
Density of Butter (g/cm^3)	Answers will vary
Density of Water (g/mL)	1 g/mL

LESSON 4 ACTIVITY SHEET: Buoyant Butter

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. What is the formula for density? What is the unit of measurement for density? The formula for density is $d = m/v$.

Density is measured in grams per cubic centimeter (g/cm^3) or grams per milliliter (g/mL).

3. Based on your calculation, is the density of the butter greater or less than the density of water? The density of butter is less than the density of water.

4. Do you think the butter will sink or float? Why? Because the density of butter is less than the density of water, the butter will float in the water.

5. If you place the stick of butter in salt water, do you think it will sink or float? Why? The stick of butter will float in the salt water. The addition of salt to water adds mass to the water. Since the formula for density is $d = m/v$, the density of the water increases. Thus, the butter is even less dense than the salt water.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 4 ACTIVITY SHEET: Buoyant Butter

ANSWER KEY *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Measurement	A technique in which properties of a substance are determined by comparing it to some sort of standard.	
Accuracy	The closeness of a given measurement to the actual (true) value for that quantity of substance; to measure a quantity as close as possible to the true measurement (true value) of that quantity.	
Precision	The degree to which repeated measurements under unchanged conditions show the same results.	

2. List some objects that you think have a density greater than water. An anchor, a coin, and a dumbbell are objects that have a greater density than water. They will sink in water.

3. List some objects that you think have a density less than water. An apple, a cork, and a beach ball are objects that have a density less than water. They will float in water.

4. If you cut the stick of butter in half, will its density change? Why or why not? No, if you cut the stick of butter in half, both the mass and the volume of the butter change. The mass will be half of what it was before. The volume will also be half of what it was before. Since the density fomula is d= m/v, the density will remain the same.

LESSON 5: Lumpy Liquids

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 5–10 minutes

- ## DESCRIPTION

  Combine two solutions to form a solid and demonstrate the process of precipitation.

- ## OBJECTIVE

  This lesson demonstrates an important chemical separation process called precipitation. Students will combine Epsom salt and detergent solutions to observe precipitation. The lesson can be extended to discuss solubility.

- ## CONTENT TOPICS

  Scientific inquiry; measurement; mixtures (solutions); separation processes (precipitation); chemical reactions

This experiment requires sodium carbonate, which is found in some powdered laundry detergents as a water softener. Many brands do not contain sodium carbonate, so be sure to find a detergent that does. Test the experiment before class to make sure the proper chemical reaction occurs.

- ## MATERIALS

  - ❑ Epsom salt
  - ❑ Powdered laundry detergent (containing sodium carbonate)
  - ❑ Water
  - ❑ Clear plastic cups
  - ❑ Food coloring
  - ❑ Eye dropper
  - ❑ Measuring spoons

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 71 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Most of the things around us are mixtures. Mixtures are two or more substances that are combined physically. A solution is a uniform mixture in which one or more substances (solutes) are dissolved into another substance (solvent). Epsom salt is combined with water to create an Epsom salt solution.

Chemists often need to separate a specific chemical substance (a specific part) from a mixture. Separating a mixture of substances into two or more distinct products is called a separation process. A separation process uses the different properties of a mixture's parts to get them to separate. A mixture can be separated either through physical or chemical means.

A physical separation process uses physical properties to separate the parts of a mixture. This separation is accomplished without changing the chemical properties of the parts. Common physical separation processes include filtration and distillation.

LESSON 5: Lumpy Liquids

A chemical separation requires some type of chemical reaction to take place, such as the process of precipitation. **Precipitation** is a separation process in which a solid is formed in a solution following a chemical reaction. After the chemical reaction, the solid that forms in the solution is called a **precipitate**. This process is called precipitation because the precipitate tends to sink, or fall, to the bottom of the liquid. Precipitation is very useful because it allows chemists to isolate specific substances from a mixture of many chemicals.

Once a precipitate has formed, it can be removed from the solution through a physical separation process. This separation is often accomplished through the use of filtration. **Filtration** is a process by which a mixture is separated based on the sizes of the parts that make up the mixture. Filter paper is often used to separate solid particles from a liquid. Filter paper comes in different grades. These grades represent the size of the tiny pores in the paper. The pores allow the liquid to pass through but not the larger solid particles. The liquid that flows through the paper is called the **filtrate**. The filtrate is free of the solid particles.

In this experiment, the chemical reaction between the Epsom salt and the powdered laundry detergent creates a precipitate. The precipitate can be removed from the solution by using filter paper.

Fun Fact

Epsom salt is named after a town in Surrey, England. The water of the natural spas in this town contains high concentrations of the salt magnesium sulfate.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures, chemical changes, and separation processes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

FORMULAS & EQUATIONS

Epsomite, commonly known as Epsom salt, is hydrated magnesium sulfate.

The chemical formula for Epsom salt is **$MgSO_4 \cdot 7(H_2O)$**.

In this experiment, the Epsom salt is mixed with water to create an Epsom salt solution.

Some powdered laundry detergent contains the compound sodium carbonate. Commonly known as soda ash, sodium carbonate works as a water softener to prevent clothing from being damaged. ("Hard water" contains a larger amount of dissolved minerals.)

The chemical formula for sodium carbonate is **Na_2CO_3**.

The chemical reaction between the magnesium sulfate and the sodium carbonate produces the precipitate magnesium carbonate, $MgCO_3$, and the byproduct sodium sulfate, Na_2SO_4.

$$MgSO_4\ (aq) + Na_2CO_3\ (aq) \rightarrow MgCO_3\ (s) + Na_2SO_4\ (aq)$$

By filtering the solution, you can separate the magnesium carbonate from the sodium sulfate.

HYPOTHESIS

▶ When Epsom salt and certain detergent solutions are combined, a chemical reaction will produce a new solid substance that can be separated from the liquid.

LESSON 5: Lumpy Liquids

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 71, but spend more time on the concepts of mixtures, solutions, and chemical reactions. Use pictures and have students write down or state their answers of whether a certain substance is a solution or simply a mixture. For example, show a picture of apple juice—a solution. Show a picture of a garden salad—a mixture. After students complete this exercise, be sure to remind them that solutions are a type of mixture. The apple juice is a solution *and* a mixture!

Likewise, use a similar method to go over chemical reactions in more detail. Show a picture of a raw biscuit and then a fluffy, baked biscuit. Ask them how they know a chemical reaction took place.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Combine two soluble salt solutions to form an insoluble solid and demonstrate the process of precipitation.

OBJECTIVE

This lesson demonstrates an important chemical separation process called precipitation and incorporates the concept of solubility.

OBSERVATION & RESEARCH

A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). For example, salt may be dissolved in water to form a saltwater solution. The salt is the solute, and the water is the solvent.

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. A substance that dissolves in another substance is **soluble**. For example, salt is soluble in water. If a substance does not dissolve, it is **insoluble**. For instance, butter is insoluble in water.

When solutions of two soluble salts are mixed, a chemical reaction may occur, forming a new solid substance. The solid that forms from the combined solutions is called a **precipitate**, and the reaction is called a **precipitation** reaction. Precipitation reactions can be used to produce insoluble salts. In this experiment, the soluble salts are magnesium sulfate (Epsom salt) and sodium carbonate (an ingredient in the powdered laundry detergent). The two soluble salts are dissolved in water to form aqueous solutions. An **aqueous solution** is any solution in which the solvent is water. When the two solutions react, another salt—magnesium carbonate—forms. Magnesium carbonate is insoluble in water.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on precipitation and solubility can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on solutions can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

LESSON 5: Lumpy Liquids

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the amount of Epsom salt solution added to the laundry detergent solution changes, do the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Place ½ cup of water in a plastic cup, and add one teaspoon of powdered laundry detergent. Stir until no more detergent will dissolve.

2. In another cup, add two tablespoons of warm water. Add one tablespoon of Epsom salt, and stir until Epsom salt will no longer dissolve.

3. Add three drops of food coloring to the cup containing the Epsom salt solution.

4. Use the eye dropper to pick up some of the colored Epsom salt solution and then submerge the tip of the dropper into the detergent solution. Look from the side and slowly squeeze out the solution. Observe the formation of a precipitate.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the physical properties of Epsom salt? What are the physical properties of the laundry detergent? What occurs when solutions of both chemicals are combined? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 5: Lumpy Liquids

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the importance of taking careful measurements.
- Compare and contrast mixtures and solutions.
- Define and identify chemical reactions.
- Differentiate between physical and chemical separation processes.
- Understand that precipitation is a separation process involving a chemical reaction.
- Define and identify solutions and the parts of a solution.
- Explain solubility and ways to change the solubility of a solution (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, ask the students what they know about precipitation in chemistry. Most likely, they will think you are talking about the weather. Tell them that two liquids can be mixed to form a solid and ask how this is possible—chemical reactions!
- Make the experiment more colorful! You can make different colored Epsom salt solutions and add them to the detergent solution to create colorful, layered precipitate designs.
- Use filter paper to filter the precipitate from the solution to demonstrate another separation technique —a physical one!

REAL-WORLD APPLICATIONS

- The process of precipitation is used to separate silver from natural spring water. In the water, the silver is dissolved. It can be removed by adding potassium chloride (KCl). The reaction between the silver and the potassium chloride creates a solid silver compound that can then be processed to remove the pure silver.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

Fun Fact

Sodium carbonate is found naturally in high concentrations in the soda lakes of Kenya and Tanzania.

LESSON 5 ACTIVITY SHEET: Lumpy Liquids

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

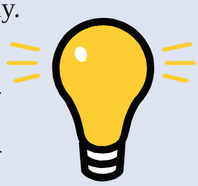
Term	Definition	Example (write or add image)
Mixture		
Solution		
Separation process		
Precipitation		
Precipitate		
Filtration		

4. Consider what will happen if an Epsom salt solution is added to a laundry detergent solution and why.

▶**Write your hypothesis.** ______________________________

____

____



LESSON 5 ACTIVITY SHEET: Lumpy Liquids

PERFORM YOUR EXPERIMENT

1. Place ½ cup of water in a plastic cup. Then, add one teaspoon of powdered laundry detergent. Stir until no more detergent will dissolve.
2. In another cup, add two tablespoons of warm water. Then, add one tablespoon of Epsom salt. Stir until no more Epsom salt will dissolve.
3. Add three drops of food coloring to the cup containing the Epsom salt solution.
4. Use the eye dropper to pick up some of the colored Epsom salt solution. Then, submerge the tip of the dropper into the detergent solution.
5. Slowly squeeze out the Epsom salt solution. Look from the side to see what happens.

ANALYZE & CONCLUDE

1. Describe the detergent solution. ______________________________

____

____

2. Describe the Epsom salt solution. ______________________________

____

____

3. What happens when you place the Epsom salt solution into the detergent solution? ______________________________

____

____

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 5 ACTIVITY SHEET: Lumpy Liquids

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solubility		
Soluble		
Insoluble		
Aqueous solution		

2. Why might chemists use precipitation reactions? ______________________________

____

____

3. How could you remove the precipitate that formed during the reaction? ______________________________

____

____

4. List some other substances that are insoluble in water. ______________________________

____

____

LESSON 5 ACTIVITY SHEET: Lumpy Liquids

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

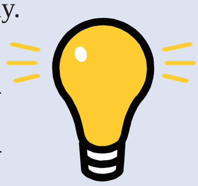
1. Write down the materials you observe. Epsom salt, powdered laundry detergent, food coloring, measuring spoon ...

2. Predict how these materials may be used. The Epsom salt may be mixed with water and used to soothe aches and pains. Laundry detergent may mix with water and be used to kill bacteria and clean materials. Food coloring may be used to dye materials. Measuring spoons are used to portion out substances. These different materials may be combined to create a new substance.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Separation process	A process that divides a mixture into two or more distinct substances.	
Precipitation	A separation process that separates a particular component from a solution by reacting the solution with another substance to form a solid.	
Precipitate	An insoluble solid that forms from a liquid solution following a chemical reaction.	
Filtration	A separation process that uses the different sizes of a mixture's parts to separate those parts.	

4. Consider what will happen if an Epsom salt solution is added to a laundry detergent solution and why.



▶**Write your hypothesis.** When Epsom salt and detergent solutions are combined, a chemical reaction will take place to form a new solid substance. Then, the solid can be separated from the liquid through a physical separation process.

LESSON 5 ACTIVITY SHEET: Lumpy Liquids

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Place ½ cup of water in a plastic cup. Then, add one teaspoon of powdered laundry detergent. Stir until no more detergent will dissolve.
2. In another cup, add two tablespoons of warm water. Then, add one tablespoon of Epsom salt. Stir until no more Epsom salt will dissolve.
3. Add three drops of food coloring to the cup containing the Epsom salt solution.
4. Use the eye dropper to pick up some of the colored Epsom salt solution. Then, submerge the tip of the dropper into the detergent solution.
5. Slowly squeeze out the Epsom salt solution. Look from the side to see what happens.

ANALYZE & CONCLUDE

1. Describe the detergent solution. The detergent solution is very cloudy with a white tint.

2. Describe the Epsom salt solution. The Epsom salt solution takes on the color of the food dye, but is fairly transparent once the salt is dissolved.

3. What happens when you place the Epsom salt solution into the detergent solution? When the Epsom salt solution is placed into the detergent solution, two soluble salts, magnesium sulfate (Epsom salt) and sodium carbonate (ingredient in detergent), create a chemical reaction that produces a solid (precipitate). These tiny solids form and fall to the bottom of the glass.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 5 ACTIVITY SHEET: Lumpy Liquids

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solubility	A measure of the amount of solute that can be dissolved in a solvent.	
Soluble	The ability of a substance to dissolve in another substance.	
Insoluble	The inability of a substance to be dissolved into another substance.	
Aqueous solution	A solution in which the solvent is water.	

2. Why might chemists use precipitation reactions? Chemists often need to separate a specific chemical or compound from a mixture of several different substances. Precipitation allows chemists to isolate specific substances from a mixture of many chemicals.

3. How could you remove the precipitate that formed during the reaction? The precipitate can be removed through filtration. Filtration is a physical separation method that uses the size of the parts that make up the mixture to separate those parts; this can be done using filter paper.

4. List some other substances that are insoluble in water. Butter, oil, and other fats are insoluble in water.

LESSON 6: Rubber Eggs

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** The effects can be observed over a 3–5 day period.

- **DESCRIPTION**
  Soak eggs in vinegar to initiate a chemical reaction and dissolve the eggshell.

- **OBJECTIVE**
  This lesson demonstrates a chemical reaction between the acetic acid in vinegar and the calcium in eggshells. Students will add hard-boiled eggs to different solutions to observe a chemical reaction. The lesson can be extended to explore acids and bases and chemistry in the human body.

- **CONTENT TOPICS**
  Scientific inquiry; elements and compounds; mixtures; chemical reactions; food chemistry; chemistry in the human body; health; acids and bases

- **MATERIALS**
  - ❑ Hard-boiled eggs
  - ❑ Vinegar
  - ❑ Clear jars or cups
  - ❑ Measuring cup

It is recommended that this experiment be started at the beginning of a week.

This experiment can be performed with a raw egg, but you will need to remind students to be especially careful to avoid a mess. Following the experiment, a raw egg will be very soft and delicate.

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 82 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- LS1.B: Growth and Development of Organisms
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter is often classified as either a pure substance or a mixture. All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O. Eggshells contain the element calcium in the form of the compound calcium carbonate. Vinegar is a mixture of water and a substance called acetic acid. A **mixture** is made of two or more substances that are combined physically.

LESSON 6: Rubber Eggs

When you let an egg soak in vinegar, the acetic acid will react with the calcium carbonate in the eggshell (along with the fats and proteins in the egg). As a result of this reaction, the vinegar completely dissolves the shell, leaving behind the soft and bouncy hard-boiled egg, covered only by a thin membrane.

The reaction in this experiment is an example of a chemical reaction. A **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). In this experiment, acetic acid reacts with calcium carbonate to form carbon dioxide, calcium acetate, and water. The bubbles that form on the egg are the carbon dioxide and are a sign that a reaction is taking place.

FORMULAS & EQUATIONS

Eggshells are made up of calcium carbonate.

The chemical formula for calcium carbonate is **$CaCO_3$**.

Vinegar is a mixture made up of very dilute acetic acid. Therefore, vinegar contains acetic acid and water.

The chemical formula for acetic acid is **CH_3COOH** or **$C_2H_4O_2$**.

The calcium carbonate in the eggshell and the acetic acid in vinegar interact setting off a chemical reaction. First, the acetic acid and calcium carbonate form carbonic acid, **H_2CO_3**, and calcium acetate, **$Ca(CH_3COO)_2$**.

$$2CH_3COOH + CaCO_3 \rightarrow H_2CO_3 + Ca(CH_3COO)_2$$

Next, the carbonic acid breaks down to form carbon dioxide and water.

$$H_2CO_3 \rightarrow H_2O + CO_2$$

Therefore, the overall reaction is ...

$$2CH_3COOH\ (l) + CaCO_3\ (s) \rightarrow H_2O\ (l) + CO_2\ (g) + Ca(CH_3COO)_2\ (s).$$

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on pure substances and mixtures can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on food chemistry and health can be found in the Applications of Chemistry in Everyday Life section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action.*

HYPOTHESIS

▶Placing eggs in vinegar will result in a chemical reaction that dissolves the eggshell.

Fun Fact

If an adult tooth is knocked out and the root is still attached, it is recommended to place the tooth in milk, as it is high in calcium. Doing so may preserve the tooth long enough for a dentist to possibly reattach it.

LESSON 6: Rubber Eggs

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Use the experiment to discuss states of matter, physical and chemical properties, and physical and chemical changes. Have students describe the properties of the egg and the vinegar and discuss solids and liquids. Then, crack one egg or pour the vinegar into a glass to illustrate physical changes. Following the experiment, discuss the chemical reaction, and ask students how they know a chemical change occurred. (Did they see a gas form in the vinegar? What was that gas?)

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Soak an egg in vinegar, which contains acetic acid, to initiate a chemical reaction that dissolves the eggshell.

OBJECTIVE

This lesson demonstrates the properties of acids and the results of a chemical reaction. Students observe as an acid in vinegar dissolves an eggshell.

OBSERVATION & RESEARCH

To describe certain chemical compounds, chemists use the terms "acid" and "base." You can determine whether a solution is an acid or a base by determining the concentration of hydrogen ions (H^+). An **ion** is an atom or molecule that has lost or gained one or more of its outer electrons. Therefore, the total number of electrons is not equal to the total number of protons, so an ion will have either a negative or a positive electric charge.

In general, a solution that contains a concentration of hydrogen ions (H^+) greater than the concentration in pure water is called an **acid**. Common household acids include lemon juice, vinegar, soda pop, and orange juice. Likewise, a solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than that of pure water is called a **base**. Common household bases include ammonia, baking soda, milk of magnesia, borax, and bleach. Solutions containing an H^+ concentration equal to that of pure water are **neutral**.

Scientists often need to know if a substance is an acid or base. To do so, they use **indicators**—substances that change color at different levels of acidity. Litmus paper is often used as an indicator. Blue litmus paper turns red in the presence of an acid, and red litmus paper turns blue in the presence of a base.

Vinegar is a mixture of acetic acid in water. When you let an egg soak in vinegar, the acetic acid will react with the calcium carbonate in the eggshell (along with the fats and proteins in the egg). As a result of this reaction, the vinegar completely dissolves the shell, leaving behind the soft and bouncy hard-boiled egg, covered only by a thin membrane.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on ions can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on acids, bases, and indicators can be found in the Acids, Bases, and pH section of CEF's *Passport to Science Exploration: Chemistry Connections.*

LESSON 6: Rubber Eggs

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the level of acidity of the solution changes, will it have the same effect on the eggshell?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Pour one cup of vinegar into a container (cup or jar).
2. Place an egg in the container. Make sure the egg is completely submerged.
3. Allow the container to remain undisturbed for three to five days. If necessary, add more vinegar to keep the egg submerged. You will be able to see the shell deteriorating from the egg. Record data each day to track the progress.
4. After three to five days, remove the egg from the vinegar and gently rinse it with water. The egg will be rubber-like. If you used a hard-boiled egg, try bouncing it.

⚠ If you used a raw egg, it will be very delicate; handle with care to avoid breaking the egg.

⚠ The materials used in this experiment are safe, but the process can be messy. Always have the students wash their hands after handling these materials, and remind them not to eat any of the substances used in the experiment.

⚠ You will want to let the experiment sit in a well-ventilated area because the vinegar and the eggs may have a strong odor.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What physical properties did they observe at the beginning of the experiment? How did those physical properties change? You can use the table provided in the activity sheet (or a similar one of your own) for students to record their data.

NOTES

LESSON 6: Rubber Eggs

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and provide examples of matter, elements, compounds, and mixtures.
- Identify the substances that make up vinegar and the calcium compound found in eggshells.
- Define and identify chemical reactions, specifically the chemical reaction occuring between an egg and vinegar.
- Understand the concept of ions (see ***Differentiation in the Classroom***).
- Define and understand the difference between acids and bases (see ***Differentiation in the Classroom***).
- Define and identify the properties of acid-base indicators (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, ask students to inspect the eggs, and challenge them to predict what gives them their strength. Explain the role of calcium in supporting bone and teeth structure (and eggshell structure!). Discuss the effects on humans and/or eggs if they were to have little or no calcium. Ask about sources of calcium for humans.
- Explain the importance of calcium to the human body. Lack of calcium can result in weak bones and teeth leading to osteoporosis or tooth decay. Also note that vitamin D is essential for calcium to be absorbed by the body.

5-8 See **Lesson 9: Egg-Dye Solutions** for a colorful lesson on chemical reactions, acids, and bases.

REAL-WORLD APPLICATIONS

- Calcium in the eggshell supports the structure of the shell. People also need calcium. Calcium helps to support bone and tooth structure, which is why we say that calcium keeps bones and teeth strong! Milk and other dairy products are primary sources of calcium in human diets, as are dark-green, leafy vegetables. Many foods have been fortified with added calcium. By eating a wide variety of foods with calcium, you can help ensure that you get the calcium you need each day to stay strong and healthy.
- Vinegar is used in dyeing eggs because the acetic acid will begin to dissolve the eggshell and allow the colorful dye to set. If you let the egg sit in the vinegar too long, the acid will dissolve the entire eggshell leaving only the soft, bouncy egg behind.
- Likewise, too much acidity can wear away at your tooth enamel. The acids in soda pops, fruit juices, and other types of highly acidic foods and beverages can corrode the calcium in your teeth, leading to sensitivity, cavities, or other health problems.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 6 ACTIVITY SHEET: Rubber Eggs

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element		
Compound		
Mixture		
Chemical reaction		

4. Consider what will happen if an egg is placed in a container of vinegar and why.

▶**Write your hypothesis.** ______________________________

____

____

LESSON 6 ACTIVITY SHEET: Rubber Eggs

PERFORM YOUR EXPERIMENT

1. Pour one cup of vinegar into a container (cup or jar).
2. Place an egg in the container. Make sure the vinegar completely covers the egg.
3. Do not touch the container for three to five days. Make observations each day. If necessary, add more vinegar to keep the egg submerged.
4. When instructed by your teacher, remove the egg from the vinegar, and gently rinse it with water.

ANALYZE & CONCLUDE

1. Record your observations of the egg in the table below.

Day	Description of Egg
1	
2	
3	
4	
5	

LESSON 6 ACTIVITY SHEET: Rubber Eggs

2. What occurs between the egg and vinegar? What is the result? ____

____

____

3. What gas makes up the bubbles that form on the outside of the eggshell? What elements make up that gas?

____

____

____

4. What do the bubbles tell us? ____

____

____

5. What element(s) is/are a main component of the eggshell? Why is the element important? ______________

____

____

6. What parts of the human body contain the element(s) listed above? ______________________________

____

____

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? __________________

____

____

LESSON 6 ACTIVITY SHEET: Rubber Eggs

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Acid		
Base		
Neutral		
Indicator		

2. List some common household acids. ______________________________

____

3. List some common household bases. ______________________________

____

4. Why is calcium important in the human body? ______________________________

____

____

LESSON 6 ACTIVITY SHEET: Rubber Eggs

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Hard-boiled eggs, vinegar, jars or cups, measuring cup ...

2. Predict how these materials may be used. Eggs and vinegar may be used in cooking. Jars or cups may be used to hold other substances, and the measuring cup may be used to portion out materials. These materials may be combined to explore physical and/or chemical changes.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom.	
Compound	A pure substance made up of two or more elements joined in a defined ratio.	
Mixture	A physical combination of two or more substances that can be physically separated.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances.	

4. Consider what will happen if an egg is placed in a container of vinegar and why.

▶ **Write your hypothesis.** Placing an egg in vinegar will result in a chemical reaction that dissolves the eggshell.

LESSON 6 ACTIVITY SHEET: Rubber Eggs

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Pour one cup of vinegar into a container (cup or jar).
2. Place an egg in the container. Make sure the vinegar completely covers the egg.
3. Do not touch the container for three to five days. Make observations each day. If necessary, add more vinegar to keep the egg submerged.
4. When instructed by your teacher, remove the egg from the vinegar, and gently rinse it with water.

ANALYZE & CONCLUDE

1. Record your observations of the egg in the table below.

Day	Description of Egg
1	The eggshell is solid, hard, and white. It is fully intact with no cracks, breakage, or deterioration.
2	Some bubbles are beginning to appear on the outside of the egg.
3	Many more bubbles are appearing on the outside of the egg with small signs of deterioration.
4	Much of the eggshell has deteriorated; bubbles are still visibly present.
5	The eggshell has dissolved, leaving behind a thin membrane. It is rubbery to the touch.

LESSON 6 ACTIVITY SHEET: Rubber Eggs

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. What occurs between the egg and vinegar? What is the result? A chemical reaction takes place when the egg is placed in vinegar. The calcium carbonate in the eggshell and the acetic acid in vinegar interact to form carbonic acid and calcium acetate. Next, the carbonic acid breaks down to form carbon dioxide and water. This reaction dissolves the eggshell.

3. What gas makes up the bubbles that form on the outside of the eggshell? What elements make up that gas?

The bubbles that form on the outside of the eggshell are made up of carbon dioxide gas. Carbon dioxide gas is made up of the elements carbon and oxygen.

4. What do the bubbles tell us? The bubbles tell us that a chemical reaction is occurring. The bubbles contain carbon dioxide, which is a product of the reaction occurring between acetic acid and calcium carbonate.

5. What element(s) is/are a main component of the eggshell? Why is the element important? The eggshell is largely composed of calcium carbonate ($CaCO_3$), so it contains the elements calcium, carbon, and oxygen.

6. What parts of the human body contain the element(s) listed above? Calcium is found in bones and teeth. Carbon and oxygen are found in large amounts throughout the human body.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 6 ACTIVITY SHEET: Rubber Eggs

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Acid	A solution that contains an excess of hydrogen ions (H^+); acids have a higher concentration of hydrogen ions than pure water.	
Base	A solution that has an excess of hydroxide ions (OH^-); bases have a lower concentration of hydrogen ions than pure water.	
Neutral	A solution that contains a concentration of hydrogen ions that is equal to pure water.	
Indicator	A substance that reveals the acidity or basicity of a solution through characteristic color changes.	

2. List some common household acids. Soda pop, vinegar, orange juice, coffee ...

3. List some common household bases. Ammonia, bleach, milk of magnesia, antacids ...

4. Why is calcium important in the human body? Calcium can be found in human bones and teeth. People need calcium to keep their bones and teeth healthy and strong. Without calcium, a person's bones and teeth may weaken or deteriorate.

LESSON 7: Milk Rainbow

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5–10 minutes

- **DESCRIPTION**

  Create swirls of color in milk and explore a property of liquids known as surface tension.

- **OBJECTIVE**

  This lesson will demonstrate the property of surface tension and the effect that soap, a surfactant, has on the surface tension of milk. Students will apply soap to milk with food coloring on the surface to visualize the effect of soap on the surface tension of milk. The lesson can be extended to discuss a type of mixtures called emulsions.

- **CONTENT TOPICS**

  Scientific inquiry; states of matter; properties of matter; attractive forces (surface tension); mixtures

- **MATERIALS**

  ❑ Whole milk
  ❑ Waterproof plate or shallow bowl
  ❑ Food coloring
  ❑ Liquid dish soap
  ❑ Cotton swabs

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 95 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- PS2.A: Forces and Motion
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, books, and trees. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and orange juice. **Gases** have no definite shape and no definite volume. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Along with differences in shape and volume, the different states of matter have other unique properties. For example, **surface tension** is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Surface tension is also the reason liquids tend to keep a low surface area. For example, water droplets will tend to form into a sphere rather than spreading out flat.

Milk is a white liquid produced by female mammals and is the primary source of nutrition for young mammals until they can digest other foods. Humans, especially children, often consume the milk of other mammals as a part of their diet. In the United States, cow's milk is produced on an industrial scale and is the most commonly consumed form of milk. Milk is made mostly of water, but it also contains vitamins, minerals, fats, and proteins.

Water has a very high surface tension because of strong attractions between the water molecules (hydrogen bonding). Because milk is primarily water, it also has a high surface tension. In this experiment, the high surface tension of the milk supports the dye molecules on the surface and keeps the dye relatively centralized. (The tendency to keep a low surface area minimizes the distance that the dye will spread across the milk's surface.)

In contrast, soap is a surfactant. A **surfactant** (or surface active agent) is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of liquid dish soap is added to milk, the surface tension of the milk is reduced. As this occurs, the fat (butterfat) and protein particles in the milk can move more freely and easily. In addition, the soap interacts with the fat and protein particles in the milk, causing the particles to move around. This action can be seen as the dye swirls through the milk.

FORMULAS & EQUATIONS

Milk is a liquid made mostly of water, but it also contains vitamins, minerals, fats, and proteins. Milk is a unique substance known as a colloid, so it does not have a specific chemical formula. A **colloid** is a mixture in which very small particles are spread evenly through another substance. In milk, the fat globules, proteins, vitamins, and minerals are spread throughout the water.

The molecules that make up soaps and detergents have two main parts (ends) that behave differently. One end of a soap molecule is attracted to water, while the other components are repelled by water but attracted to fats.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states of matter and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶When drops of liquid dish soap are added to milk with drops of food coloring on the surface, the soap will reduce the surface tension of the milk and react with the fat. This interaction will cause the particles in the milk to move around and create swirls of color.

Fun Fact

The fat content of milk depends on the type of milk (skim, whole, etc.) and the type of cow. Holstein-Friesian cows tend to produce milk with a lower percentage of butterfat than Jersey cows.

LESSON 7: Milk Rainbow

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Use **Lesson 15: Floating Paper Clips** to introduce the concept of surface tension. Then, perform this experiment to add some color to the lesson and explore the concept further!

Pour small drops of water on a plate to illustrate surface tension. Students should notice that the water does not spread out completely. Instead, it will form droplets, and those droplets will attract other small droplets to form larger "puddles."

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Examine the composition of the milk and how soap interacts with the components of the milk.

OBJECTIVE

This lesson examines the properties and composition of milk and uses soap to illustrate the effects of surfactants on the properties and components of milk.

OBSERVATION & RESEARCH

Most of the things around us are mixtures, like the air we breathe and the orange juice we drink! A **mixture** is made of two or more substances that are combined physically. Mixtures are generally classified as homogeneous or heterogeneous. A **homogeneous mixture** is a type of mixture that is considered to be the same throughout. Solutions, like apple juice, are homogeneous mixtures. A **heterogeneous** mixture is a type of mixture in which the makeup is not the same throughout. They are not evenly mixed. For example, pepperoni pizza and chicken noodle soup are heterogeneous mixtures. Not all mixtures, however, are simply homogeneous or heterogeneous.

Milk is classified as a **colloid**. A colloid is a mixture in which very small particles are spread evenly through another substance. It is a type of mixture between homogeneous and heterogeneous. Specifically, milk is a type of colloid called an emulsion. **Emulsions** consist of liquids spread through other liquids. The liquids in an emulsion do not completely mix like the particles in a solution do. Instead the particles of one liquid are suspended in the other. Emulsions generally have a cloudy appearance and will often separate if not continuously mixed. Examples of emulsions include mayonnaise and oil and vinegar salad dressing.

Milk is a natural emulsion of fats (oils) and proteins spread throughout water. Raw milk will eventually separate, with the fat rising to the top. However, store-bought milk generally looks homogeneous. The reason is that most store-bought milk goes through a process called homogenization that breaks down the fat particles so the milk appears to have a uniform consistency.

Because milk is mainly made of water, it has properties similar to water, such as a high surface tension. **Surface tension** is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid.

Soap is a surfactant. A **surfactant** is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of liquid dish soap is added to milk, the surface tension of the milk is reduced. As this occurs, the fat and protein particles in the milk can move more freely and easily. In addition, the molecules that make up soaps and detergents have two main parts (ends) that behave differently. The ends attracted to fat will move and clump together around the fat particles. As this movement occurs, the dye moves through the milk as well, creating colorful swirls in the milk.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on properties of matter, mixtures, and colloids can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 7: Milk Rainbow

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If soap is not added to the milk, do the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill the plate with whole milk, and let the milk settle for a minute.
2. Add several drops of different food coloring close together, but separate, in the center of the plate of milk.
3. Dip a cotton swab in the liquid dish soap, and then touch the tip of the cotton swab to the milk's surface near the drops of food coloring. Observe the reaction.
4. Then, move the swab to different areas of the plate to initiate more reactions.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happened when the dye was first added to the milk? What happened when the soap was added? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Differentiate between the different states of matter.
- Understand the property of surface tension.
- Describe the effect of soap, a surfactant, on surface tension.
- Describe the general composition of milk.
- Compare and contrast homogeneous and heterogeneous mixtures (see ***Differentiation in the Classroom***).
- Define and identify colloids (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Try the experiment using other types of milk, such as skim milk, and observe the results. You may also want to try other liquids, like water or oil. Are the results the same? Discuss why or why not?
- Set up the experiment as described in the lesson, but before adding the soap, try a different test first. Dip the cotton swab in water, and touch the cotton swab to the milk. Observe what happens. Likewise, if you put a water-soaked cotton swab in the middle of a dye droplet, what happens? Discuss these results with the class.

K-4 See **Lesson 26: Swimming Specs** for a simplified lesson on surface tension.

5-8 See **Lesson 15: Floating Paper Clips** for an introductory lesson on surface tension.

REAL-WORLD APPLICATIONS

- You may have seen commercials for liquid dish soaps that claim the soap has the ability to "cut the grease." Grease is mostly fat. While one part of the soap is attracted to water, other parts bind to the fat. Moving the soapy water around allows the soap to pull the grease away from the dishes or your hands, and be rinsed away by the water.
- Along with being homogenized, the milk found in most grocery stores has also been pasteurized. Pasteurization is a process of heating a food, usually a liquid, to a specific temperature and for a specific length of time to kill bacteria, molds, and yeast. This process was invented by French chemist and biologist Louis Pasteur in 1863 (see the ***Famous Chemist*** section in the ***Resource Guide***).

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 7 ACTIVITY SHEET: Milk Rainbow

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

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2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid		
Liquid		
Gas		
Surface tension		
Surfactant		

4. Consider how the addition of liquid dish soap will affect milk with food coloring on the surface and why.

▶**Write your hypothesis.** ______________________________

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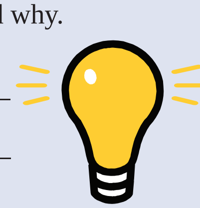

LESSON 7 ACTIVITY SHEET: Milk Rainbow

PERFORM YOUR EXPERIMENT

1. Fill the plate with whole milk, and let the milk settle for a minute.
2. Add several drops of different food coloring close together, but separate, in the center of the plate of milk.
3. Dip a cotton swab in the liquid dish soap. Then, touch the tip of the cotton swab to the milk's surface near the drops of food coloring. Observe.
4. Try touching the cotton swab to different areas of the plate of milk to initiate more reactions.

ANALYZE & CONCLUDE

1. What happens when you first place the drops of food coloring on the milk's surface? ____________________________

____

____

2. What happens to the food coloring when you touch the milk with the cotton swab soaked in soap? ______________

____

____

3. What are the components of milk? (What makes up milk?) ____

____

____

4. What effect does the soap have on the surface tension of the milk? ______________________________________

____

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5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 7 ACTIVITY SHEET: Milk Rainbow

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Homogeneous mixture		
Heterogeneous mixture		
Colloid		
Emulsion		

2. What other substances are considered surfactants? ______________________________

____

____

3. Why do the components of grocery store milk not separate? ______________________________

____

____

LESSON 7 ACTIVITY SHEET: Milk Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Milk, food coloring, liquid dish soap, cotton swabs ...

2. Predict how these materials may be used. Milk may be used for drinking. Food coloring may be used to make food products or other substances colorful. Liquid dish soap may be used to remove dirt and grease. Cotton swabs may be used as an applicator. These materials may be used together to explore physical properties.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid	A state of matter characterized by a definite volume and a definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it.	
Gas	A state of matter that has no definite volume or shape.	
Surface tension	A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface “film.”	
Surfactant	Any substance with the ability to reduce the surface tension of a liquid; also known as a surface active agent.	

4. Consider how the addition of liquid dish soap will affect milk with food coloring on the surface and why.

▶ **Write your hypothesis.** When liquid dish soap is added to milk with drops of food coloring on the surface, the soap reduces the surface tension of the milk and reacts with the fat. This interaction causes the fat particles in the milk to move and create swirls of color.

LESSON 7 ACTIVITY SHEET: Milk Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill the plate with whole milk, and let the milk settle for a minute.
2. Add several drops of different food coloring close together, but separate, in the center of the plate of milk.
3. Dip a cotton swab in the liquid dish soap. Then, touch the tip of the cotton swab to the milk's surface near the drops of food coloring. Observe.
4. Try touching the cotton swab to different areas of the plate of milk to initiate more reactions.

ANALYZE & CONCLUDE

1. What happens when you first place the drops of food coloring on the milk's surface? When droplets of food coloring are placed onto the milk's surface, the food coloring stays suspended on the surface in a small area.

2. What happens to the food coloring when you touch the milk with the cotton swab soaked in soap? When you touch a cotton swab soaked in soap to the milk, the colors spread throughout the milk creating colorful swirls.

3. What are the components of milk? (What makes up milk?) Milk is made mostly of water, but it also contains vitamins, minerals, fats, and proteins.

4. What effect does the soap have on the surface tension of the milk? Soap is a surfactant, which reduces the surface tension of the milk and allows the food coloring to move around the milk.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 7 ACTIVITY SHEET: Milk Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Homogeneous mixture	A type of mixture that is considered to be the same throughout; the substances are evenly mixed.	
Heterogeneous mixture	A type of mixture in which the makeup is not the same throughout; the substances are not evenly mixed.	
Colloid	A mixture, between homogeneous and heterogeneous, in which very small particles are spread evenly throughout another substance.	
Emulsion	A colloid that consists of liquids spread throughout other liquids; the liquids in an emulsion do not completely mix and are often unstable.	

2. What other substances are considered surfactants? Other soaps and laundry detergents are examples of surfactants.

3. Why do the components of grocery store milk not separate? Raw milk will actually separate because it is an emulsion. However, most milk purchased at grocery stores goes through a process called homogenization. This process breaks down the fat in the milk so it has a more uniform consistency, which, in turn, keeps the components of milk from separating.

LESSON 8: The Moving Molecule Stomp

ESTIMATED TIME **Procedure:** 15–20 minutes

- ## DESCRIPTION

Use students as models to explore the differences between the motion of particles in solids, liquids, and gases.

- ## OBJECTIVE

This activity demonstrates the molecular differences in the solid, liquid, and gaseous states of matter. Students represent the movement of particles at their teacher's direction. This lesson can be extended to explain the role of energy in changing states of matter.

- ## CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; physical changes; energy

- ## MATERIALS

For Modifications/Extensions:

- ❑ Ice (optional)
- ❑ Beakers of water (optional)
- ❑ Hot plate and a pan (optional)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 106 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- PS2.A: Forces and Motion
- PS3.A: Definitions of Energy (see ***Differentiation in the Classroom***)
- PS3.B: Conversion of Energy and Energy Transfer (see ***Differentiation in the Classroom***)
- PS3.C: Relationship Between Energy and Forces (see ***Differentiation in the Classroom***)
- PS3.D: Energy in Chemical Processes and Everyday Life (see ***Differentiation in the Classroom***)

OBSERVATION & RESEARCH

BACKGROUND

Matter exists primarily as a solid, liquid, or gas on the earth. Changes between these states of matter are physical changes. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. For example, ice, water, and water vapor are all H_2O in different physical states. The chemical formula remains H_2O regardless of whether it is in the solid, liquid, or gaseous state.

The difference between solids, liquids, and gases is in the motion of the particles within the substance. For example, the molecules of H_2O move differently in the form of ice than they do in the form of water vapor.

The particles in a **solid** are generally locked into place giving the solid substance a definite shape and volume. The particles are held tightly together. However, the particles are not completely still. They do move but not freely. They only vibrate slightly in place.

LESSON 8: The Moving Molecule Stomp

Certain solids, called **crystalline solids**, are made up of atoms or molecules that have a specific, orderly structure. The particles in these solids are arranged in a specific, repeating pattern. Ice and salt are crystalline solids. Other solids are made up of atoms or molecules that are locked into place but do not have a specific, repeating structure. Those solids are known as **amorphous solids**. Wax is an example of an amorphous solid.

Particles in a **liquid** are not as close as particles in a solid, and they move more freely. The particles roll over each other, which is why liquids flow. However, liquids still experience weak forces of attraction. These attractive forces make the liquid particles remain fairly close as they slide past one another. Therefore, liquids do not have definite shapes, but they have definite volumes. They take the shape of the vessel that contains them, filling the bottom of the container first.

The particles in a **gas** are spaced far apart. They do not have strong bonds or attractions between them. Therefore, they move about freely and rapidly in random directions. Particles in a gas can move over very large distances and go much farther than liquids without touching another particle. Gases do not have a definite shape or volume. If a gas is put into a container, it will take the shape of the container, filling that container completely.

Matter can change from one state to another, generally as a result of a change in temperature. **Melting** is a change in state from a solid to a liquid. The opposite change is freezing. **Freezing** is a change in state from a liquid to a solid. A change in state from a liquid to a gas is known as **vaporization**, while a change in state from a gas to a liquid is known as **condensation**. Changes directly between the solid and gaseous states, without going through the liquid state first, are less common. **Sublimation** is a change in state from a solid directly to a gas. The opposite is **deposition**, when a gas changes directly into a solid.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on physical changes and states of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

FORMULAS & EQUATIONS

During a physical change, the structure or chemical formula of the substance does not change. As energy (in the form of heat) is added or removed from the substance, it changes from one state of matter to another. The following equation illustrates the physical change of water (ice) from the solid to the liquid state.

$$\mathbf{H_2O\ (s) + energy \rightarrow H_2O\ (l)}$$

Keep in mind, enough energy has to be added to cause this change. The temperature of the solid substance must reach its melting point. The **melting point** is the temperature at which a substance begins to change states from a solid to a liquid.

The following equation illustrates the physical change of water from the liquid to the gaseous state.

Likewise, $\mathbf{H_2O\ (l) + energy \rightarrow H_2O\ (g)}$

The substance must reach its boiling point for this change to begin. The **boiling point** is the temperature at which a liquid begins to form a gas.

HYPOTHESIS

- Particles in solids, liquids, and gases move in different ways and have different amounts of energy.

LESSON 8: The Moving Molecule Stomp

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the activity as described on page 106, but spend more time on states of matter. Show pictures of different things, and have the students identify the states of matter.

Likewise, show images of matter changing states—snow melting, a pond freezing, etc. Again, have the students identify which change they see and how they know.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Explore the differences between the motion of particles in solids, liquids, and gases and how adding or removing energy can cause matter to change from one state to another. Students represent the movement of particles at changing energy levels.

OBJECTIVE

This lesson demonstrates the motion of particles in different states of matter, as well as the role of energy in changing matter from one state to another.

OBSERVATION & RESEARCH

The motion of particles in a substance is associated with energy. **Energy** is a measure of the ability to do work or generate heat. The particles in a solid move very little and, therefore, have very little energy. Liquid particles have more movement and more energy than particles in a solid, but less energy than particles in a gas. The particles in a gas are highly energized.

Matter can change states when energy is added or taken away. The energy is transferred between a substance and its surroundings, and these changes are often the result of changes in temperature. When energy is added to a substance, its particles move faster and more freely. For example, as the temperature of a solid increases, energy enters the solid. When the amount of added energy reaches a certain point, this increased energy begins to release the particles of the solid, allowing them to move around more freely. As a result the solid melts, becoming a liquid.

Alternately, when a gas is converted into a liquid or a liquid is converted into a solid, energy is removed. The removal of energy slows down the movement of the particles. For example, as energy is removed from a liquid, the particles will slow down. The liquid substance will begin to form a solid when it reaches its freezing point. At this point, the particles begin to become locked in place.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states of matter, physical changes, and energy changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on energy can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry* and the Energy section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action.*

LESSON 8: The Moving Molecule Stomp

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the students' movement changes, does their symbolic state of matter change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

Remind student volunteers to be careful as they move about the classroom and demonstrate the movement of particles. They should not run; they should slide past one another gently.

1. Ask for six to eight volunteers from your class to be models in the demonstration. Inform the class that these students represent particles of matter.

2. Have all of the volunteers stand in one corner of the classroom. Tell them to clump together tightly and move their bodies slightly back and forth without moving their feet. (They should be careful not to step on each other's toes and not to bump into each other forcefully.)

3. At this point, they represent the particles in a solid: close together, tightly packed, and only little movement.

4. Now have the volunteers stay close, but help them form into an orderly structure. Tell the class that in some solids, the particles are not only tightly packed, but they are arranged in a specific, repeating pattern. These are crystalline solids.

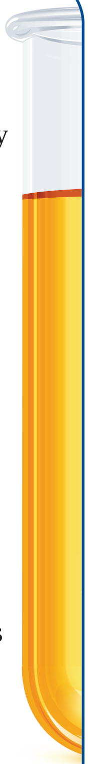
5. Now tell the class that in order for the solid to become the next state of matter, they need to supply the particles with some energy. Ask them what would happen if the solid had more energy.

6. Tell the student volunteers that they have been energized! Tell them they have more energy, so they cannot stay in one place anymore. They can move around a little bit more, but they have to stay together and gently slide past one another in one area of the classroom.

7. Tell the class that the volunteers now represent a liquid. They have more energy and can move a little bit more because they are not as crammed together. However, they must stay in the designated area.

8. Now tell the volunteers that they have even more energy than before. Ask the class how they would feel with all that energy. (For example, hyper, energetic, like running around.) Tell the volunteers to move around the entire room. They can walk quickly and can also gently tap the walls and each other. The volunteers should be scattered throughout the entire room. Remind the volunteers to be careful and watch their steps as they move.

9. Ask the class what state of matter they just witnessed. Tell them that in a gas, the particles are free to move very quickly and anywhere they want.



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What do particles in a solid look like? What about particles in liquids and gases? Students can use the activity sheet or a separate piece of paper to illustrate the structures and motions of particles in the different states of matter.

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Differentiate between the different states of matter.
- Describe the movement of particles in a solid, liquid, and gas.
- Define and identify different physical changes between states of matter.
- Define energy and its relation to the states of matter (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- At the end of the activity, place some water in a beaker on a hot plate, and heat it until water vapor rises from the beaker. Tell the students that this process illustrates a liquid changing to a gas.
- Give the students a piece of ice. Let them hold it in their hands, moving it from one hand to the other. The ice will begin to melt. Ask them what is causing the ice to change states. Ask them where the heat in their hands originally came from. Discuss how their bodies produce this energy.

Instruct students to put the ice down on their desks or in a cup if their hands get too cold or start to ache.

REAL-WORLD APPLICATIONS

- Matter is all around you in different states. The change of H_2O from one state to another can be seen on the earth. On cold winter days, a pond or lake may freeze into a solid sheet of ice. Likewise, on a hot summer day, water in a puddle on the ground may quickly disappear as the water evaporates (a type of vaporization). In addition, if the temperature drops in the evening after a long, hot summer day, you may see the effects of condensation. As the cooler air gets closer to the surface of the earth, it may come in contact with the grass, a car, or some other structure. When the water vapor in the air touches the cool surface, the water vapor will condense into liquid water, leaving water droplets on the grass, car, or other structures.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

Fun Fact

It is possible to turn a gas into a liquid by compressing it or by making the container that holds it smaller. Propane tanks are filled with liquid propane, but when the propane is released, it becomes a gas again because the pressure has decreased.

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical change		
Solid		
Liquid		
Gas		
Melting		
Freezing		
Vaporization		
Condensation		
Sublimation		
Deposition		

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

4. Consider how changing the movement of the student volunteers represents different changes in the states of matter and why.

▶ **Write your hypothesis.** ____

____

____

PERFORM YOUR EXPERIMENT

1. Follow your teacher's instructions.

2. **Have fun!**

ANALYZE & CONCLUDE

1. Draw the arrangement of particles in each state of matter below, using small circles to represent particles.

Solid	Liquid	Gas

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

2. Describe the properties of a solid. ______________________________

____

____

3. Describe the properties of a liquid. ______________________________

____

____

4. Describe the properties of a gas. ______________________________

____

____

5. Which state of matter has the most energy? Which has the least? ______________________________

____

____

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Energy		
Crystalline solid		
Amorphous solid		

2. What is required for a substance to change states? Explain. ______________________________

____

____

3. List other types of energy. ______________________________

____

____

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. No materials, or simply classmates/people. Optional equipment: ice, beakers, water, pan/hot plate ...

2. Predict how these materials may be used. People may be used as models. Ice may be used to cool a substance. Beakers may be used as a container or a measuring device. A pan/hot plate may be used to heat materials.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Solid	A state of matter characterized by a definite volume and a definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	
Melting	A physical change in which a substance changes states from a solid to a liquid.	
Freezing	A physical change in which a substance changes states from a liquid to a solid.	
Vaporization	A physical change in which a substance changes states from a liquid to a gas.	
Condensation	A physical change in which a substance changes states from a gas to a liquid.	
Sublimation	A physical change in which a substance changes states from a solid to a gas.	
Deposition	A physical change in which a substance changes states from a gas to a solid.	

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. Consider how changing the movement of the student volunteers represents different changes in the states of matter and why.

▶ **Write your hypothesis.** Particles in solids, liquids, and gases move in different ways and have different amounts of energy.

PERFORM YOUR EXPERIMENT

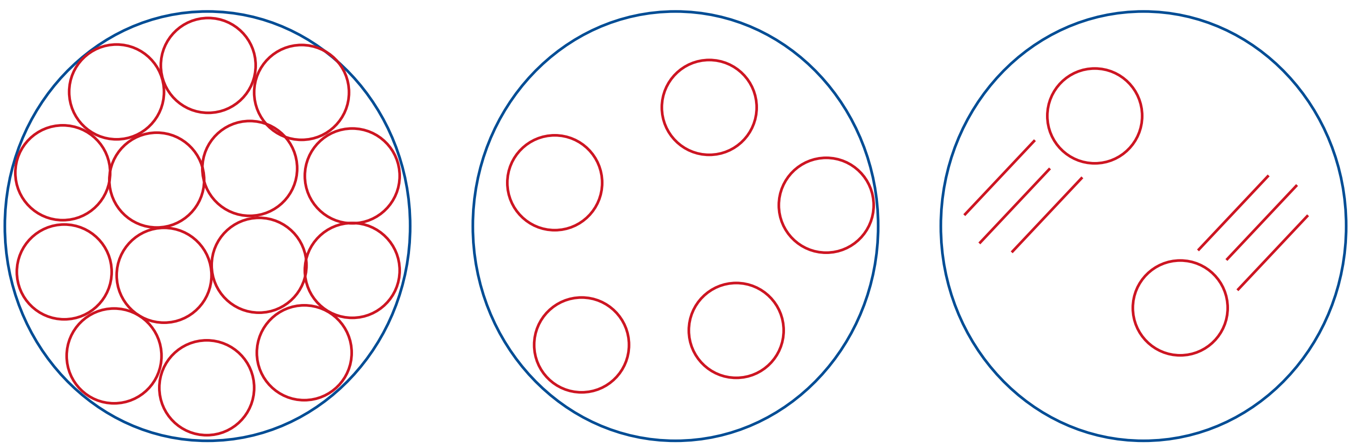
1. Follow your teacher's instructions.

2. Have fun!

ANALYZE & CONCLUDE

1. Draw the arrangement of particles in each state of matter below, using small circles to represent particles.

Solid | **Liquid** | **Gas**



LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. Describe the properties of a solid. Solids have a definite shape and volume. Particles in solids are closely packed together and only vibrate slightly in place.

3. Describe the properties of a liquid. Liquids have a definite volume but no definite shape. Particles in liquids flow around each other and experience weak attractive forces.

4. Describe the properties of a gas. Gases have no definite volume or shape. Particles in a gas move about freely in constant, random motion.

5. Which state of matter has the most energy? Which has the least? Gases have the most energy, and solids have the least. Particles in solids have little energy and are generally locked into place, giving the solid substance a definite shape and volume. Particles in a gas have a lot of energy. They move about quickly and freely.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 8 ACTIVITY SHEET: The Moving Molecule Stomp

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Energy	The ability to do work or produce heat.	
Crystalline solid	A solid made up of atoms or molecules organized in specific, repeating patterns; these regular, repeating patterns form crystals.	
Amorphous solid	A solid made up of atoms or molecules that are locked into place but do not have a specific form or neat, repeating structure.	

2. What is required for a substance to change states? Explain. Energy is generally required for matter to change states. It is either added or taken away. Pressure can also cause a substance to change states.

3. List other types of energy. Electrical energy, nuclear energy, mechanical energy, electromagnetic energy (light) ...

LESSON 9: Egg-Dye Solutions

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 10–15 minutes

• DESCRIPTION

Use food dye and a variety of acids and bases to determine which solution works best for dyeing eggs.

• OBJECTIVE

This lesson addresses the differences between acids and bases and how they interact with eggshells. Students place eggs into various acid and base solutions containing food dyes to determine which solution works best for dyeing the eggs. The lesson can be simplified to reinforce the concept of chemical reactions.

• CONTENT TOPICS

Scientific inquiry; mixtures (solutions); atomic structure; acids and bases; physical changes; chemical reactions

• MATERIALS

- ❑ Sample of household acids: vinegar, lemon juice, orange juice
- ❑ Sample of household bases: borax, milk of magnesia, ammonia
- ❑ Hard-boiled eggs (3–6 per group)
- ❑ Food coloring or dye
- ❑ Cups
- ❑ Plastic spoons (one per cup)
- ❑ Red and blue litmus paper (optional)
- ❑ Wax crayon (optional)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 119 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- EST1.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

To describe certain chemical compounds, chemists use the terms "acid" and "base." You can determine whether a solution is an acid or a base by determining the concentration of hydrogen ions (H^+). An ion is an atom or molecule that has lost or gained one of more of its outer electrons. Therefore, the total number of electrons is not equal to the total number of protons, so an ion will have either a negative or a positive electric charge.

In general, a solution that contains a concentration of hydrogen ions (H^+) greater than the concentration in pure water is called an acid. Common household acids include lemon juice, vinegar, soda pop, and orange juice. Likewise, a solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than that of pure water is called a base. Common household bases include ammonia, baking soda, milk of magnesia, borax, and bleach. Solutions containing an H^+ concentration equal to that of pure water are neutral.

LESSON 9: Egg-Dye Solutions

The concentration of hydrogen ions in acids and bases are measured on the **pH scale**. The higher the concentration of H^+, the lower the pH will be. A substance with a pH lower than 7 is considered to be acidic. The lower the concentration of H^+, the higher the pH will be. A substance with a pH higher than 7 is considered to be basic. Most substances range from 0 to 14 on the pH scale, with 0 being the most acidic, 7 being neutral, and 14 being the most basic. Pure water is neutral with a pH of 7.

Scientists often need to know if a substance is an acid or a base. To do so, they use **indicators**—substances that change color at different levels of acidity. Litmus paper is often used as an indicator. Blue litmus paper turns red in the presence of an acid, and red litmus paper turns blue in the presence of a base.

An eggshell is mainly made of calcium carbonate with a protein coating. Neutral and basic solutions will not cause any change to the eggshell, except that some dye may get stuck in the pores of the shell giving it a slight color. On the other hand, the acetic acid in vinegar will react with the protein of the shell, allowing the dye to chemically bind to it. Likewise, acetic acid also reacts with calcium carbonate, causing the shell to dissolve. If you use too much vinegar or let an egg sit in the vinegar too long, the acid will eventually dissolve the eggshell completely.

FORMULAS & EQUATIONS

The acids used in this experiment range in pH from approximately 2.0 to 3.5.

Vinegar is very diluted acetic acid. Therefore, vinegar is a mixture of acetic acid and water, which generally has a pH ranging from 2.4 to 3.4.

The chemical formula for acetic acid is **CH_3COOH**.

Lemon juice contains citric acid and has a pH ranging from 2.0 to 3.0. Orange juice also contains citric acid and generally has a pH around 3.5.

The chemical formula for citric acid is **$C_6H_8O_7$**.

The bases used in this experiment range in pH from approximately 9.5 to 11.6. Thus they are considered to be moderately basic.

Borax has a pH of about 9.5 and the formula **$Na_2B_4O_7 \cdot 10H_2O$** or **$Na_2[B_4O_5(OH)_4] \cdot 8H_2O$**.

Milk of magnesia is another common household base and has a pH of approximately 10.5. Milk of magnesia is a mixture of magnesium hydroxide in water. It has a milky appearance which is the reason for its name.

The chemical formula for magnesium hydroxide is **$Mg(OH)_2$**.

Common household solutions of ammonia have a pH of about 11.5.

The chemical formula for ammonia is **NH_3**.

Eggshells contain the element calcium in the form of the compound calcium carbonate.

The formula for calcium carbonate is **$CaCO_3$**.

5-8 See **Lesson 6: Rubber Eggs** for information on the reaction between the acetic acid in vinegar and the calcium carbonate in eggshells.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on ions can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on acids, bases, and indicators can be found in the Acids, Bases, and pH section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

▶ When placing eggs in different solutions containing food dye, the pH of the solution will create different reactions, resulting in varying levels of color absorption.

LESSON 9: Egg-Dye Solutions

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Use solutions with different levels of acidity to dye eggs and illustrate a chemical reaction.

OBJECTIVE

This lesson addresses the differences between acids and bases and how they interact with eggshells. Students place eggs into various solutions to observe physical and chemical changes.

OBSERVATION & RESEARCH

Matter can undergo a number of changes. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. Breaking an egg in half does not change the chemical makeup of the egg. Thus, breaking an egg is a physical change. Likewise, placing a whole, hard-boiled egg into a basic solution with dye may result in a minor color change if some of the dye particles become trapped in the pores of the eggshell. Yet again, the chemical makeup of the egg is still the same, in the same way that coloring on a piece of paper does not change the chemical makeup of the paper.

On the other hand, a **chemical change** or **chemical reaction** occurs when two or more substances interact, producing a change in the substances. As a result of a chemical reaction, new substances with new properties are formed. The starting material or materials for a chemical reaction are referred to as the **reactants**. The substance or substances produced from a chemical reaction are called **products**. Sometimes a secondary product, a **byproduct**, can also be created at the same time as the desired product(s).

An eggshell is mainly made of calcium carbonate with a protein coating. When you let an egg soak in vinegar, the acetic acid will react with the protein of the shell, allowing the dye to chemically bind to the shell. Likewise, acetic acid also reacts with calcium carbonate, causing the shell to dissolve. If you use too much vinegar or let an egg sit in the vinegar too long, the acid will eventually dissolve the eggshell completely. The bubbles that form on the egg are carbon dioxide and are a sign that a chemical reaction is taking place.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Use this lesson to explore acids and bases further, including their properties and the reactions in which they participate. For example, review acid-base reactions or acid-metal reactions. Look at different chemical equations to identify the reactants and products of these reactions.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on physical and chemical changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on food chemistry and health can be found in the Applications of Chemistry in Everyday Life section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 9: Egg-Dye Solutions

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the level of acidity changes, will the effect on the eggshell be the same?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Test each of your solutions with litmus paper to determine if they are acids or bases. If you do not have litmus paper, have the students make predictions before you tell them which are acids and bases.

2. Fill one cup with water to serve as a control.

3. Pour a different acid or base into each remaining cup. Make sure you pour enough solution into the cup to submerge the egg. (For borax, which is a solid, create a borax solution by dissolving borax into warm water until no more borax can be added. Milk of magnesia can also be diluted in water.)

3. Add 3–5 drops of food coloring/dye to the water cup. Add the same color dye to the other cups, and try to make the colors in all cups the same shade.

Making the solutions the same shade may require different amounts of food coloring per solution. For example, since milk of magnesia is white, its solution will be softer in color and will require more drops of food coloring.

4. Place an egg in each cup, and let the eggs soak for 10 minutes.

5. After 10 minutes, remove each egg from its solution. The milk of magnesia egg should be very gently rinsed under water. Be sure not to mix up the eggs.

6. Observe each egg's appearance.

NOTES

This experiment can be messy, so you may want to protect the work surface with newspaper. Students should also wear gloves to protect their hands.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the properties of the substances used in the experiment? You can use the charts on the activity sheet (or similar charts of your own) for students to record their data.

LESSON 9: Egg-Dye Solutions

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and understand the difference between acids and bases.
- Understand pH and identify the pH of different solutions.
- Define and identify the properties of acid-base indicators.
- Differentiate between physical and chemical changes (see ***Differentiation in the Classroom***).

Fun Fact

Originally, dyes were made from vegetables, edible flowers, fruits, coffee, tea, plants, and minerals. For example, people used saffron to color cloth a vibrant yellow, and indigo plants produced a rich blue dye.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lessons or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

Fun Fact

Bases can be used to neutralize acids and vice versa.

- Before the experiment, have the students predict whether each solution is an acid or a base. Then, use the litmus paper to determine the answer.
- Use a wax crayon to write or draw on a few eggs. In the best egg-dyeing solution (the vinegar solution), the dye will not adhere to the part of the eggshell with the wax. Discuss the properties of wax with your students.

REAL-WORLD APPLICATIONS

- Dyes have been used since ancient times to color various fabrics. Today, both natural and synthetic dyes are used to color fabrics, but not all dyes work on all fabrics. Certain types of dyes work well on polyester but do not work well on cotton and vice versa.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

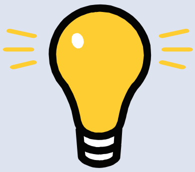
____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution		
Ion		
Acid		
Base		
Dye		

4. Consider how changing the level of acidity in a solution will affect the amount of dye absorbed by the eggshell and why.



▶ **Write your hypothesis.** ______________________________

____

____

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

PERFORM YOUR EXPERIMENT

1. Determine which solutions are acids and which are bases. Follow your teacher's instructions.

2. Then, fill one cup with water and pour a different acid or base into each remaining cup. Make sure you pour enough into each cup to submerge the egg. (For borax, which is a solid, create a borax solution by dissolving borax into warm water until no more borax can be added. Milk of magnesia can also be diluted in water.)

3. Add 3–5 drops of food coloring to the water cup. Add the same color dye to the other cups, and try to make the color in all cups the same shade.

Making the solutions the same shade may require different amounts of food coloring per solution. For example, since milk of magnesia is white, its solution will be softer in color and will require more drops of food coloring.

4. Place an egg in each cup, and let the eggs soak for 10 minutes.

5. After 10 minutes, remove each egg from its solution. (The milk of magnesia egg should be very gently rinsed under water. Be sure not to mix up the eggs.)

6. Observe each egg's appearance.

ANALYZE & CONCLUDE

1. Complete the chart below.

Solution	Prediction: Acid or Base?	Result: Acid or Base?

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

2. Describe any differences you see in each solution as the eggs soak. ______________________________

____

____

3. Shade the ovals below to represent the resulting color of each egg (the amount of dye absorbed by each egg in the different solutions). Below each egg image, write in the solution that was used.

Solution #1	Solution #2	Solution #3	Solution #4	Solution #5	Solution #6
Vinegar	________	________	________	________	________

4. Are acids or bases better for dyeing eggs? Explain. ______________________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ____________________

____

____

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical change		
Chemical change		
Reactant		
Product		
Byproduct		

2. Why does vinegar work so well when dyeing eggs? ______________________________

____

____

3. What is the composition of vinegar? ______________________________

____

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Household acids (vinegar, lemon juice, orange juice), household bases (borax, milk of magnesia, ammonia), hard-boiled eggs, food coloring …

2. Predict how these materials may be used. The household acids and bases may be used in a variety of ways. Hard-boiled eggs may be eaten or used for decorating. The food coloring may be used to dye other substances. These materials may be combined to examine the differences between acids and bases and to observe chemical reactions.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Ion	An atom or group of atoms that has lost or gained one or more of its outer electrons; an ion will have either a positive or a negative charge.	
Acid	A solution that contains an excess of hydrogen ions (H^+); acids have a higher concentration of hydrogen ions than pure water.	
Base	A solution that has an excess of hydroxide ions (OH^-); bases have a lower concentration of hydrogen ions than pure water.	
Dye	A soluble substance used to stain or color fabrics and fibers, such as paper, cotton, etc.	

4. Consider how changing the level of acidity in a solution will affect the amount of dye absorbed by the eggshell and why.

▶ **Write your hypothesis.** When placing eggs in different solutions containing food coloring, acidic solutions will react with the eggshell and absorb more dye.

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Determine which solutions are acids and which are bases. Follow your teacher's instructions.

2. Then, fill one cup with water and pour a different acid or base into each remaining cup. Make sure you pour enough into each cup to submerge the egg. (For borax, which is a solid, create a borax solution by dissolving borax into warm water until no more borax can be added. Milk of magnesia can also be diluted in water.)

3. Add 3–5 drops of food coloring to the water cup. Add the same color dye to the other cups, and try to make the color in all cups the same shade.

Making the solutions the same shade may require different amounts of food coloring per solution. For example, since milk of magnesia is white, its solution will be softer in color and will require more drops of food coloring.

4. Place an egg in each cup, and let the eggs soak for 10 minutes.

5. After 10 minutes, remove each egg from its solution. The milk of magnesia egg should be very gently rinsed under water. Be sure not to mix up the eggs.

6. Observe each egg's appearance.

ANALYZE & CONCLUDE

1. Complete the table below. Answers will vary depending on the solutions used in the experiment. Sample answers are provided below.

Solution	Prediction: Acid or Base?	Result: Acid or Base?
Vinegar	Answers will vary	Acid
Lemon juice	Answers will vary	Acid
Ammonia	Answers will vary	Base
Borax	Answers will vary	Base

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. Describe any differences you see in each solution as the eggs soak. Bubbles form on the eggshell soaking in the vinegar, which shows that there is a chemical reaction occurring between the acid and the eggshell. In the ammonia solution, there is no noticeable change …

3. Shade the ovals below to represent the resulting color of each egg (the amount of dye absorbed by each egg in the different solutions). Below each egg image, write in the solution that was used.

Solution #1	Solution #2	Solution #3	Solution #4	Solution #5	Solution #6
Vinegar	Lemon Juice	Ammonia	Borax		

4. Are acids or bases better for dyeing eggs? Explain. Acids work better than bases to dye eggs because acids react with the eggshell allowing the dye to be absorbed.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 9 ACTIVITY SHEET: Egg-Dye Solutions

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Chemical change	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a chemical reaction.	
Reactant	A starting material for a chemical reaction.	
Product	A substance formed as a result of a chemical reaction.	
Byproduct	A secondary product that is created from a chemical reaction at the same time as the primary, desired product(s).	

2. Why does vinegar work so well when dyeing eggs? Vinegar works well when dyeing eggs because it is an acid. Acids work better than bases to dye eggs because acids react with the protein in and may even begin to dissolve the eggshell, which allows the dye to be absorbed.

3. What is the composition of vinegar? Vinegar is a mixture of acetic acid and water. The high acidity levels in vinegar come from the acetic acid.

LESSON 10: Iron in Cereal

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 5–10 minutes

- **DESCRIPTION**

  Use a magnet to remove particles of iron from a mixture containing iron-fortified breakfast cereal.

- **OBJECTIVE**

  This lesson demonstrates the presence of iron in some foods and explains the importance of iron in human diets. Students will use magnets to pull the iron from the cereal mixture. The lesson can be simplified to illustrate the difference between pure substances and mixtures.

- **CONTENT TOPICS**

  Scientific inquiry; properties of matter; elements and compounds; mixtures; attractive forces (magnetism); food chemistry; chemistry in the human body; health; metals

- **MATERIALS**

  - ❑ A box of flaky breakfast cereal with a high iron content
  - ❑ Bowl
  - ❑ Large spoon
  - ❑ Strong magnets or magnetic wands
  - ❑ Ziploc® bags (quart size with easy zipper)

Other types of breakfast cereal with high iron content per serving will also work, but flakes are generally easier to crush.

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 132 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- PS2.B: Types of Interactions
- LS1.A: Growth and Development of Organisms
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

Fun Fact

Iron is the main component of rust, which forms when iron reacts with moist air.

OBSERVATION & RESEARCH

BACKGROUND

Iron is a metal element that plays a vital role in the human body. It is needed to transport oxygen throughout the body. Iron is found in all cells and is used in energy metabolism, gene regulation, cell growth, enzyme reactions, protein synthesis, and more. Its most critical role is within hemoglobin. **Hemoglobin** is the protein molecule in red blood cells that picks up oxygen in the lungs and transports it to different parts of the body. The oxygen is released by the hemoglobin when it is needed for functions in the body, such as converting sugars into energy.

Some people may experience an iron deficiency, which is a lack of iron in the body. When someone has an iron deficiency, he or she will have difficulty processing and transporting oxygen. An iron deficiency can result in a

LESSON 10: Iron in Cereal

Fun Fact

Iron-rich hemoglobin gives blood its red color.

general lack of energy and tiredness because of the lack of oxygen. It can be caused by inadequate amounts of iron in the diet or because of an insufficient amount of healthy red blood cells. When the body has an insufficient amount of healthy red blood cells, the condition is called **anemia**. Anemia may be indicated by red blood cells that are smaller in size than normal or by a lower than usual number of red blood cells.

When iron deficiencies are identified, it is important for a person to find out the reason. An iron deficiency may be a signal of illness, such as sickle cell anemia. A diet low in iron-rich foods, such as red meat and green leafy vegetables, is occasionally the cause. While it isn't a very common cause, it can be seen in rapidly growing adolescents who are picky about their diets or in vegetarians who do not make sure they are getting a balanced diet. Likewise, in countries with extreme poverty, lack of iron in the diet is a common cause of iron deficiency.

Many foods contain iron, but not all iron consumed can be easily used by the body. In addition, drinking black tea or coffee at mealtimes decreases iron absorption, while eating foods rich in vitamin C increases the absorption of iron. Foods that are considered to be rich in iron are red meats, egg yolks, leafy dark-green vegetables, and iron-enriched cereals and grains.

The iron found in iron-fortified cereals is pure iron. It is the same iron found in nails and automobiles. Iron is mixed in the cereal batter along with many other vitamins and minerals. The very tiny particles of iron quickly react with hydrochloric acid and other chemicals in the digestive tract, changing the iron into a form that can be absorbed by the body more easily.

A unique property of the element iron is that it is a strongly magnetic metal. **Magnetism** is a force of attraction or repulsion between various substances, especially those made of iron and is caused by the motion of electric charges. Because iron has magnetic properties, during this experiment, a magnet is used to separate the iron particles from the cereal mixture.

FORMULAS & EQUATIONS

Iron is one of the most abundant metals on the earth, forming about 5.6% of the earth's crust.

The chemical symbol for iron is **Fe**. Its atomic number is 26, and its atomic weight is approximately 55.8 atomic mass units (amu).

The core of the earth is believed to be mostly made up of molten iron.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on elements, including iron, can be found in the Atomic Structure and Periodic Table sections of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on food chemistry and health can be found in the Organic Chemistry and Applications of Chemistry in Everyday Life sections of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

HYPOTHESIS

▶ Iron-fortified cereal contains pure iron, which can be separated from a mixture of the cereal and water.

LESSON 10: Iron in Cereal

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Use a magnet to remove particles of iron from a mixture containing iron-fortified breakfast cereal.

OBJECTIVE

This lesson demonstrates the ways to classify matter and identify properties of matter. Students use a magnet to remove particles of the element iron from a mixture.

OBSERVATION & RESEARCH

Matter is often classified as either a pure substance or a mixture. All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. Iron is a metal element. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O.

A **mixture** is made of two or more substances that are combined physically. The different parts of a mixture have different properties. The chemical structure of each part of the mixture remains the same when they are combined. Scientists are able to separate mixtures into their original parts through a physical separation process.

Most of the things around you are mixtures. Tossed salad is a mixture because it is made of different parts—lettuce, carrots, and dressing. Salt water is a mixture too. It is made of salt and water. In the experiment, the iron-fortified cereal is a mixture. A new mixture is made when the cereal is combined with water.

In a mixture, the chemical structure of each part of the mixture remains the same. Therefore, scientists are able to separate mixtures into their original parts. Separating a mixture of substances into two or more distinct products is called a **separation process**. A separation process uses the different properties of a mixture's parts to get them to separate. The iron can be separated from the mixture using a magnet.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Explore the force of magnetism. Discuss different types of forces and what makes magnetism unique. Conduct a simple activity with different metals to determine which metals exhibit magnetic properties. Iron, cobalt, and nickel are the only elements known to produce a magnetic field. Use this information to determine what elements make up certain substances. Is a nickel made of nickel? What are the components of a penny? What about a paper clip? Have the students conduct research to find out the answers.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, compounds, and mixtures can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on magnetism can be found in the Forces of Attraction section of CEF's *Passport to Science Exploration: Chemistry Connections.*

LESSON 10: Iron in Cereal

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the type of cereal, will you get the same results?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. In a bowl, crush one to two servings of cereal using your hands or a large spoon.

Do not crush the dry cereal inside the Ziploc® bag as the cereal will puncture the bag.

2. Place the crushed cereal into a quart-sized Ziploc® bag, and fill the bag with water to about an inch below the seal. Seal the bag.

3. Let the cereal dissolve and soften a bit. Gently shake the contents of the bag for a few minutes.

4. Hold the magnet in the palm of your hand, and place the bag on top of the magnet. Keeping the bag flat (horizontal) in your hand, gently move the bag around to swirl the contents of the bag for 15–30 seconds.

5. Keeping the magnet touching the bag, carefully turn the bag and the magnet over so that the magnet is now on top of the bag. Squeeze the bag slightly so the magnet is lifted above the cereal mixture to see what it has collected.

6. Be sure the magnet is still touching the bag. Look closely at the magnet and on the inside of the bag; you should see tiny iron particles.

If the plastic bag is too thick and students cannot see the particles in the bag, you can have them carefully try the following: attach the magnet to a ruler (or use a magnetic wand). Next, open the bag carefully, and place the end of the ruler with the magnet in the bag. Move the magnet slowly back and forth in the mixture, and then pull it out. Dip the magnet in water to carefully rinse away the cereal, if necessary, and observe the iron particles left on the magnet.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the properties of the substances used in the experiment? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 10: Iron in Cereal

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Explain how the human body uses iron.
- Understand that iron is found in most foods and is vital to a human's diet.
- Describe the causes and effects of iron deficiencies.
- Distinguish between pure substances and mixtures (see ***Differentiation in the Classroom***).
- Understand the magnetic properties of some substances (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the start of the activity, tell the students that they probably eat iron every day. Then present an iron (steel) object, such as a nail, and ask if anyone would eat it. Ask them if they know how the iron gets into their bodies and if it is the same iron that is found in the nail.
- If you do not wish to perform the experiment using Ziploc® bags or if you want to do one group demonstration, use a large bowl to collect the iron. Fill the bowl halfway with cereal, and crush the cereal as much as possible. Add water, and stir to make a soupy mixture. Attach the magnet to the end of a ruler or rod (or use a magnetic wand). Dip the magnet into the mixture, and move it slowly back and forth. Then, pull the magnet out of the mixture and observe. If necessary, dip the magnet in water to carefully rinse away the cereal, and then observe the iron particles left behind.

It may be helpful to use a colored magnet, so the iron particles can be seen more easily.

REAL-WORLD APPLICATIONS

- Restrictive vegetarian or vegan diets can be associated with iron-deficiency anemia. Therefore, people on such diets should make sure they are getting the proper nutrients. Including iron-fortified cereals or iron supplements in their diets may help to make sure they are getting the necessary amount of iron. In addition, eating foods high in vitamin C, such as oranges, strawberries, and broccoli, helps the body to absorb iron.
- Too much iron in the blood can be toxic to humans. The body normally absorbs less iron if it has enough, but some individuals have lower defenses against excess iron. Iron overload is usually caused by a gene that enhances iron absorption.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 10 ACTIVITY SHEET: Iron in Cereal

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Hemoglobin		
Anemia		
Mixture		

4. Consider how iron can be separated by its magnetic properties from iron-fortified cereal.

▶ **Write your hypothesis.** ______________________________

____

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LESSON 10 ACTIVITY SHEET: Iron in Cereal

PERFORM YOUR EXPERIMENT

1. In a bowl, crush one to two servings of cereal using your hands or a large spoon.

   Do not crush the dry cereal inside the Ziploc® bag because the cereal will puncture the bag.

2. Place the crushed cereal into a quart-sized Ziploc® bag. Then, fill the bag with water to about an inch below the seal. Seal the bag.

3. Let the cereal dissolve and soften a bit. Gently shake the contents of the bag for a few minutes.

4. Hold the magnet in the palm of your hand, and place the bag on top of the magnet. Keeping the bag flat (horizontal) in your hand, gently move the bag around to swirl the contents of the bag for 15–30 seconds.

5. Keeping the magnet touching the bag, carefully turn the bag and the magnet over so that the magnet is now on top of the bag. Squeeze the bag slightly so the magnet is lifted above the cereal mixture to see what it has collected.

6. Be sure the magnet is still touching the bag. Look closely at the magnet and on the inside of the bag.

ANALYZE & CONCLUDE

1. Describe the dry cereal. ______________________________

____

____

2. Describe the cereal and water mixture. ______________________________

____

____

3. Do you see anything collecting on the magnet? If so, what do you think it is? ______________________________

____

____

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 10 ACTIVITY SHEET: Iron in Cereal

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element		
Compound		
Separation process		

2. Why is iron important in our diets? What is its function in the body? ______________________________

____

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3. What are other sources of iron that can be added to our diets? ______________________________

____

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4. List other separation processes and why they are used. ______________________________

____

____

LESSON 10 ACTIVITY SHEET: Iron in Cereal

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Flaky breakfast cereal with high iron content, water, magnets ...

2. Predict how these materials may be used. The cereal may be eaten for breakfast. Water may be used to drink, clean, or bathe. A magnet may be used to attract an object made from iron. These materials may be used together to investigate the composition of a cereal.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Hemoglobin	A protein found in red blood cells that contains iron and transports oxygen from the lungs to different parts of the body.	
Anemia	A condition in which the red blood cell count or the hemoglobin in red blood cells is abnormally low.	
Mixture	A physical combination of two or more substances that can be physically separated.	

4. Consider how iron can be separated by its magnetic properties from iron-fortified cereal and why.

▶ **Write your hypothesis.** A magnet held to a sealed bag filled with a mixture of water and iron-fortified cereal will attract tiny iron particles from the mixture.

LESSON 10 ACTIVITY SHEET: Iron in Cereal

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. In a bowl, crush one to two servings of cereal using your hands or a large spoon.

   Do not crush the dry cereal inside the Ziploc® bag because the cereal will puncture the bag.

2. Place the crushed cereal into a quart-sized Ziploc® bag. Then, fill the bag with water to about an inch below the seal. Seal the bag.

3. Let the cereal dissolve and soften a bit. Gently shake the contents of the bag for a few minutes.

4. Hold the magnet in the palm of your hand, and place the bag on top of the magnet. Keeping the bag flat (horizontal) in your hand, gently move the bag around to swirl the contents of the bag for 15–30 seconds.

5. Keeping the magnet touching the bag, carefully turn the bag and the magnet over so that the magnet is now on top of the bag. Squeeze the bag slightly so the magnet is lifted above the cereal mixture to see what it has collected.

6. Be sure the magnet is still touching the bag. Look closely at the magnet and on the inside of the bag.

ANALYZE & CONCLUDE

1. Describe the dry cereal. The cereal is brown, dry, and flaky. The pieces look about the same, but each piece has a slightly different size and shape. The cereal would be crunchy if eaten.

2. Describe the cereal and water mixture. The cereal and water mixture is wet and brown. You cannot see through the mixture. If the mixture was eaten, it would be mushy.

3. Do you see anything collecting on the magnet? If so, what do you think it is? Tiny gray/black particles are visible on the magnet. These particles are tiny pieces of iron, which are being drawn from the mixture by the magnet. The iron particles move as the magnet is moved around the bag.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 10 ACTIVITY SHEET: Iron in Cereal

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom.	
Compound	A pure substance made up of two or more elements joined in a defined ratio.	
Separation process	A process that divides a mixture into two or more distinct substances.	

2. Why is iron important in our diets? What is its function in the body? Iron is vital to the transportation of oxygen throughout the human body. Iron is found in every cell, but its most critical role is within the protein called hemoglobin that is carried by red blood cells.

3. What are other sources of iron that can be added to our diets? Foods high in iron content include red meat, egg yolks, mollusks, turkey, and artichokes.

4. List other separation processes and why they are used. Distillation and filtration are processes that can be used to separate solid particles from liquids, such as removing salt from sea water.

LESSON 11: Diaper Polymers

ESTIMATED TIME **Setup:** 10 minutes | **Procedure:** 5–10 minutes

• DESCRIPTION

Use crystals found in diapers to absorb water and illustrate the properties of super-absorbent polymers.

• OBJECTIVE

This lesson introduces students to molecules, monomers, and polymers. Students will observe the diffusion of water in and out of super-absorbent polymer crystals found in diapers. The lesson can be simplified to focus on just the process of diffusion.

• CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; diffusion; polymers

• MATERIALS

- ❑ Disposable diapers
- ❑ Distilled water
- ❑ Graduated cylinder (or measuring cups)
- ❑ Table salt
- ❑ Paper bag
- ❑ Spoons
- ❑ Paper cups
- ❑ Magnifying glass (optional)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 143 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from “A Framework for K–12 Science Education,” established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

A molecule is the smallest particle of an element or compound that retains the chemical properties of that element or compound. It is composed of two or more atoms chemically bonded together by an exchange or sharing of electrons. At the beginning of the 20th century, chemists learned how to create special molecules by combining many smaller molecules in a regular pattern. These large molecules are called polymers. Polymers are long, chain-like molecules that are formed by connecting many repeating units (monomer units). The most common polymers are made of long chains of carbon atoms. A monomer is a single molecule capable of combining with other similar molecules.

The super-absorbent polymer found in many brands of disposable diapers is called sodium polyacrylate. This long polymer is able to absorb large amounts of water because the sodium ions attached to it attract water. These ions attract water into the polymer by diffusion or osmosis. Diffusion is the movement of particles from an area of high concentration to an area of low concentration. Osmosis is the diffusion of water across a semi-permeable membrane.

LESSON 11: Diaper Polymers

When sodium polyacrylate is exposed to water, the higher concentration of water outside the polymer (and higher concentration of sodium ions inside the polymer) draws the water into the molecule through osmosis. Sodium polyacrylate will continue to absorb water until there is an equal concentration of water inside and outside the polymer. Each sodium polyacrylate molecule is able to attract and hold thousands of water molecules.

Table salt is primarily composed of the compound sodium chloride. When sodium chloride is added to the hydrated polymer, the sodium ions from the salt attract the water. As a result, water molecules diffuse back out of the polymer.

FORMULAS & EQUATIONS

Sodium polyacrylate is known as a super-absorbent polymer because it has the ability to absorb several hundred times its mass in water.

It is a polymer that consists of repeating units of the monomer $\mathbf{CH_2CH(CO_2Na)}$**-** or $\mathbf{(C_3H_3NaO_2)_n}$. *The* n *stands for any number of molecules.*

Common table salt is mainly made up of the compound sodium chloride.

The chemical formula for sodium chloride is **NaCl**.

Most table salts are made of about 97–99% NaCl. The remaining 1–3% is usually iodine and other ingredients.

Fun Fact

Ever wonder what happens when astronauts are on a long space journey without a port-a-potty handy? They need super-absorbent polymers too!

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on molecules can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on polymers can be found in the Industrial Applications of Chemistry section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action.*
- Additional information on diffusion can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶Adding water to the super-absorbent polymer found in diapers will cause the polymer to swell as water diffuses inside. When table salt is added to the swollen polymer, the water will diffuse back out of the polymer.

LESSON 11: Diaper Polymers

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Use polymer crystals found in diapers to illustrate the process of osmosis (diffusion).

OBJECTIVE

This lesson explores properties of matter and illustrates the processes of diffusion and osmosis.

OBSERVATION & RESEARCH

Different states of matter exhibit different properties. Liquids and gases are considered fluids. A **fluid** is any substance made up of particles that flow or move freely. A fluid easily changes shape when a force is applied. For example, if you push on a balloon filled with gas, you can easily change its shape. Likewise, if you push on a water balloon, you can change the shape of the balloon filled with water as well.

Fluids can undergo a process called diffusion. **Diffusion** is the movement of particles from an area of high concentration to an area of low concentration. The particles will move at random from an area with many particles to an area with few particles. Diffusion will continue until the particles are spread evenly throughout an area. Water undergoes a special type of diffusion called osmosis. **Osmosis** is the diffusion of water across a semi-permeable membrane. Osmosis is an important process in our bodies because it allows water to pass into and out of our cells.

The super-absorbent substance, called sodium polyacrylate, is found in many brands of disposable diapers. It uses osmosis to soak up water. Because there is a higher concentration of water outside the sodium polyacrylate, it draws in the water through osmosis. Each sodium polyacrylate molecule is able to attract and hold thousands of water molecules.

Likewise, table salt is primarily composed of sodium chloride. When sodium chloride is added to the hydrated sodium polyacrylate, the water molecules diffuse back out of the polymer.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 143, but challenge your students to determine what type of change is occurring and to support their decision. There is no easy answer to this one!

The polymer sodium polyacrylate is called super-absorbent because it is able to absorb much more water than its own weight. Polymers are formed through a specific bonding process called cross-linking. **Cross-linking** is the formation of chemical bonds between complex molecules or molecular chains, such as polymers. Cross-linking causes the polymer chains to stick together and overlap, forming a net-like or web-like structure, instead of being spread straight out in a long chain.

Although sodium polyacrylate looks like salt crystals, the polymer is very complex. It has so many cross-linked bonds between its molecules that adding water causes the polymer to swell and allows more water to diffuse into the spaces inside.

Think of a balloon. A balloon is made of a polymer substance that will expand to allow air and water inside. Its shape changes when this occurs but its chemical composition does not. Likewise, when a sodium polyacrylate crystal is exposed to water, it expands and allows the water to diffuse inside the polymer.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on fluids, diffusion, and osmosis can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 11: Diaper Polymers

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you use different diapers, will you get the same results?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

Part One: Obtaining the Polymer Crystals

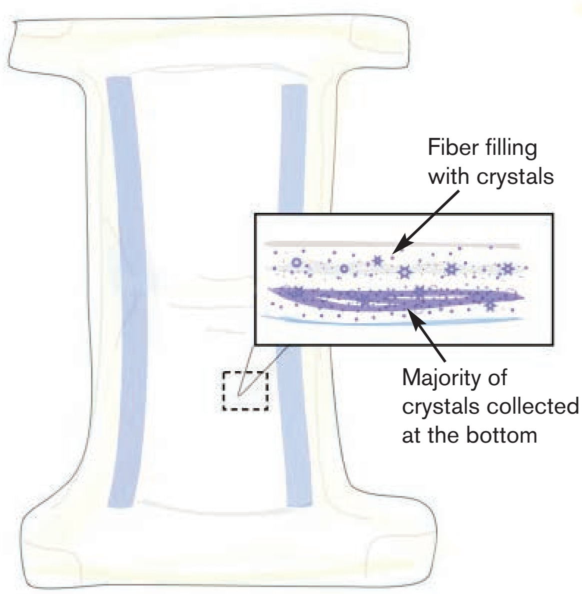
1. Remove the cotton-like fiber filling from a disposable diaper. (If you look at the filling through a magnifying glass, you will notice tiny flakes or crystals attached to the filaments. In some brands, these filaments are obvious without a magnifying glass.)
2. Carefully, shred the fiber filling into smaller pieces. Make sure to include any leftover crystals that may remain on the diaper!
3. Place the filling in a paper bag and shake it vigorously for a minute. The crystals will dislodge and collect in the bottom of the bag.
4. Lift the cotton fibers carefully from the bag and dispose of them, leaving the crystals in the bottom of the bag.

The fine powder released when shaking the crystals from the diapers can irritate the respiratory system if inhaled. You may want to obtain the crystals for the students before the lesson. Otherwise, have your students wear small filter masks that cover their mouths and noses, as well as safety goggles to protect their eyes. If you obtain the crystals for them, be sure to wear a filter mask and safety goggles yourself.

Part Two: Experiment

1. Place a spoonful of the crystals in the bottom of a paper cup.
2. Slowly pour 200 mL (or approximately $^4/_5$ cup) of distilled water into the cup. Stir gently and allow the cup to stand for about five minutes.
3. Observe the substance in the cup.
4. Sprinkle table salt on the substance in the cup and stir. Keep adding salt until it liquefies.

Distilled water is a better choice for this experiment because it does not contain any ions that would compete with the sodium in the polymer. Tap water also works but not as effectively.



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What changes do students notice between the original polymer and the polymer once it has absorbed the water? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

LESSON 11: Diaper Polymers

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and identify the properties of polymers and monomers.
- Differentiate between the processes of diffusion and osmosis.
- Define and give examples of fluids (see ***Differentiation in the Classroom***).
- Explain the importance of osmosis in the human body (see ***Differentiation in the Classroom***).
- Describe the process of cross-linking (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before you start the lesson, add some crystals to a paper or Styrofoam™ cup without the students knowing. Allow the students to watch you pour water into the cup. Stir the water around a bit and then invert the cup. Nothing should fall out. Ask students for an explanation to test their knowledge. (Make sure you test this first to be sure you have the right amount of crystals and water to make this work.)

REAL-WORLD APPLICATIONS

- Super-absorbent polymers have other uses too. These polymers may be used in special soils to store water near a plant's roots. The plant is then able to access this water when less water is available, such as when it hasn't rained in a while. It also helps prevent erosion from water runoff.
- Polymers can be found all over the place. They include rubber, plastics, Styrofoam™, and clothing fibers, such as nylon and rayon. What other examples can you find?

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 11 ACTIVITY SHEET: Diaper Polymers

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

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2. Predict how these materials may be used. ______________________________

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____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Molecule		
Monomer		
Polymer		
Diffusion		
Osmosis		

4. Consider how crystals contained within a disposable diaper will react when water is added and why.

▶**Write your hypothesis.** ______________________________

____

____

LESSON 11 ACTIVITY SHEET: Diaper Polymers

PERFORM YOUR EXPERIMENT

Part One:

1. Wearing the proper safety equipment, remove the fiber filling from a disposable diaper. Observe the filling.
2. Carefully shred the fiber filling into smaller pieces, and place the filling in a paper bag.
3. Shake the bag vigorously for a minute. (Be sure you are still wearing your safety gear!) The crystals will dislodge and collect in the bottom of the bag.
4. Remove the fibers from the bag and dispose of them. Make sure the crystals remain in the bottom of the bag.

Part Two:

1. Place a spoonful of the crystals in the bottom of a paper cup.
2. Slowly pour approximately 200 mL of distilled water into the cup and observe.
3. Sprinkle table salt on the mass and stir. Keep adding salt until the properties of the mass change.

ANALYZE & CONCLUDE

1. Describe the fiber filling of the diaper. ______________________________

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2. Why do you think there are crystals in the diaper? ______________________________

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3. What happens when you add water to the crystals? ______________________________

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4. Describe the polymer after the water is added. ______________________________

____

____

LESSON 11 ACTIVITY SHEET: Diaper Polymers

5. What happens when you add salt to the water-soaked polymer? ______________________________

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6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________

____

____

SHARE YOUR KNOWLEDGE

1. Define the following key term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Fluid		

2. What are other ways that super-absorbent polymers may be used? ______________________

____

____

3. Provide other examples of diffusion. ____

____

____

LESSON 11 ACTIVITY SHEET: Diaper Polymers

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Diapers (super-absorbent crystals), table salt, water, magnifying glass ...

2. Predict how these materials may be used. Diapers may be used to absorb a liquid. Water may be used to drink, clean, or bathe. Table salt may be used to add flavor to food. Together the materials may be used to observe the processes of diffusion and osmosis.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Molecule	The simplest structural unit of an element or compound that is made up of atoms held together by chemical bonds and maintains the chemical properties of the element or compound.	
Monomer	A single molecule capable of combining with other similar molecules to forrm a polymer.	
Polymer	A large molecule formed by combining many smaller molecules (monomers) in a regular pattern.	
Diffusion	The movement of particles from an area of high concentration to an area of low concentration.	
Osmosis	The diffusion of water across a semi-permeable membrane (a membrane that allows some ions or molecules to pass through but not others).	

4. Consider how crystals contained within a disposable diaper will react when water is added and why.

▶ **Write your hypothesis.** By adding water to the super-absorbent crystals found in diapers, the crystals will swell as they take in the water. Adding salt to the swelled, gel-like polymer will cause the water to diffuse back out of the polymer.

LESSON 11 ACTIVITY SHEET: Diaper Polymers

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

Part One:

1. Wearing the proper safety equipment, remove the fiber filling from a disposable diaper. Observe the filling.
2. Carefully shred the fiber filling into smaller pieces, and place the filling in a paper bag.
3. Shake the bag vigorously for a minute. (Be sure you are still wearing your safety gear!) The crystals will dislodge and collect in the bottom of the bag.
4. Remove the fibers from the bag and dispose of them. Make sure the crystals remain in the bottom of the bag.

Part Two:

1. Place a spoonful of the crystals in the bottom of a paper cup.
2. Slowly pour approximately 200 mL of distilled water into the cup and observe.
3. Sprinkle table salt on the mass and stir. Keep adding salt until the properties of the mass change.

ANALYZE & CONCLUDE

1. Describe the fiber filling of the diaper. The fiber filling of the diaper is soft, but strong. The fibers are woven together, which makes them strong. Once the woven fiber is removed from the diaper lining, it can be torn into smaller pieces.

2. Why do you think there are crystals in the diaper? The crystals in the diaper are super-absorbent polymer crystals used to draw in liquid and keep a baby's bottom dry.

3. What happens when you add water to the crystals? When you add water to the crystals, the water moves into the polymer through osmosis (diffusion). The crystals swell from the added water.

4. Describe the polymer after the water is added. The polymer is clear, thick, and soft like a gel. It is mushy, but it is not a fluid.

LESSON 11 ACTIVITY SHEET: Diaper Polymers

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

5. What happens when you add salt to the water-soaked polymer? When you add salt to the water-soaked polymer, the water molecules diffuse back out of the polymer.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Fluid	Any substance made up of particles that flow or move freely, such as a liquid or gas.	

2. What are other ways that super-absorbent polymers may be used? Super-absorbent polymers have been used in spill-control sheets, as water-retention objects for supplying water to plants, in filtration applications, and in medical waste solidification.

3. Provide other examples of diffusion. If you put a drop of food coloring into a cup of water, the dye particles will eventually spread throughout the water. Likewise, you can smell food cooking in a kitchen from other rooms because of diffusion.

LESSON 12: The Great Escape

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** 5 minutes

• DESCRIPTION

Place soda pop bottles, with balloons over the openings, in separate bowls of water with different temperatures to determine which setup releases the most gas.

• OBJECTIVE

This lesson introduces solubility and demonstrates the relationship between solubility and temperature. Students use soda pop to explore the solubility of gases. The lesson can be extended to explain the relationship between temperature and energy.

• CONTENT TOPICS

Scientific inquiry; measurement (temperature); states of matter; properties of matter; elements and compounds; mixtures (solutions); energy (thermal energy, energy transfer)

• MATERIALS

- ❑ Three identical 2-liter bottles of soda pop at room temperature
- ❑ Three balloons
- ❑ Three large bowls (with flat bottoms)
- ❑ Ruler
- ❑ Thermometer
- ❑ Water
- ❑ Ice cubes
- ❑ Device for heating water (hot plate)
- ❑ String

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 155 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter is often classified as either a pure substance or a mixture. All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. For example, silver is a metal element. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O. Likewise, carbon dioxide gas is a compound with the formula CO_2.

A **mixture** is made of two or more substances that are combined physically. The different parts of a mixture have different properties. The chemical structure of each part of the mixture remains the same when they are combined. Scientists are able to separate mixtures into their original parts through separation processes.

LESSON 12: The Great Escape

A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). For example, salt may be dissolved in water to form a saltwater solution. The salt is the solute, and the water is the solvent.

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. Several factors can affect solubility, including temperature, pressure, and the nature of the solute or solvent. This lesson focuses on temperature. For solid solutes, as temperature increases, solubility increases. Therefore, when the temperature of a liquid is increased, more solute can be dissolved in the liquid than when the temperature was lower.

Interestingly, this rule is quite different for gases. With gas solutes, as the temperature of the solvent increases, the solubility of the gas decreases. As the temperature of the solvent decreases, the solubility of the gas increases. Therefore, when the temperature of a liquid is increased, less and less gas will be able to dissolve in the liquid; in fact, previously dissolved gases may begin to escape from the solution!

Soda pop is a solution with various solutes, such as high-fructose corn syrup and carbon dioxide gas, dissolved in water. As the soda pop is heated, the solubility of the CO_2 gas decreases. Since the solvent can no longer hold that much CO_2, it is released from the solution. By placing a balloon over the opening of a soda pop bottle, you can collect any CO_2 being released. The hot water will cause the solution to release the most CO_2, thus, inflating the balloon. The room-temperature water will cause very little, if any, CO_2 to be released, and the ice water will not release any CO_2.

FORMULAS & EQUATIONS

Soda pop is a solution of water (**H_2O**), carbon dioxide (**CO_2**), and additives like high-fructose corn syrup or artificial sweeteners.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on pure substances, mixtures, and solubility can be found in the Classification of Matter section in CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on solutions can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

▶ As the temperature of a soda pop solution increases, the solubility of the CO_2 gas inside decreases and causes the gas to be released from the solution.

LESSON 12: The Great Escape

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Use the experiment to discuss the different states of matter. Conduct the experiment as described on page 155, but focus on the different properties of solids, liquids, and gases. Name things in the classroom, and ask the students to say whether it is a solid, liquid, or gas. In which state is the soda pop bottle? Solid! It has a definite shape and volume. In which state is the water or soda pop? Liquid! They have definite volumes but not definite shapes. Pour the water into different containers to illustrate how the shape changes but not the volume. n which state is the substance inside the balloon? Gas! It has no definite shape or volume. Discuss with the class how they know certain gases exist if they cannot see them.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Place soda pop bottles, with balloons over the openings, in separate bowls of water with different temperatures to demonstrate energy transfer and the impact of energy changes on matter.

OBJECTIVE

This lesson explores the relationship between temperature and energy and ways of transferring energy from one substance to another. Students use soda pop to explore the effects of temperature (average kinetic energy) changes on solubility.

OBSERVATION & RESEARCH

Energy is defined as the capacity to do work or produce heat. Energy can take many different forms, including light, sound, electricity, chemical bonds, mechanical motion, and thermal energy. The **law of conservation of energy** (first law of thermodynamics) states that while energy can change from one form to another, it can neither be created nor destroyed. When matter changes, whether through a physical or chemical change, the amount of energy in the system is the same before and after the change, but the energy may be in a different form or forms.

Temperature is a measure of the average kinetic energy (energy of motion) of particles in a substance. (It is a measure of how fast the particles are moving around.) The temperature of a substance is measured using a thermometer. Temperature, thermal energy, and heat are related, but they are not the same thing.

Thermal energy is the total energy of particles in a substance. The transfer of thermal energy from an object at a higher temperature to an object at a lower temperature is known as **heat**. Heat is commonly transferred (moved from one substance to another) in one of three ways—conduction, convection, or radiation.

Conduction is the transfer of energy by collisions between nearby atoms. Conduction is the most common means of heat transfer in solid matter. For example, on a hot summer day, if you grab the handle of a car door, the heat will move from the door handle to your hand. If you touch that hand to your face, you will notice that your hand will feel warmer than usual because of the energy transfer.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states of matter and energy changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on types of measurements can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on heat and energy transfer can be found in the Energy section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action.*

LESSON 12: The Great Escape

DIFFERENTIATION IN THE CLASSROOM

Convection is the transfer of energy by the bulk molecular motion within a liquid or gas. Convection occurs because of temperature differences within the fluid or between the fluid and its container. In homes or buildings that are a few stories high, you may notice the results of convection. If there are not special temperature controls on each floor, the upper floors will often be warmer than the bottom floor because the hot air will rise and the cooler air will fall.

Radiation is the transfer of energy (as electromagnetic waves) through an empty space or clear material without heating the empty space or clear material. The most common form of radiation is solar radiation. In solar radiation, the rays from the sun heat up the earth.

In this experiment, when the water in one bowl is heated, the heat from the water transfers by conduction through the soda pop bottle, heating the liquid inside. As the liquid inside becomes warmer, the dissolved CO_2 gas is released from the solution. Likewise, in the ice water setup, the heat from the water and outside air will move into the ice, slowly melting the ice.

NOTES

LESSON 12: The Great Escape

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the temperature of the water changes, does the amount of gas that fills the balloon change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

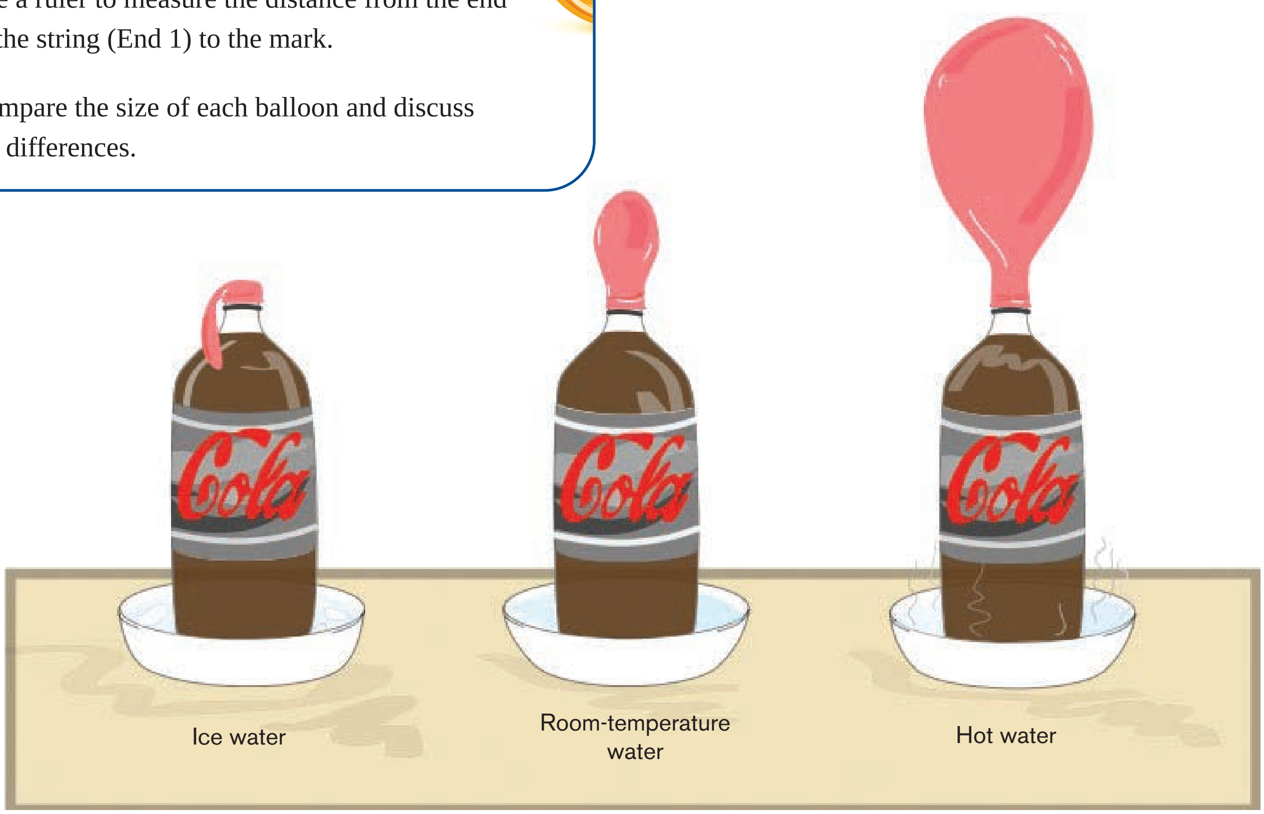
1. Stretch out the balloons to make them more flexible before using them.
2. Open one bottle of soda pop, and quickly cover the bottle opening with a balloon. Repeat with the two other bottles of soda pop.
3. Place one balloon-covered bottle in a bowl of ice water, the second in a bowl of room temperature water, and the third in a bowl of hot water.
4. Wait approximately five minutes.
5. Gently wrap a string around the widest part of each balloon to measure its size. Draw a mark on the string where one end (End 1) comes back around together with the rest of the string.
6. Use a ruler to measure the distance from the end of the string (End 1) to the mark.
7. Compare the size of each balloon and discuss the differences.

If a heating device is not readily available in the classroom, heat the water prior to class and store it in a hot beverage thermos to keep it as warm as possible.

To reduce waste, you can do the experiment as a demonstration.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What was the temperature of the water in each container? What was the circumference of each balloon? You can use the table provided in the activity sheet (or a similar one of your own) for students to record their data.



LESSON 12: The Great Escape

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Distinguish between pure substances and mixtures.
- Define and identify solutions and the parts of a solution.
- Explain solubility and the relationship between temperature and the solubility of gases.
- Define energy and explain the law of conservation of energy (see ***Differentiation in the Classroom***).
- Compare and contrast the different types of heat transfer (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- To discuss solubility further, ask students what happens when you open a soda pop bottle? When a bottle of soda pop is opened, it generally makes a hissing sound. Carbon dioxide gas is dissolved in the soda pop under pressure. Therefore, the pressure inside the bottle is much higher than the pressure outside the bottle. When the bottle is opened, the change in pressure affects the solubility of the liquid, allowing some of the gas to escape.
- The relationship between temperature and solubility explored in this lesson can also be seen when boiling tap water. As you heat the water, small bubbles of air will form on the bottom and sides of the pot, but the water isn't boiling yet. These bubbles are the air that was dissolved in the water at room temperature. Air becomes less soluble in water as the temperature increases. The bubbles form because less and less air is able to be dissolved in the water. If you cool the water and then boil it again, bubbles will not appear until the water begins to boil because the dissolved air has already been removed.

5-8 See **Lesson 16: Fountain of Soda Pop** for another lesson on solubility.

REAL-WORLD APPLICATIONS

- The solubility of gases in water plays a major role in the survival of fish. Since an increase in temperature causes the solubility of gases to decrease, water at high temperatures lacks dissolved oxygen. Therefore, many fish are only capable of living in cooler waters where more oxygen exists.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 12 ACTIVITY SHEET: The Great Escape

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

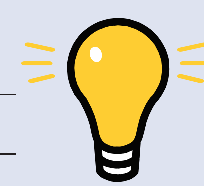
Term	Definition	Example (write or add image)
Element		
Compound		
Mixture		
Solution		
Solubility		

4. Consider what will happen to the balloons if they are placed over the openings of identical soda pop bottles with different temperatures and why.

▶**Write your hypothesis.** ____

____

____



LESSON 12 ACTIVITY SHEET: The Great Escape

PERFORM YOUR EXPERIMENT

1. Stretch out the balloons to make them more flexible before using them.
2. Open one bottle of soda pop and quickly cover the bottle opening with a balloon. Repeat with the two other bottles of soda pop.
3. Place one balloon-covered bottle in a bowl of ice water. Place the second balloon-covered bottle in a bowl of room-temperature water, and place the third in a bowl of hot water.
4. Wait approximately five minutes.
5. Gently wrap a string around the widest part of each balloon to measure its size. Draw a mark on the string where one end (End 1) comes back to meet the rest of the string.
6. Use a ruler to measure the distance from the end of the string (End 1) to the mark. This distance is the size of the widest part of the balloon.
7. Compare the size of each balloon, and discuss the differences.

ANALYZE & CONCLUDE

1. Record the size of the balloons in the table below.

Temperature of Water	Size of Balloon
Ice water	
Room-temperature water	
Hot water	

LESSON 12 ACTIVITY SHEET: The Great Escape

2. What do you hear when you open the bottle? What sound is it making? ______________________________

____

____

3. What are the components of soda pop? ____

____

____

4. Which balloon becomes the biggest? Why? ____

____

____

5. What is the relationship between temperature and the solubility of gases? ___________________

____

____

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________

____

____

LESSON 12 ACTIVITY SHEET: The Great Escape

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Energy		
Heat		
Conduction		
Convection		
Radiation		

2. What is the law of conservation of energy? ____

____

____

3. Changes to what other conditions, besides temperature, would cause the gas to escape faster? ______________

____

____

4. Does water contain dissolved gases? If so, which gases? ______________________________

____

____

LESSON 12 ACTIVITY SHEET: The Great Escape

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Soda pop, balloons, ruler, ice water, hot water, room-temperature water …

2. Predict how these materials may be used. Soda pop may be used to drink. The balloons may be used as decorations. The ruler may be used to measure items. Water may be used for drinking, cleaning, and many other things. These materials may be combined at different temperatures to observe the physical properties of soda pop.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom.	
Compound	A pure substance made up of two or more elements joined in a defined ratio.	
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Solubility	A measure of the amount of solute that can be dissolved in a solvent.	

4. Consider what will happen to the balloons if they are placed over the openings of identical soda pop bottles with different temperatures and why.

▶**Write your hypothesis.** As the temperature of a soda pop solution increases, the solubility of the CO_2 gas inside decreases, causing more gas to be released from the higher-temperature solution.

LESSON 12 ACTIVITY SHEET: The Great Escape

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Stretch out the balloons to make them more flexible before using them.
2. Open one bottle of soda pop and quickly cover the bottle opening with a balloon. Repeat with the two other bottles of soda pop.
3. Place one balloon-covered bottle in a bowl of ice water. Place the second balloon-covered bottle in a bowl of room-temperature water, and place the third in a bowl of hot water.
4. Wait approximately five minutes.
5. Gently wrap a string around the widest part of each balloon to measure its size. Draw a mark on the string where one end (End 1) comes back to meet the rest of the string.
6. Use a ruler to measure the distance from the end of the string (End 1) to the mark. This distance is the size of the widest part of the balloon.
7. Compare the size of each balloon, and discuss the differences.

ANALYZE & CONCLUDE

1. Record the size of the balloons in the table below.

Temperature of Water	Size of Balloon
Ice water	Answers will vary
Room-temperature water	Answers will vary
Hot water	Answers will vary

LESSON 12 ACTIVITY SHEET: The Great Escape

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. What do you hear when you open the bottle? What is making the sound? You hear a hissing sound when you open the bottle. That sound is some of the compressed gas in the bottle being released and escaping into the outside air.

3. What are the components of soda pop? Soda pop is a solution of high-fructose corn syrup or other sweeteners, carbon dioxide (CO_2) gas, and other flavor and color additives dissolved in water.

4. Which balloon becomes the biggest? Why? The hot water will produce the biggest balloon because it causes the greastest amount of gas to be released. With gas solutes, when the temperature of the solvent increases, the solubility of the gas decreases. Thus, at a higher temperature, less CO_2 gas can stay dissolved in the soda pop.

5. What is the relationship between temperature and the solubility of gases? In general, as the temperature of the solution increases, the solubility of the gas decreases. Less gas can be dissolved in a solvent at higher temperatures.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 12 ACTIVITY SHEET: The Great Escape

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Energy	The ability to do work or produce heat.	
Heat	The flow of thermal energy from one substance to another because of differences in temperature.	
Conduction	The transfer of energy by collisions between nearby atoms.	
Convection	The transfer of energy by the bulk molecular motion within a liquid or gas.	
Radiation	The transfer of energy (as electromagnetic waves) through an empty space or clear material without heating the empty space or clear material.	

2. What is the law of conservation of energy? The law of conservation of energy states that energy can neither be created nor destroyed; it can only change form.

3. Changes to what other conditions, besides temperature, would cause the gas to escape faster? A decrease in pressure will cause gas to escape from a solution more easily.

4. Does water contain dissolved gases? If so, which gases? Yes, water contains dissolved oxygen gas, which fish and other organisms like zooplankton need to survive. This oxygen enters the water from the atmosphere and dissolves in the water for fish to breathe. While the water molecules contain oxygen, this is not the form of oxygen that the fish need to breathe.

LESSON 13: Disappearing Glass

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5–10 minutes

DESCRIPTION
Submerge Pyrex® glass in vegetable oil and observe the effects of refraction.

OBJECTIVE
This lesson teaches students about energy, light, and refraction. Students will make predictions and provide explanations based on what they see or do not see. This lesson can be simplified to discuss properties of matter and energy.

CONTENT TOPICS
Scientific inquiry; measurement; states of matter; properties of matter; energy (electromagnetic waves); light (refraction)

MATERIALS
- ❑ Large clear container
- ❑ Vegetable oil
- ❑ Pyrex® glass container, with or without markings
- ❑ Regular glass container without markings

⚠ Try using a one-quart clear container and a 50-mL Pyrex® beaker to perform this experiment.

⚠ Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 168 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER
This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from “A Framework for K–12 Science Education,” established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS3.A: Definitions of Energy
- PS4.A: Wave Properties
- PS4.B: Electromagnetic Radiation

OBSERVATION & RESEARCH

BACKGROUND
Energy is a measure of the ability to do work or generate heat. Energy is found in many forms and can change from one form to another. Some forms of energy include kinetic energy, chemical energy, thermal energy, and electromagnetic energy.

Electromagnetic waves carry energy through space by a type of energy transfer known as radiation. Light, microwaves, and X-rays are all types of electromagnetic waves. **Light** is a combination of electromagnetic waves that are visible to the human eye. White light is made up of different colors (different waves). If you pass white light through a prism, you can split the light into different colors. The general order of the resulting colors is red, orange, yellow, green, blue, and violet.

Light has a number of unique properties. Light reflects off surfaces, which allows us to see images in mirrors. Light also exhibits a property known as refraction. Scientists coined the word **refraction** to describe the bending of light as it passes from one medium to another. This property is used in optical devices, such as microscopes, prescription glasses, and magnifying glasses.

LESSON 13: Disappearing Glass

Most students have experienced the refraction of light when looking at objects submerged in water. The object under the water usually looks larger than when you take it out of the water because of refraction.

The amount the light bends is based on the index of refraction of the substances being compared. The **index of refraction** refers to the angle that is formed between the light and the surface of the object. A substance's index of refraction is determined by dividing the speed of light in a vacuum by the speed of light through that substance.

Because the index of refraction of oil is almost the same as that of Pyrex® glass, light is not significantly refracted (bent) as it passes from the oil through the glass. Therefore, the Pyrex® glass seems to disappear because the light is not bent. Common glass has a different index of refraction than that of oil and therefore is visible when submerged in the oil.

FORMULAS & EQUATIONS

Electromagnetic waves are characterized by wavelength and frequency. **Wavelength** is the distance between one wave crest (top of the wave) and the next or between one wave trough (bottom of the wave) and the next. **Frequency** is the number of complete waves or pulses that passes a given point per second.

The product of the wavelength and frequency of a wave is a constant (c), the speed of light: $\mathbf{c = 3 \times 10^8}$ **m/sec.**

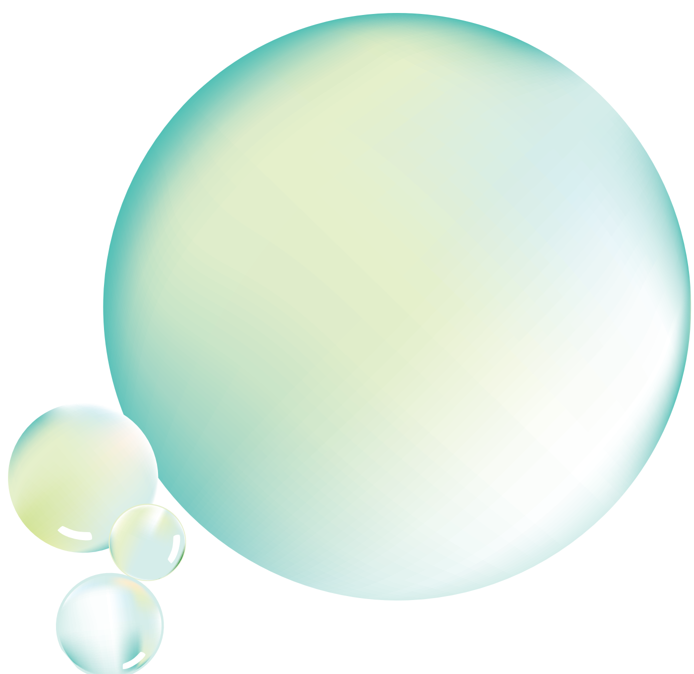
CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on electromagnetic waves and light can be found in the Energy section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

HYPOTHESIS

▶ When Pyrex® glass is submerged in a container of vegetable oil, the glass will seem to disappear because the light does not refract between the two materials.



Fun Fact

Scientists use refraction to determine the brand or composition of unknown glass.

LESSON 13: Disappearing Glass

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Submerge Pyrex® glass in vegetable oil and observe as the glass seems to disappear.

OBJECTIVE

This lesson emphasizes properties of matter and properties of energy, specifically light.

OBSERVATION & RESEARCH

Matter is everything around us! It is characterized and classified by its properties. Mass and volume are two basic properties of all matter.

Mass is a measure of the amount of matter in a substance. The mass of an object can be measured with a balance. To determine the mass of an object, the object is compared to another object with a mass that is known. The unit of measurement that scientists use to measure mass is the kilogram (kg) or gram (g).

Volume is a measure of the amount of space an object occupies. Volume can be measured in a number of different ways. For liquids, volume can be measured using a graduated cylinder. To determine the volume of a rectangular solid, multiply its length, width, and height ($\mathbf{v = l \times w \times h}$). Volume is measured in liters or cubic units, such as cubic meters. A cubic meter is a cube that is one meter long on each side.

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, glasses, and trees. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and oil. **Gases** have no definite shape and no definite volume. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Along with differences in shape and volume, the different states of matter have other unique properties. Students can use the Pyrex® glass and oil to compare and contrast solids and liquids.

Likewise, different forms of energy can be identified by different properties as well. **Energy** is a measure of the ability to do work or generate heat. Energy is found in many forms and can change from one form to another. Some forms of energy include kinetic energy, chemical energy, thermal energy, and light.

Light has a number of unique properties. Light reflects off surfaces, which allows us to see images in mirrors. Light also exhibits a property known as refraction. **Refraction** is the bending of light as it passes from one medium to another. Most students have experienced the refraction of light when looking at objects submerged in water. The object under the water usually looks larger than when you take it out of the water because of refraction.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Complete the experiment as described on page 168, but discuss the properties of light further. Another interesting property of light combines both refraction and reflection. It is called total internal reflection. For example, when light coming from the air strikes water, part is reflected and part is refracted. When the angle at which the light strikes the water is large enough, it gets totally reflected and, in fact, cannot leave the water. Scientists have made use of this property of light in fiber optics. Fiber optic cables can carry digital information over very long distances.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of physical measurements can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on states of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 13: Disappearing Glass

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you use a different type of glass, will you get the same results?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill a glass container with enough vegetable oil to submerge the Pyrex® glass.
2. Submerge the Pyrex® glass in the oil, and observe what happens.
3. Next, submerge a regular glass in the oil, and observe what happens.

⚠ Because of the large amount of materials used, it is best to do this experiment as a demonstration.

⚠ For this experiment to work properly, the Pyrex® glassware must be absolutely clean. After washing and rinsing the Pyrex® glass thoroughly with soap and water, you might need to give it a final rinse with acetone or nail-polish remover. Any spotting left on the glass will create telltale indicators of the "invisible glass."

⚠ The large clear container used to hold the oil should be clean as well; it does not need to be made of Pyrex® glass.

⚠ Try to create as few bubbles as possible when pouring the oil into the large glass container. If bubbles adhere to the Pyrex® glass, they will reveal the glass. Therefore, you should wait a few minutes for the bubbles to settle.

NOTES

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the properties of the Pyrex® glass? What are the properties of the oil? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

LESSON 13: Disappearing Glass

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand that light is composed of visible electromagnetic waves that carry energy through space.
- Understand refraction of light and explain why the Pyrex® glass seems to disappear when placed in vegetable oil.
- Identify and understand the different properties of matter (see ***Differentiation in the Classroom***).
- Compare and contrast the different states of matter (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Tell the students before the experiment that you can dissolve glass in oil. If you have marked and unmarked Pyrex® glass, use the unmarked glass first and tell the students it has dissolved. Then try the marked glass. Since they will be able to see the markings, ask if they can explain what is really occurring. If you only have a marked Pyrex® glass, ask the students why the labels are not moving if the glass is dissolving.

REAL-WORLD APPLICATIONS

- You may observe refraction when you are at a swimming pool. The parts of our bodies that are out of the water may not line up with the parts in the water. This distortion is all due to the bending, or refraction, of light through the water.
- Refraction can be used to make distant objects visible. Some telescopes use the refraction of light through a convex glass lens to bend light and bring it into focus. Because the lens is thicker in the center than it is toward its edges, light at the edges is bent more than in the center. This process allows all of the light to come together at a focus point where the image is created.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 13 ACTIVITY SHEET: Disappearing Glass

OBSERVE & RESEARCH

1. Write down the materials you observe.

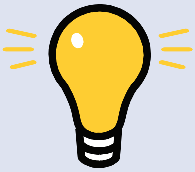
2. Predict how these materials may be used.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Energy		
Electromagnetic waves		
Light		
Refraction		
Index of refraction		

4. Consider what will happen if you place the Pyrex® glass in vegetable oil and why.

▶**Write your hypothesis.**



LESSON 13 ACTIVITY SHEET: Disappearing Glass

PERFORM YOUR EXPERIMENT

1. Fill the large glass container with enough vegetable oil to submerge the Pyrex® glass.
2. Carefully place the Pyrex® glass into the oil, and observe what happens.
3. Carefully place a regular glass in the oil, and observe what happens.

ANALYZE & CONCLUDE

1. What happens when you place Pyrex® glass in the oil? Why does that happen? ______________________________

____

____

2. What do you think will happen if you submerge regular glass in vegetable oil? ______________________________

____

____

3. Why do you think you can see some types of glass in the oil and not others? ______________________________

____

____

____

4. When you put a pencil straight down into a glass of water and look through the glass from the side, does the pencil appear to be straight? Why or why not? ______________________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 13 ACTIVITY SHEET: Disappearing Glass

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter		
Mass		
Volume		
Solid		
Liquid		
Gas		

2. List some properties used to describe matter. ______________________________

3. List some properties of light. ______________________________

LESSON 13 ACTIVITY SHEET: Disappearing Glass

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Vegetable oil, Pyrex® glass ...

2. Predict how these materials may be used. The vegetable oil may be used for cooking. The Pyrex® glass may be used to hold various substances. Together, they can be used to illustrate the effects of refraction.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Energy	The ability to do work or produce heat.	
Electromagnetic waves	Waves (continuous vibrations through space) that carry energy through space by radiation.	
Light	A specific group of electromagnetic waves that travels freely through space and can be detected by the human eye; also known as visible light.	
Refraction	The bending of light as it passes from one medium to another.	
Index of refraction	The ratio of the speed of light in a vacuum to the speed of light in a substance.	

4. Consider what will happen if you place Pyrex® glass in vegetable oil and why.

▶ **Write your hypothesis.** When the Pyrex® glass is submerged in a container of vegetable oil, the glass will seem to disappear because the vegetable oil and glass have similar refractive indexes.

LESSON 13 ACTIVITY SHEET: Disappearing Glass

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill the large glass container with enough vegetable oil to submerge the Pyrex® glass.
2. Carefully place the Pyrex® glass into the oil, and observe what happens.
3. Carefully place a regular glass in the oil, and observe what happens.

ANALYZE & CONCLUDE

1. What happens when you place Pyrex® glass in the oil? Why does that happen? The Pyrex® glass seems to disappear because the glass and vegetable oil have about the same index of refraction, so the light does not bend as it passes from one substance to the other.

2. What do you think will happen if you submerge regular glass in the vegetable oil? If you submerge regular glass in vegetable oil, the light is refracted between the oil and the glass surface, allowing you to see the glass through the oil.

3. Why do you think you can see some types of glass in the oil and not others? You can see some types of glass in vegetable oil when the angles of refraction are not equal. As a result, the light bends through the glass at a different angle than it does through the oil, and you can see the object because of this difference. The Pyrex® glass has the same angle of refraction as the vegetable oil, so the light bends at the same angle. As a result, the Pyrex® glass seems invisible.

4. When you put a pencil straight down into a glass of water and look through the glass from the side, does the pencil appear to be straight? Why or why not? The pencil does not appear straight because the angles of refraction of the water and the glass are not equal. This makes the pencil appear to bend in the water.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?
Answer 1: Valid because the data support my hypothesis.
Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 13 ACTIVITY SHEET: Disappearing Glass

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter	Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth.	
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Solid	A state of matter characterized by a definite volume and a definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	

2. List some properties used to describe matter. Mass, volume, size, shape, texture, melting point ...

3. List some properties of light. Reflection, refraction, visible ...

LESSON 14: Wacky Waxy Watercolors

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** 5–10 minutes

• DESCRIPTION

Use white crayons and watercolor paints to make designs on paper and demonstrate the interaction of water and wax.

• OBJECTIVE

This lesson demonstrates the interaction of water and wax. Students attempt to paint over wax images with watercolor paints and learn about soluble and insoluble substances. The lesson can be extended to address colloids and polarity.

• CONTENT TOPICS

Scientific inquiry; properties of matter; mixtures (solutions); attractive forces (polarity)

• MATERIALS

- ❑ White paper
- ❑ White or clear wax crayons or candles
- ❑ Watercolor paints
- ❑ Paintbrushes
- ❑ Water
- ❑ Small cups for water

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 179 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from “A Framework for K–12 Science Education,” established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter

OBSERVATION & RESEARCH

BACKGROUND

Waxes are pliable solid substances that do not have a specific chemical formula and can be made both naturally and synthetically. Despite this variety, waxes tend to have similar physical properties. Most waxes melt at moderate temperatures and can be buffed or polished under slight pressure to produce a glossy appearance. Beeswax is an example of a natural wax. Crayons are another example of wax. They are made from paraffin wax and colored with pigments. (Rub the tip of a crayon back and forth on a piece of paper. Then, look at the tip of the crayon. Does it look glossy where you “polished” it against the paper?)

Paraffin wax is a white, pliable solid obtained from crude oil. Paraffin wax and crude oil are mixtures. A **mixture** is a physical combination of two or more substances.

Paraffin wax has many uses. In addition to crayons, paraffin is used in candles, waterproof paper, and preservative coatings. Paraffin wax, like other waxes, is insoluble in water. A substance that dissolves in another substance is **soluble**. A substance that does not dissolve is **insoluble**. Thus, wax will not dissolve in water. In fact, it will not mix with or react with water at all. It actually repels water. Therefore, if you place water on a wax candle, it will simply sit on top of the candle or roll off.

LESSON 14: Wacky Waxy Watercolors

Other substances tend to mix well with water. For example, sugar and salt easily dissolve in water.

Likewise, watercolor paints are soluble in water. To apply the watercolor paint, the brush is dipped in water and then in the paint. The paint mixes with the water in the brush, allowing it to be applied to paper. However, when the brush moves over wax, the water will simply roll off the area with the wax, preventing the paint from being applied to that part of the paper.

FORMULAS & EQUATIONS

Paraffin wax is the main ingredient in crayons and is obtained from crude oil. **Crude oil** is a mixture of hydrocarbon compounds. A **hydrocarbon** is a compound made of only the elements hydrogen (**H**) and carbon (**C**).

Paraffin waxes are the solid form of paraffin, and mainly contain straight-chain hydrocarbons from approximately $C_{20}H_{42}$ to $C_{30}H_{62}$.

Pure water is a liquid at standard temperature and pressure.

It has the chemical formula H_2O.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on properties of matter, mixtures, and solubility can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶ Watercolor paint will not cover parts of a paper that have been covered with wax, because wax is not soluble in water.

Fun Fact

Beeswax is a yellow to grayish-brown wax secreted from the underside of worker honeybees. The wax is used to make honeycombs. Beeswax is used by humans in many body care products, including lip balm.

LESSON 14: Wacky Waxy Watercolors

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 179, but focus on properties and states of matter. Discuss the three common states of matter, and have students give examples of solids, liquids, and gases. You can expand further to address crystalline and amorphous solids. **Crystalline solids** are made up of atoms or molecules that are arranged in a specific, repeating pattern. Ice and salt are crystalline solids. **Amorphous solids** are made up of atoms or molecules that are locked into place but do not have a specific, repeating structure. Wax is an example of an amorphous solid. Challenge the students to think of ways crystalline and amorphous solids look and behave differently. Ask them to name other examples of crystalline and amorphous solids.

Continue to address different properties of matter by explaining that some substances have certain properties that prevent them from mixing together. Discuss what happened between the water and wax in the experiment.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Use white crayons and watercolor paints to make designs on paper and explore colloids and polarity.

OBJECTIVE

This lesson introduces colloids and illustrates polarity as students attempt to apply watercolor paint to wax designs on paper.

OBSERVATION & RESEARCH

Waxes are pliable solid substances that do not have a specific chemical formula and can be made both naturally and synthetically. Despite this variety, waxes tend to have similar physical properties. Most waxes melt at moderate temperatures and can be buffed or polished under slight pressure to produce a glossy appearance. Another common property of waxes is polarity: waxes are nonpolar substances. Conversely, water is a polar substance.

Polar substances are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. Generally, polar solutes will only dissolve in polar solvents. (Essentially, polar substances will only mix with other polar substances.) Other polar substances include acetic acid, salt, and sugar. **Nonpolar substances** are made up of particles that have an even distribution of electrons. The charges on the particles are neutralized. Nonpolar solutes generally only dissolve in nonpolar solvents. (Essentially, nonpolar substances will only mix with other nonpolar substances.) Other nonpolar substances include oil, fats, alkanes, and benzene.

To figure out whether certain substances will mix, remember that "like dissolves like." This means that the oils, fats, alkanes, and wax will mix, but they will not mix with water or substances similar to water. However, sugars and salts will easily dissolve in water.

Paints are a type of colloid. A **colloid** is a mixture in which very small particles are spread evenly through another substance. The particles in a colloid usually have a size of about one micrometer to one nanometer. Because of the tiny size of these particles, some colloids look like uniform solutions. However, the particles in a solution are even smaller than the particles in a colloid. You just can't see this difference without a powerful microscope.

Paints are classified as sols, which are colloids made of fine solid particles spread throughout a liquid. To apply the watercolor paint, the brush is dipped in water and then in the solid paint material. The solid paint material mixes with the water on the brush, creating the sol that can be applied to the paper. Because the solid paint particles are dispersed in water, the paint will roll off the area with the wax. Therefore, the paint is not applied to the parts of the paper covered with the wax.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on polar and nonpolar substances can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on colloids can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*

LESSON 14: Wacky Waxy Watercolors

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you use colored pencils, pens, or markers, will you get the same results?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Give each student a piece of white paper.
2. Use white crayons to draw designs on the paper. Be sure to press firmly.
3. Use different watercolor paints to lightly paint the entire sheet of paper. Observe the results. The paint will not be absorbed in the areas of the paper that are covered by crayon wax.

Make sure the students mix plenty of water with the paint and paint lightly. If the brush is relatively dry and pressed hard against the wax, color particles may stick to the wax.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What are the properties of wax? What are the properties of the watercolor paint? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 14: Wacky Waxy Watercolors

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define soluble and insoluble substances and give examples.
- Identify wax substances and their properties.
- Differentiate between polar and nonpolar substances (see ***Differentiation in the Classroom***).
- Define and identify colloids (see ***Differentiation in the Classroom***).

Fun Fact

Waxes generally consist of hydrocarbons and will burn with a yellow flame because of the presence of carbon.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Because you are using white or clear crayons/wax, it will be very difficult to see what the students are creating. You can have the students write secret messages and exchange them between classmates. The message can only be revealed by painting the paper.
- You can also have the students bring in pictures or cut pictures out of magazines to trace. Have each student place a piece of white paper over the picture and trace the outline of the picture with the crayon. Then, the students can paint their papers with various watercolors to reveal the picture.
- Discuss the different types of wax—natural versus synthetic—and provide examples of both natural and synthetic waxes.

REAL-WORLD APPLICATIONS

- Surfers use wax to make their surfboards less slippery. Since they stand or lie on the surfboard, they need the wax to repel some of the water so that they do not lose their footing and fall off the board.
- Paraffin wax is edible and is added to foods as a preservative and to make the food more attractive. Many chocolates and sweets contain paraffin wax to give candy a shiny coating. The wax also stops moisture from leaving the coated candy, keeping the candy moist and less likely to spoil in unrefrigerated conditions.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 14 ACTIVITY SHEET: Wacky Waxy Watercolors

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Paraffin wax		
Soluble		
Insoluble		
Crude oil		
Hydrocarbon		

4. Consider what will happen if you apply watercolor paint to wax and why.

▶ **Write your hypothesis.** ____

____

____

LESSON 14 ACTIVITY SHEET: Wacky Waxy Watercolors

PERFORM YOUR EXPERIMENT

1. Use a white or clear crayon to draw or write on a piece of white paper. Be sure to press firmly.
2. Use different watercolor paints to paint lightly over the entire sheet of paper. Observe.

ANALYZE & CONCLUDE

1. Describe the crayon. How does it look and feel? What makes up the crayon? ______________________________

____

____

2. Can you see the designs you drew with the crayon before applying the paint? If so, how well can you see the designs?

____

____

____

3. What happens when you paint the paper? ____

____

____

4. Why does the paint not have the same effect on the wax as it does on the paper? ____________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? __________________

____

____

LESSON 14 ACTIVITY SHEET: Wacky Waxy Watercolors

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance		
Nonpolar substance		
Colloid		

2. Can wax be dissolved in water? Why or why not? ____

3. What other ways can wax be used? ____

4. List some other nonpolar substances. ____

5. List some other polar substances. ____

LESSON 14 ACTIVITY SHEET: Wacky Waxy Watercolors

ANSWER KEY *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Paper, white or clear crayons, watercolor paints ...

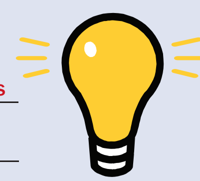
2. Predict how these materials may be used. The paper and crayons may be used to write information or draw designs. Watercolor paints may be used to make designs on the paper. These materials may be combined to illustrate physical properties of the substances.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Paraffin wax	A white, pliable solid that can be obtained from crude oil.	
Soluble	The ability of a substance to dissolve in another substance.	
Insoluble	The inability of a substance to be dissolved into another substance.	
Crude oil	A mixture made of hydrocarbon compounds, used to produce various fuels, such as gasoline.	
Hydrocarbon	A compound made of only the elements hydrogen (H) and carbon (C).	

4. Consider what will happen if you apply watercolor paint to wax and why.

▶ **Write your hypothesis.** Watercolor paint will not stain a paper that has been covered with the wax from crayons because wax is not soluble in water. The wax will repel the water.



LESSON 14 ACTIVITY SHEET: Wacky Waxy Watercolors

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Use a white crayon to draw or write on a piece of white paper. Be sure to press firmly.
2. Use different watercolor paints to paint lightly over the entire sheet of paper. Observe.

ANALYZE & CONCLUDE

1. Describe the crayon. How does it look and feel? What makes up the crayon? The crayon is hard, shiny, and white or clear. The crayon is made of wax.

2. Can you see the designs you drew with the crayon before applying the paint? If so, how well can you see the designs?

If you draw on white paper, only a faint reflection of the wax will be visible on the paper.

3. What happens when you paint the paper? When you paint over the wax designs on the paper, the water (and dissolved pigment) will repel from the areas covered with wax. The color will stain the rest of the paper, leaving behind fun designs around the wax.

4. Why does the paint not have the same effect on the wax as it does on the paper? The paint will not stain the wax because wax is not soluble in water. The wax repels the water containing the paint. The water will bead up and roll off the wax if it is applied. On the other hand, the color (pigment) is soluble in water, so the water collects the paint, which is then absorbed by the paper.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 14 ACTIVITY SHEET: Wacky Waxy Watercolors

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	
Nonpolar substance	A substance made up of particles that have an even distribution of electrons; the charges on these particles are neutralized.	
Colloid	A mixture, between homogeneous and heterogeneous, in which very small particles are spread evenly throughout another substance.	

2. Can wax be dissolved in water? Why or why not? No, paraffin wax is made from crude oil, which is insoluble in water. Other waxes are made from other fats or oils, which are also insoluble in water.

3. What other ways can wax be used? Waxes can be used to repel water from a surfboard and as a water-repellent film on the bottoms of skis and snowboards. Wax can also be used to line paper cups so they can hold water without leaking.

4. List some other nonpolar substances. Other nonpolar substances include fats, alkanes, and benzene.

5. List some other polar substances. Other polar substances include sugar, salt, and ammonia.

LESSON 15: Floating Paper Clips

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 5–10 minutes

DESCRIPTION

Utilize a careful technique to make a paper clip "float" on top of water.

OBJECTIVE

This lesson demonstrates a property of liquids known as surface tension and explains the difference between surface tension and buoyancy. Students use a careful technique to keep a paper clip suspended on the surface of a cup of water. The lesson can be simplified to reinforce the different properties of matter.

CONTENT TOPICS

Scientific inquiry; measurement; states of matter; properties of matter; attractive forces (surface tension)

MATERIALS

- ❑ Plastic cups
- ❑ Water
- ❑ Forks
- ❑ Tissues or toilet paper
- ❑ Paper clips
- ❑ Liquid soap

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 190 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Liquids are a state of matter that have a definite volume but no definite shape. Examples of liquids are water and orange juice. One unique property of liquids is called surface tension. Surface tension is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Surface tension is also the reason liquids tend to keep a low surface area. For example, water droplets will tend to form into a sphere rather than spreading out flat.

An object suspended by water's surface tension is different from an object that is floating because of buoyancy. Buoyancy is the upward force that a fluid exerts on an object that enables the object to float. The buoyant force on an object is equal to the weight of the fluid displaced by the object. A fluid is any substance made up of particles that flow or move freely such as liquids and gases. Fluids easily change shape when a force is applied. Displacement is the act of moving something out of its original position or of one substance taking the place of another.

LESSON 15: Floating Paper Clips

Weight is also a measure of force. **Weight** is a measure of the pull of gravity between an object and the earth. Therefore, an object will float when the upward force on an object (buoyant force) is greater than the downward force on the object (gravity or the object's weight).

In the experiment, the force of buoyancy is not enough to allow a paper clip to float. The metal that makes up the paper clip is denser than the water. In addition, because its metal structure is so thin, the amount of water the paper clip displaces is minimal. Thus, the paper clip has a greater weight than the water it displaces. If you simply drop a paper clip in water, it will sink.

However, using a specific technique, a paper clip can essentially sit on top of the water. By placing a piece of tissue or a fork on the water first, a platform is created for the paper clip. When the paper clip is laid horizontally on the water, and the platform is removed, the paper clip will remain suspended. If you push the paper clip slightly, it will sink. Remember, the paper clip is not floating; it is sitting on the surface of the water being supported by surface tension.

In contrast, soap is a **surfactant**. A surfactant (or surface active agent) is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of soap is added to the water, the surface tension of the water is reduced. Even a single drop of soap will reduce the surface tension of water enough that the paper clip can no longer rest on top.

FORMULAS & EQUATIONS

Over 2,000 years ago, ancient Greek mathematician Archimedes discovered how buoyancy works. He determined the following:

Buoyant force on an object = weight of fluid displaced by object.

Therefore, if a boat weighs 1,000 pounds, it will sink into the water until it has displaced 1,000 pounds of water. If the boat displaces 1,000 pounds of water before it is submerged, the boat will float. If more and more weight is added to the boat, such as when a leak allows water to enter the boat, the weight of the boat will exceed the weight of the water it displaces and sink.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states of matter and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on displacement can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶ A paper clip placed horizontally on the surface of a cup of water using a careful technique will stay on top of the water because of surface tension. If soap is added, the paper clip will sink.

LESSON 15: Floating Paper Clips

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Utilize a careful technique to make a paper clip "float" on top of water.

OBJECTIVE

This lesson explores the liquid state of matter and a unique property of liquids known as surface tension.

OBSERVATION & RESEARCH

Matter is anything that has mass and takes up space. It is everything around us! It is characterized and classified by its properties. Mass and volume are two basic properties of all matter. **Mass** is a measure of the amount of matter in a substance. **Volume** is a measure of the amount of space an object occupies.

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, books, and paper clips. **Liquids** have a definite volume but no definite shape. Examples of liquids are milk and water. **Gases** have no definite shape and no definite volume. Examples of gases are the oxygen and water vapor in the air we breathe.

Along with differences in shape and volume, the different states of matter have other unique properties. For example, **surface tension** is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid.

Water has a very high surface tension because of strong attractions between the water molecules (hydrogen bonding). In this experiment, simply dropping the paper clip in the water easily breaks the surface tension. As a result, the paper clip falls to the bottom of the cup. However, when placed horizontally on the surface with a careful technique, the high surface tension of the water supports the paper clip on the surface.

Liquid dish soap is a different type of liquid substance, called a surfactant (or surface active agent). A **surfactant** is a substance that has the ability to reduce the surface tension of a liquid. Therefore, when a drop of soap is added to water, the surface tension of the water is reduced, and the paper clip falls to the bottom of the cup.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 190, and then challenge students to get other materials to rest on top of the water. Discuss what is causing these items to float or sink. Is it surface tension, buoyancy, a combination of both, or something else entirely?

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of physical measurements can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on states of matter and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 15: Floating Paper Clips

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If students try different techniques to put the paper clip on the water, does the action of the paper clip change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

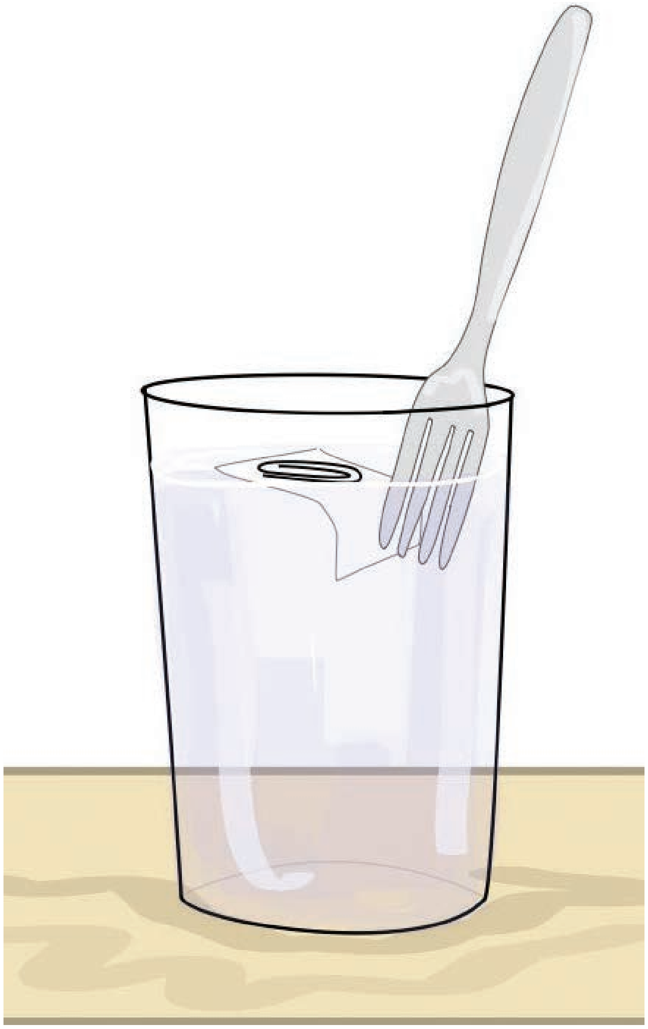
1. Fill a cup with water. Be sure there is no soap residue in the cup.
2. Place a piece of tissue or toilet paper, big enough to support the paper clip, on the water.
3. Gently place the paper clip horizontally on top of the tissue so that the tissue supports the paper clip.
4. Use a fork to very gently submerge the tissue by pushing down on the tissue from its edges. Do not touch the paper clip with the fork.
5. Once the tissue is submerged, watch as the paper clip continues to be suspended on the surface of the water.
6. While the paper clip is suspended, add one drop of soap to the water where the paper clip is suspended. Watch as the paper clip sinks.
7. Repeat the experiment, but this time, add one drop of soap to the water first. See if you can make the paper clip "float."

Tissues and toilet paper typically come in layers. Only one layer is needed and works the best.

If you cannot get the tissue to work, you can just use the fork. Place the paper clip on the fork and hold the fork so the paper clip is resting on the fork at the water's surface. Then, slowly submerge the fork in the water. The paper clip should remain suspended on the water's surface.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens to the paper clip when the tissue paper or fork is submerged? What happens when soap is added? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.



LESSON 15: Floating Paper Clips

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the property of surface tension.
- Describe the force of buoyancy and how it relates to fluids and displacement.
- Differentiate between surface tension and buoyancy.
- Describe the effects of soap, a surfactant, on surface tension.
- Define and identify different types of measurements, such as mass and volume (see ***Differentiation in the Classroom***).
- Compare and contrast the different states of matter and provide examples of each (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, ask the students if a paper clip will float or sink in water. See if the students can get a paper clip to float on top of the water before explaining the procedure for this experiment. Tell the students that you can get the paper clip to float. Show them the suspended paper clip, and ask them if they know how this is possible. Ask them if they know what surface tension is and the role it plays in this experiment. Have the students try the experiment.

K-4 See **Lesson 26: Swimming Specs** for a simplified lesson on surface tension.

5-8 See **Lesson 7: Milk Rainbow** for a more advanced lesson on surface tension.

REAL-WORLD APPLICATIONS

- Surfactants, such as liquid dish soap, detergents, fabric softeners, and shampoo, play an important role in cleaning products because they break up grease and stains. One side of a surfactant particle attracts the fats and oil, while the other side attracts the water. This interaction allows the water to mix with the fats and oils and wash them away.
- The effects of surface tension can be seen in the formation of raindrops or the "beading" of rainwater. Water will form into spheres (droplets) rather than spread out completely because of the attraction of water molecules. Likewise, ask students if they have ever filled a cup with water slightly above the rim without the water spilling over. Ask them if they can figure out why.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Liquid		
Surface tension		
Buoyancy		
Fluid		
Displacement		
Weight		
Surfactant		

4. Consider what will happen if you place a paper clip in a cup of water and why. Then, consider ways to keep the paper clip on the surface.

▶**Write your hypothesis.** ____

____

____

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

PERFORM YOUR EXPERIMENT

1. Fill a cup with water. Be sure there is no soap residue in the cup.
2. Place a piece of tissue or toilet paper, big enough to support the paper clip, on the water.
3. Gently place the paper clip horizontally on top of the tissue so that the tissue supports the paper clip.
4. Use a fork to very gently submerge the tissue by pushing down on the tissue from its edges. Do not touch the paper clip with the fork. Observe what happens.
5. If the paper clip remains on the surface of the water, add one drop of soap to the water where the paper clip is suspended. Observe what happens.
6. Repeat steps 1–4, but this time, add one drop of soap to the water *before* adding the tissue and paper clip. Observe.

ANALYZE & CONCLUDE

1. What happens when you first place the tissue on the water? ____________________

____

____

2. What happens when you place the paper clip horizontally on the tissue? ____________________

____

____

3. When the tissue is submerged, does the paper clip remain on top of the water? Why or why not? ____________________

____

____

4. What happens when you add soap to the water? ____________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ____________________

____

____

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter		
Mass		
Volume		
Solid		
Liquid		
Gas		

2. List other examples of surface tension. ______________________________

____

____

3. Do all liquids have the same surface tension? How do you know? ______________________________

____

____

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Water, forks, paper clips, tissue or toilet paper, liquid dish soap …

2. Predict how these materials may be used. The water may be used to drink, clean, or bathe. The forks may be used to pick up food. The tissue paper may be used to package something or for cleaning. Paper clips may be used to hold pieces of paper together. Liquid dish soap may be used to clean dishes. Together, these materials may be used to explore physical properties.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Surface tension	A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface "film."	
Buoyancy	An upward force that a fluid exerts on an object and enables the object to float.	
Fluid	Any substance made up of particles that flow or move freely, such as a liquid or gas.	
Displacement	The act of moving something out of its original position or of one substance taking the place of another.	
Weight	A measure of the pull of gravity between an object and the earth.	
Surfactant	Any substance with the ability to reduce the surface tension of a liquid; also known as a surface active agent.	

4. Consider what will happen if you place a paper clip in a cup of water and why. Then, consider ways to keep the paper clip on the surface.

▶ **Write your hypothesis.** A paper clip will normally sink in water because it has a greater density than water and weighs more than the water it can displace. However, a paper clip can be suspended on top of water because of the water's surface tension.

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill a cup with water. Be sure there is no soap residue in the cup.
2. Place a piece of tissue or toilet paper, big enough to support the paper clip, on the water.
3. Gently place the paper clip horizontally on top of the tissue so that the tissue supports the paper clip.
4. Use a fork to very gently submerge the tissue by pushing down on the tissue from its edges. Do not touch the paper clip with the fork. Observe what happens.
5. If the paper clip remains on the surface of the water, add one drop of soap to the water where the paper clip is suspended. Observe what happens.
6. Repeat steps 1–4, but this time, add one drop of soap to the water before adding the tissue and paper clip. Observe.

ANALYZE & CONCLUDE

1. What happens when you first place the tissue on the water? When you place the tissue on the water, the tissue rests on the top of the water. The surface tension of the water prevents the tissue from sinking down to the bottom of the cup.

2. What happens when you place the paper clip horizontally on the tissue? When you place a paper clip on the tissue, the paper clip will rest on top of the tissue.

3. When the tissue is submerged, does the paper clip remain on top of the water? Why or why not? When the tissue is submerged, the paper clip remains on top of the water because of the surface tension of the water.

4. What happens when you add soap to the water? Adding soap reduces the surface tension of water. Soap, a surfactant, will cause the paper clip to sink.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 15 ACTIVITY SHEET: Floating Paper Clips

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter	Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth.	
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Solid	A state of matter characterized by a definite volume and definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	

2. List other examples of surface tension. Examples of surface tension include the beading of rainwater and skipping of rocks.

3. Do all liquids have the same surface tension? How do you know? No, all liquids do not have the same surface tension. Vegetable oil has a lower surface tension than water and will spread farther than water if the same amount of both liquids are poured on a flat surface.

LESSON 16: Fountain of Soda Pop

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 5 minutes

DESCRIPTION

Add Mentos® mints to a bottle of diet soda pop to initiate a forceful escape of carbon dioxide gas.

OBJECTIVE

This lesson introduces solubility of gases and ways to affect solubility. Students observe as Mentos® mints allow carbon dioxide gas to form and quickly escape from the soda pop solution. This lesson can be expanded to address polarity.

CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; chemical reactions; mixtures (solutions); attractive forces (polarity)

This experiment should be performed outside, preferably in a large grassy area. Remind students to stand back.

MATERIALS

- ❑ Original Mentos® breath mints
- ❑ A 2-liter bottle of diet cola soda pop
- ❑ Test tube or construction paper rolled into a tube
- ❑ Index card

Diet soda pop generally works better than regular soda pop and is less sticky.

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 201 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- PS2.A: Forces and Motion
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

A solution is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). For example, salt may be dissolved in water to form a saltwater solution. The salt is the solute, and the water is the solvent. In soda pop, high-fructose corn syrup (or other sweeteners), flavorings, and carbon dioxide (CO_2) gas are the solutes, and water is the solvent.

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. A substance that dissolves in another substance is soluble. For example, salt is soluble in water. If a substance does not dissolve, it is insoluble. For instance, butter is insoluble in water.

Several factors can affect solubility, including temperature, pressure, and the nature of the solute or solvent. Under normal temperature and pressure conditions, CO_2 is relatively insoluble in water, which causes the gas to form bubbles and escape from the liquid. However, manipulating pressure allows us to change the solubility of gases. As pressure increases, solubility increases. (More solute can be dissolved in a liquid at higher pressures.) Therefore, increasing pressure allows the CO_2 to be dissolved into the soda pop. The bottle is then sealed under high pressure as well. When you open a can or bottle of soda pop, you are releasing some pressure and allowing some of the gas to escape, which creates the distinctive hissing sound.

In addition, water molecules are strongly attracted to one another. (Water molecules like to be next to other water molecules.) Therefore, the water molecules hold the rest of the dissolved CO_2 gas in the solution. Over time, the changes in conditions allow all or almost all of the CO_2 to escape (unless you drink it first!). Certain conditions can cause the gas to escape quickly.

Bubbles of CO_2 can form in the soda pop solution, and the CO_2 gas can escape when a rough surface is introduced. The rough surface of Mentos® mints is the perfect place for bubbles to form. The bubbles form quickly all over the surface of the mint and begin to escape from the solution. The formation of the CO_2 gas bubbles is much greater than the rate at which the gas can escape through the small opening of the bottle. Because the mints are heavy and sink to the bottom of the solution, many bubbles will form at the bottom of the solution. All of the gas bubbles moving toward the opening forcefully push the liquid out of the bottle as well, creating a geyser effect.

FORMULAS & EQUATIONS

Soda pop is a solution made of various solutes, such as high-fructose corn syrup (or other sweeteners), flavorings, and carbon dioxide gas, dissolved in water (the solvent).

The chemical formula for carbon dioxide is $\mathbf{CO_2}$.

The chemical formula for pure water is $\mathbf{H_2O}$.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on solutions and solubility can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

▶ Adding Mentos® mints to a bottle of diet cola soda pop will initiate a rapid release of carbon dioxide gas from the solution, resulting in an "explosion" of soda pop from the bottle.

Fun Fact

Effervescence is the term used to describe the escape of gas from a solution, generally in the form of foam or fizz.

LESSON 16: Fountain of Soda Pop

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 201, but focus on states of matter: solids, liquids, and gases. Use pictures and have students write down or state their answers of whether a certain substance is a solid, liquid, or gas. For example, show a picture of or point to a desk—solid. Show a picture of apple juice—liquid. Show a picture of a clear sky (air)—gas. Then, tell students that a bottle of soda pop can illustrate all three states. The bottle is a solid, the soda pop is a liquid, but where is the gas? Discuss how they know a gas is inside the liquid as well.

Another option is to focus on mixtures and solutions. Use pictures and have students write down or state whether a certain substance is a solution or simply a mixture. For example, show a picture of apple juice—solution. Show a picture of chicken noodle soup—mixture. After they complete this exercise, be sure to remind them that solutions are a type of mixture. The apple juice is a solution *and* a mixture.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Add Mentos® mints to a bottle of diet soda pop, causing the attraction of the water molecules to decrease and allowing the carbon dioxide gas to escape.

OBJECTIVE

This lesson introduces solubility of gases, polarity of water, and ways to affect solubility and the attraction of water molecules. Students observe as Mentos® mints allow carbon dioxide gas to form and quickly escape from the soda pop solution.

OBSERVATION & RESEARCH

A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). For example, salt may be dissolved in water to form a saltwater solution. The salt is the solute, and the water is the solvent. In soda pop, high-fructose corn syrup (or other sweeteners), flavorings, and carbon dioxide (CO_2) gas are the solutes, and water is the solvent.

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. Several factors can affect solubility, including temperature, pressure, and the nature of the solute or solvent. Under normal temperature and pressure conditions, CO_2 is relatively insoluble in water, which causes the gas to form bubbles and escape from the liquid. However, manipulating pressure allows us to control the solubility of gases. As pressure increases, solubility increases (more solute can be dissolved in a liquid). Therefore, increasing pressure causes the CO_2 to be dissolved into the soda pop. The bottle is then sealed under high pressure as well. When you open a can or bottle of soda pop, you are releasing some pressure and allowing some of the gas to escape, which creates the distinctive hissing sound.

In addition, water molecules are strongly attracted to one another. Water molecules are polar molecules. **Polar substances** are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. The oxygen atom has a partial negative charge, and the hydrogen atoms have partial positive charges. Because "opposites attract," the negatively charged oxygen atoms attract the positively charged hydrogen atoms in other water molecules. When the molecules interact, they form strong hydrogen bonds. These strong attractions help to hold the CO_2 inside.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on solutions, solubility, and polar substances can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

LESSON 16: Fountain of Soda Pop

DIFFERENTIATION IN THE CLASSROOM

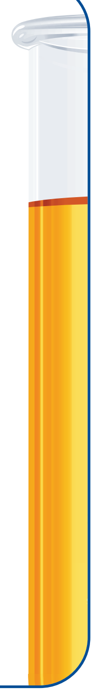
In order for a bubble to form or expand, the water molecules must be pushed away from one another. When Mentos® mints are added to the diet soda pop, the polar attraction between the water molecules is disrupted. In addition, the surface of Mentos® mints is loaded with tiny nooks and crannies, called **nucleation sites**. These nucleation sites are where the bubbles form.

The bubbles form quickly all over the surface of the mint in the nucleation sites and begin to escape from the solution. The formation of the CO_2 gas bubbles is much greater than the rate at which the gas can escape through the small opening of the bottle. Because the mints are heavy and sink to the bottom of the solution, all of the gas bubbles rush upward toward the opening and forcefully push the liquid out of the bottle.

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If students try adding different substances to the soda pop, does the result change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE



1. Open a 2-liter bottle of diet soda pop.
2. Place approximately 10 Mentos® mints into a column. You may use a test tube to hold the Mentos®, or you can wrap a piece of construction paper into a tube around the Mentos® to hold them in place.
3. Place an index card over the opening of the bottle and then place the column of mints on top of the card directly over the opening of the bottle.
4. Pull the card away and let the mints drop into the bottle.
5. Step away quickly and carefully.

Because of the large amount of materials used, it is best to do this experiment as a demonstration.

Again, this experiment must be done outside. The reaction is very quick and forceful, propelling the soda pop 5–15 feet in the air.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happened when the Mentos® mints were added to the diet soda pop? What did the "fountain" look like? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 16: Fountain of Soda Pop

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and give examples of solutions, solutes, and solvents.
- Explain solubility and ways to change the solubility of a solution.
- Identify the gas that is dissolved in soda pop.
- Explain the polarity of water (see ***Differentiation in the Classroom***).
- Define nucleation sites and how they allow the formation of bubbles (see ***Differentiation in the Classroom***).

Fun Fact

Carbon dioxide (CO_2) is the gas that we exhale when we breathe.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, drop one or two Mentos® mints into a small glass of diet cola soda pop. Have the students observe what happens. Ask them if they know what creates the fizz, and explain that the fizz forms as a result of the release of carbon dioxide gas. Next, ask the students what will happen if you place 10 Mentos® mints in a 2-liter bottle filled with diet cola soda pop.
- Challenge students to create different experimental setups to determine what variables create different results. Try different types of soda pop and observe the result. Try different candies or other substances and observe the result. Try crushed Mentos® mints. The smaller pieces will fall more slowly and will create a less forceful expulsion of gas.

5-8 See **Lesson 12: The Great Escape** for another lesson on solubility.

REAL-WORLD APPLICATIONS

- The concept of increasing pressure and releasing that pressure at a high speed is the same concept used to propel rockets. A simple rocket could be made from Mentos® and diet soda pop.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 16 ACTIVITY SHEET: Fountain of Soda Pop

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution		
Solubility		
Solute		
Solvent		

4. Consider what will happen when Mentos® mints are added to a bottle of diet cola soda pop and why.

▶**Write your hypothesis.** ______________________________

____

____

LESSON 16 ACTIVITY SHEET: Fountain of Soda Pop

PERFORM YOUR EXPERIMENT

1. Follow your teacher's instructions.
2. Observe as your teacher performs the experiment.

ANALYZE & CONCLUDE

1. What do you see and hear when the bottle of soda pop is opened? What creates the sound? ____________________

____

____

2. What are the components of soda pop? ____

____

____

3. What happens when the Mentos® mints are dropped into the bottle of diet cola soda pop? Why does that occur?

____

____

____

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ____________________

____

____

LESSON 16 ACTIVITY SHEET: Fountain of Soda Pop

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance		
Nonpolar substance		
Nucleation site		

2. What do people mean (scientifically) when they say soda pop is "flat"? ______________________________

3. Would a reaction with Mentos® occur if the soda pop was "flat"? Why or why not? ______________________________

4. What other ways can soda pop be forced out of the bottle? What creates the force? ______________________________

LESSON 16 ACTIVITY SHEET: Fountain of Soda Pop

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Mentos® mints, diet cola soda pop ...

2. Predict how these materials may be used. The Mentos® mints may be used to freshen breath. You may drink diet cola soda pop to quench your thirst. These materials may be combined to create a chemical reaction.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Solubility	A measure of the amount of solute that can be dissolved in a solvent.	
Solute	A substance that is dissolved in a solution.	
Solvent	A substance capable of dissolving another substance.	

4. Consider what will happen when Mentos® mints are added to a bottle of diet cola soda pop and why.

▶ **Write your hypothesis.** When Mentos® mints are added to a bottle of diet cola soda pop, carbon dioxide bubbles will form rapidly around the mints, pushing the liquid out of the bottle.

LESSON 16 ACTIVITY SHEET: Fountain of Soda Pop

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Follow your teacher's instructions.
2. Observe as your teacher performs the experiment.

ANALYZE & CONCLUDE

1. What do you see and hear when the bottle of soda pop is opened? What creates the sound? When the bottle of soda pop is opened, you hear a hissing sound and you see bubbles rising to the top of the soda pop bottle. The sound is created by the release of pressure. As the pressure is released, some carbon dioxide bubbles escape from the solution and make their way out of the soda pop bottle.

2. What are the components of soda pop? Soda pop is a solution of high-fructose corn syrup (or other sweeteners), flavorings, and carbon dioxide gas dissolved in water.

3. What happens when the Mentos® mints are dropped into the bottle of diet cola soda pop? Why does that occur?
When the Mentos® mints are dropped into the bottle, they cause carbon dioxide gas bubbles to form and rise rapidly from the soda pop and forcefully leave the bottle. The soda pop comes out of the bottle like a geyser.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?
Answer 1: Valid because the data support my hypothesis.
Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 16 ACTIVITY SHEET: Fountain of Soda Pop

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	
Nonpolar substance	A substance made up of particles that have an even distribution of electrons; the charges on these particles are neutralized.	
Nucleation site	An area where droplets of liquid can condense from a vapor, bubbles of gas can form in a boiling liquid, or new crystals can grow in a solution.	

2. What do people mean (scientifically) when they say soda pop is "flat"? When people say soda pop is flat, they mean that it lacks carbon dioxide (CO_2) gas. Over time, CO_2 gas will escape from the solution, reducing the amount of CO_2 contained in the soda pop. Thus, the soda pop loses its "fizz."

3. Would a reaction with Mentos® occur if the soda pop was "flat"? Why or why not? No, the reaction would not be as forceful because the rapid release of CO_2 is what causes the explosion. When there is not much CO_2, the force will not be as great.

4. What other ways can soda pop be forced out of a bottle? What creates the force? Shaking a soda pop bottle also forces the solution out of the bottle. When the soda pop is shaken, the excess CO_2 that fills the space above the soda pop in the bottle is then mixed throughout the bottle, which causes a lot of CO_2 bubbles to form and increases the pressure in the bottle. When the top is then opened, these CO_2 bubbles push up and out of the bottle quickly, forcing the liquid out as well.

LESSON 17: Balloon Rockets

ESTIMATED TIME **Setup:** 5–10 minutes | **Procedure:** 5–10 minutes

• DESCRIPTION

Apply the concepts of pressure and Newton's laws of motion to build simple rockets.

• OBJECTIVE

This lesson demonstrates the basic principles of rocketry by applying the concept of pressure and Newton's Second and Third Laws of Motion. Students use a balloon to explore these concepts. The lesson can be extended to introduce the concepts of drag and power.

• CONTENT TOPICS

Scientific inquiry, measurement; force (pressure)

⚠ It is best to use long, thin balloons for this experiment.

• MATERIALS

- ❑ Balloons
- ❑ Straws
- ❑ String
- ❑ Permanent marker
- ❑ Cargo (paper clips, bottle caps, candy, etc.)
- ❑ Cereal boxes, construction paper, or any other material to make lightweight cargo containers
- ❑ Tape, glue, scissors, and any other materials needed for construction

⚠ Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 212 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS2.A: Forces and Motion
- PS2.C: Stability and Instability in Physical Systems
- PS3.C: Relationship Between Energy and Forces
- ETS1.A: Definiting and Delimiting an Engineering Problem (see ***Analysis & Conclusion***)
- ETS1.B: Developing Possible Solutions (see ***Analysis & Conclusion***)
- ETS1.C: Optimizing the Design Solution (see ***Analysis & Conclusion***)
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Rocketry has existed for hundreds of years. Although the technology has greatly improved and there are numerous methods for propelling a rocket, the simple science behind rockets has always been the same. To propel a rocket, some kind of force must be expelled from the rocket in order to push it forward. A force is the amount of push or pull on an object. The mechanical force that pushes a rocket or aircraft through the air is known as thrust.

Two of Newton's laws of motion relate to force, and therefore, relate to thrust. Newton's Second Law of Motion states that the relationship between an object's mass (m), its acceleration (a), and the applied force (F) is **F = ma**. For example, the force of a basketball pushed toward the ground is equal to the mass of the ball multiplied by the acceleration of the ball toward the ground. Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. For example, when a basketball is pushed toward the ground, the force with which the basketball hits the ground is oppositely and equally applied back to the ball by the ground. As a result, the ball bounces back upward.

In this experiment, the rocket is propelled by pressure. Pressure is the amount of force exerted on an area. When you blow up the balloon, you are filling the balloon with gas particles (mainly oxygen). The gas particles move freely within the balloon and may collide with one another. As more gas is added to the balloon, the number of gas particles in the balloon increases, as well as the number of collisions. While the force of a single gas particle collision is too small to notice, the total force created by all of the gas particle collisions within the balloon is significant. As the number of collisions within the balloon increases, so does the pressure within the balloon.

In addition, the pressure of the gas inside the balloon becomes greater than the air pressure outside of the balloon. The pressure inside the balloon serves as the fuel for the rocket. When you release the opening of the balloon, gas quickly escapes to equalize the pressure inside with the air pressure outside of the balloon. As the air escapes from the balloon, it exerts a force on the ground and the air outside of the balloon. According to Newton's Third Law of Motion, as the gas is released from the balloon and pushes against the outside air, the outside air pushes back. As a result, the rocket is propelled forward by the opposing force. This opposing force is thrust.

FORMULAS & EQUATIONS

Newton's laws of motion have played a key role in humans' understanding of the universe.

- **Newton's First Law of Motion (the Law of Inertia) states:** Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on scientific laws can be found in the Science—A Way of Thinking section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on types of measurements, including force and pressure, can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on states of matter can be found in the in Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

- **Newton's Second Law of Motions states:** The acceleration (a) of an object as produced by a net force is directly proportional to the magnitude of the net force (F), in the same direction as the net force, and inversely proportional to the mass (m) of the object. This relationship is described by the equation: **F = ma**.
- **Newton's Third Law of Motion states:** For every action, there is an equal and opposite reaction.

Pressure is the amount of force exerted on an area.

This relationship is described by the following equation: **p = F/A**.

HYPOTHESIS

▶A simple rocket made with a balloon will be propelled down a string according to Newton's laws of motion, because of thrust generated by pressure.

LESSON 17: Balloon Rockets

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 212 (or perform the experiment as a demonstration), and focus on gases and pressure. How do they know the pressure is increasing in the balloon? Use the amount of people in the room as an example. If more people were crammed into the room and moving around, would they feel more pressure on their bodies as they bumped into one another? Likewise, if you have marbles or similar objects available, you can instruct students to hold one marble closed in between both hands. When they shake their hands with the marble inside, they will feel the marble move around and collide with the inside of their hands. If they hold three marbles closed within both hands and shake them, do they notice a difference?

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Build simple rockets by applying the concepts of pressure and Newton's laws of motion.

OBJECTIVE

This lesson demonstrates the basic principles of rocketry, addressing Newton's laws of motion and the concepts of force, pressure, drag, and power.

OBSERVATION & RESEARCH

The development of flight and rocketry has led to major advances for humans, and these inventions rely on similar principles. To propel an aircraft or rocket, some kind of force must be expelled from the vehicle in order to push it forward. A **force** is the amount of push or pull on an object.

The mechanical force that pushes a rocket or aircraft through the air is known as **thrust**. On the contrary, **drag** is a mechanical force that opposes an aircraft's motion through the air. It is generated by the difference in velocity between a solid object and a **fluid** (liquid or gas). Without the presence of a fluid or without motion, there is no drag.

In this experiment, the rocket is propelled by pressure. **Pressure** is the amount of force exerted on an area. When you blow up the balloon, you are filling the balloon with gas particles (mainly oxygen). The gas particles move freely within the balloon and may collide with one another. As more gas is added to the balloon, the number of gas particles in the balloon increases, as well as the number of collisions. While the force of a single gas particle collision is too small to notice, the total force created by all of the gas particle collisions within the balloon is significant. As the number of collisions within the balloon increases, so does the pressure within the balloon.

In addition, the pressure of the gas inside the balloon becomes greater than the air pressure outside of the balloon. The pressure inside the balloon serves as the fuel for the rocket. When you release the opening of the balloon, gas quickly escapes to equalize the pressure inside with the air pressure outside of the balloon. As the gases escape from the balloon, the gas particles exert a force on the ground and the air outside of the balloon. According to Newton's Third Law of Motion, every action has an equal and opposite reaction. Therefore, as the gas is released from the balloon, it pushes against the outside air, and the outside air pushes back. As a result, the rocket is propelled forward by the opposing force. This opposing force is thrust.

In an aircraft or rocket, the engine provides power to the propeller, which produces the thrust. **Power** is the rate at which energy is converted or work is performed. In general, an engine with more power produces more thrust. In addition, the thrust must be greater than drag in order for an aircraft or rocket to accelerate forward for takeoff and to increase its speed during flight. If an aircraft is flying at a constant speed, the amount of thrust will equal drag.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on scientific laws can be found in the Science—A Way of Thinking section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on types of measurements, including force and pressure, can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on states of matter can be found in the in Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*

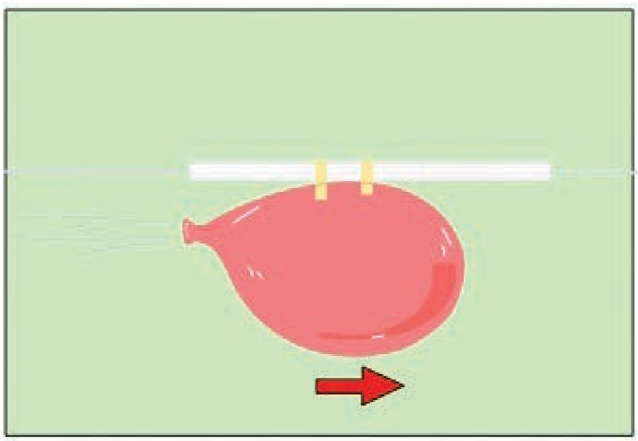
LESSON 17: Balloon Rockets

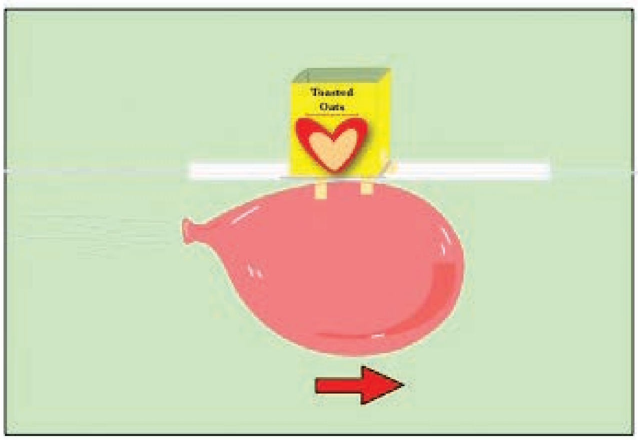
EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: As the amount of gas in the balloon changes, does the distance the rocket travels change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Tie one end of a string to a chair, doorknob, or other support.
2. Put the other end of the string through a straw. Then pull the string tight, and tie it to another support in the room.
3. Blow up the balloon, and pinch the end of the balloon to keep the air inside. Do not tie the balloon.
4. Tape the balloon to the straw so that the opening of the balloon is horizontal with the ground. You may need two students for this: one to keep the air pinched inside the balloon and the other to tape the balloon to the straw.
5. Have one student pull the balloon all the way back to the end of the string (the starting line), so the balloon opening is against one support. That student should hold the balloon opening closed. Have another student use the marker to draw a finish line near the other end of the string.
6. Let go of the balloon and watch it move along the string!
7. Then, have students test different methods to transport "cargo" across the string to the finish line.





DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happened when the opening of the balloon was released and the gas was allowed to escape? If they timed the process, how long did it take for a rocket to cross the finish line? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

LESSON 17: Balloon Rockets

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Describe force, pressure, and thrust.
- Define and provide examples of Newton's Second and Third Laws of Motion.
- Explain the general science behind rocketry.
- Describe drag and power (see ***Differentiation in the Classroom***).
- Differentiate between thrust and drag (see ***Differentiation in the Classroom***).

Fun Fact

Fireworks, developed by the Chinese, are considered the earliest form of rockets.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Tell your students that they need to devise a way to transport cargo across a string using only the materials you provide them. Have the students work in groups or individually to test methods. Discuss how they may accomplish this task and offer hints as needed.
- Use the lesson to practice measurement and apply calculations. Measure the distance from the start to the finish line on the string. Measure the mass of the inflated balloon. (They can use a clip to keep the balloon opening closed and then subtract the mass of the clip.) Then, time how long it takes for the balloon to move across the finish line. Students can then use these measures to calculate the rocket's force.

REAL-WORLD APPLICATIONS

- Jet engines work by igniting fuel, combined with compressed oxygen, inside the engine. As a result of the reaction, large amounts of gas are released quickly out of the rear of the aircraft. The extremely high acceleration of the mass of gas creates a large force. Then, as indicated by Newton's Third Law of Motion, an equal and opposite force (thrust) is created in the opposite direction of the released gas, propelling the jet forward.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 17 ACTIVITY SHEET: Balloon Rockets

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Force		
Thrust		
Newton's Second Law of Motion		
Newton's Third Law of Motion		
Pressure		

4. Consider how a balloon can be propelled down a string and how/why that would work.

▶**Write your hypothesis.** ______________________________

____

____

LESSON 17 ACTIVITY SHEET: Balloon Rockets

PERFORM YOUR EXPERIMENT

1. Tie one end of a string to a chair, doorknob, or other support.
2. Put the other end of the string through a straw. Then pull the string tight, and tie it to another support in the room.
3. Blow up the balloon, and pinch the end of the balloon to keep the air inside. Do not tie the balloon.
4. Have a partner tape the balloon to the straw so that the opening of the balloon is horizontal with the ground, while you keep the air pinched inside the balloon.
5. Have your partner use the marker to draw a finish line near the end of the string. Then, let go of the balloon and observe!
6. Test different methods to transport "cargo" across the string to the finish line. See your teacher for materials.

ANALYZE & CONCLUDE

1. Once you have the balloon set, what happens when you let go of it? What causes this to happen? ____________________

____

____

____

2. What do you think will make the balloon move faster? ____

____

____

3. What happens when you add cargo to the balloon rocket? ____

____

____

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________

____

____

LESSON 17 ACTIVITY SHEET: Balloon Rockets

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Fluid		
Drag		
Power		

2. How are modern rockets propelled? ______________________________

____

____

3. If a pilot wants to fly at a constant speed, what must occur? What if the pilot wants the aircraft to accelerate?

____

____

____

4. What is Newton's First Law of Motion? ______________________________

____

____

LESSON 17 ACTIVITY SHEET: Balloon Rockets

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Balloons, straws, string, permanent marker, paper clips, cereal boxes, tape, scissors …

2. Predict how these materials may be used. The balloons may be used as decorations. Straws may be used to drink a liquid. String may be used to tie things together. Permanent markers may be used to draw or write on something. These materials may be combined to create and test a transport system.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Force	A push or pull acting on an object, which sometimes causes a change in position or motion.	
Thrust	The mechanical force that pushes a rocket or aircraft through the air.	
Newton's Second Law of Motion	Sir Isaac Newton's Second Law of Motion states that the relationship between an object's mass (m), its acceleration (a), and the applied force (F) is described by the formula $F = ma$.	
Newton's Third Law of Motion	Sir Isaac Newton's Third Law of Motion states that for every action, there exists an equal and opposite reaction.	
Pressure	The amount of force exerted on an area.	

4. Consider how a balloon can be propelled down a string and how/why that would work.

▶ **Write your hypothesis.** A simple rocket made with a balloon will be propelled down a string because of pressure and opposing forces.

LESSON 17 ACTIVITY SHEET: Balloon Rockets

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Tie one end of a string to a chair, doorknob, or other support.
2. Put the other end of the string through a straw. Then pull the string tight, and tie it to another support in the room.
3. Blow up the balloon, and pinch the end of the balloon to keep the air inside. Do not tie the balloon.
4. Have a partner tape the balloon to the straw so that the opening of the balloon is horizontal with the ground, while you keep the air pinched inside the balloon.
5. Have your partner use the marker to draw a finish line near the end of the string. Then, let go of the balloon and observe!
6. Test different methods to transport "cargo" across the string to the finish line. See your teacher for materials.

ANALYZE & CONCLUDE

1. Once you have the balloon set, what happens when you let go of it? What causes this to happen? The balloon travels along the string "track." Pressure from the gases inside the balloon pushes those gases out of the balloon when it is released. As the gases escape from the balloon, they exert a force on the outside air, which in turn exerts an opposing force and pushes the balloon forward.

2. What do you think will make the balloon move faster? Increasing the pressure of the gas inside the balloon will make the balloon move faster along the track.

3. What happens when you add cargo to the balloon rocket? The increased weight from the cargo slows down the balloon rocket.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 17 ACTIVITY SHEET: Balloon Rockets

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Fluid	Any substance made up of particles that flow or move freely, such as a liquid or gas.	
Drag	The resistance of motion through a fluid; a mechanical force that opposes an aircraft's motion through the air.	
Power	The rate at which energy is converted or work is performed.	

2. How are modern rockets propelled? Modern rockets are propelled using Newton's Third Law of Motion. The engines on the rocket emit a force that pushes against the ground, which sends the rocket into the air. The force exerted on the ground is equal and opposite to the force exerted on the rocket.

3. If a pilot wants to fly at a constant speed, what must occur? What if the pilot wants the aircraft to accelerate?

If a pilot wants to fly at a constant speed, the amount of thrust must equal the amount of drag. If the pilot wants to accelerate the aircraft, the aircraft needs more power to produce more thrust. The aircraft will go faster when the amount of thrust is greater than the amount of drag.

4. What is Newton's First Law of Motion? Newton's First Law of Motion states that an object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

LESSON 18: Puffed Rice Fleas

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5 minutes

- **DESCRIPTION**

Charge kernels of puffed rice cereal with static electricity to explore the structure and interactions of matter.

- **OBJECTIVE**

This lesson introduces static electricity and the structure of matter. Students witness the movement of puffed rice cereal to and from a balloon after it has been "charged." The lesson can be extended to address ions and electricity.

- **CONTENT TOPICS**

Scientific inquiry; properties of matter; atomic structure; attractive forces (static electricity)

- **MATERIALS**

- ❑ Plate
- ❑ Puffed rice cereal
- ❑ Balloons
- ❑ Charging cloths (wool, plastic wrap, carpet, etc.)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 223 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.B: Types of Interactions
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. Elements are composed of atoms. The elemental form of a substance is made up of only one type of atom. An **atom** is the fundamental unit of an element; it is the smallest particle of an element that retains the element's chemical properties. Atoms are made up of even smaller parts—protons, neutrons, and electrons.

Protons and **neutrons** are held tightly together in the nucleus, or core, of an atom, while **electrons** occupy the space outside of the nucleus. Protons, neutrons, and electrons have different characteristics, such as different masses and electric charges. Protons have a positive charge, neutrons have no electric charge, and electrons are negatively charged. When the number of protons in an atom equals the number of electrons, the positive and negative charges are balanced. The atom is **electrically neutral**. However, atoms can gain or lose electrons, leaving them with a positive or a negative charge.

Likewise, larger objects can gain or lose electrons becoming positively or negatively charged. **Static electricity** is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material. Some materials, such as glass, human hair, and nylon tend to give up

LESSON 18: Puffed Rice Fleas

electrons easily and become positively charged. Other materials, such as silicon and polyester, tend to collect electrons from other materials.

In addition, like charges repel one another, while opposite charges attract one another. Therefore, a positively charged object will attract a negatively charged object, but two negatively charged objects will repel one another. (Think of magnets!)

In the experiment, when students rub balloons against a charging cloth, the cloth easily gives up electrons to the balloon. Because the balloon is collecting extra electrons, it becomes negatively charged. When the balloon is held near a relatively neutral object, such as puffed rice cereal, the balloon will attract that object. Although the puffed rice cereal is neutral, it has a slightly positive charge compared to the balloon. Because opposites attract, the puffed rice cereal will be attracted to the balloon.

Eventually, some of the excess negative charge on the surface of the balloon will move to the kernels of puffed rice cereal, causing the kernels to become negatively charged. The similar charges will then repel each other, causing the kernels to "jump" away from the balloon.

FORMULAS & EQUATIONS

Protons, neutrons, and electrons make up atoms. Protons have a positive electric charge, neutrons are neutral, and electrons have a negative electric charge.The charge of an atom can be determined from the net (total) electric charge of the protons and electrons. Therefore, if an atom has two protons (a charge of $^{+}2$) and two electrons (a charge of $^{-}2$), the total charge is zero ($^{+}2 + ^{-}2 = 0$).

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, atoms, and electrons can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry.*

HYPOTHESIS

▶Puffed rice cereal will move to and from a balloon as a result of electric charges created on different materials. When objects have opposite electric charges they will attract, and when they have similar charges, they will repel.

Fun Fact

Atoms and molecules are very small. A piece of paper is about 1,000,000 atoms thick! Even when several atoms are combined, the resulting molecule is very, very small.

LESSON 18: Puffed Rice Fleas

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 223 and focus on the structure and properties of matter. Discuss how matter is made up of particles that are too tiny to see; however, we know those particles exist because of certain properties and interactions. You can also use gases to help explain how we know things exist that we can't see.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Charge kernels of puffed rice cereal with static electricity to explore the structure and interactions of matter.

OBJECTIVE

This lesson introduces static electricity, the structure of matter, and ions as students witness the movement of puffed rice cereal to and from a balloon after it has been "charged." The lesson also addresses ions and other types of electricity.

OBSERVATION & RESEARCH

All elements, and therefore all matter, are composed of atoms. An **atom** is the fundamental unit of an element; it is the smallest particle of an element that retains the element's chemical properties. Atoms are made up of even smaller parts—protons, neutrons, and electrons.

Protons and **neutrons** are held tightly together in the nucleus, or core, of an atom, while **electons** occupy the space outside of the nucleus. Protons have a positive charge, neutrons have no electric charge, and electrons are negatively charged. When the number of protons in an atom equals the number of electrons, the positive and negative charges are balanced. The atom is **electrically neutral.**

An **ion** is an atom or molecule that has lost or gained one or more of its outer electrons. Therefore, ions have either a positive or a negative charge. Because ions have an overall electric charge, they interact with other charged objects. A positive ion will attract negatively charged objects, such as negatively charged ions or free electrons. (Certain materials, such as metals, have loosely held electrons that move freely through the material.) Likewise, negative ions will attract positively charged objects.

Larger objects can also gain or lose electrons becoming positively or negatively charged. **Electricity** is a general term that includes a variety of occurrences that result from the flow of electric charges. These occurrences include lightning, the flow of electric currents in wires, and static electricity.

Static electricity is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material. Electrons can be transferred from one object to another as a result of chemical reactions, mechanical motion (such as rubbing), or other means. In addition, like charges repel one another, while opposite charges attract one another. Therefore, a positively charged object will attract a negatively charged object, but two negatively charged objects will repel one another.

In the experiment, when students rub balloons against a charging cloth, the cloth easily gives up electrons to the balloon. Because the balloon is collecting extra electrons, it becomes negatively charged. When the balloon is held near a relatively neutral object, such as puffed rice cereal, the balloon will attract that object. Although the puffed rice cereal is neutral, it has a slightly positive charge compared to the balloon. Because opposites attract, the puffed rice cereal will be attracted to the balloon.

Eventually, some of the excess negative charge on the surface of the balloon will move to the kernels of puffed rice cereal, causing the kernels to become negatively charged. The similar charges will then repel each other, causing the kernels to "jump" away from the balloon.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, atoms, electrons, and ions can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry.*

LESSON 18: Puffed Rice Fleas

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If a noncharged object is moved toward the puffed rice cereal, will it behave differently?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Sprinkle several kernels of puffed rice cereal on a plate.
2. Rub an inflated balloon over a charging cloth in one direction to create static electricity.
3. Slowly bring the charged balloon near the puffed rice cereal. The kernels of puffed rice cereal will “jump” off the plate and adhere to the surface of the balloon.
4. Hold the balloon motionless. Some of the kernels will repel from the balloon.
5. Try rotating the balloon immediately after collecting several kernels of puffed rice cereal; position the balloon so that the kernels are on top. Wait until the kernels are repelled from the balloon. (This action should dispel the notion that the kernels are merely falling off the balloon rather than being repelled from it.)

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens after you rub the balloon against a charging cloth? How does the puffed rice cereal behave in relation to the balloon? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 18: Puffed Rice Fleas

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define atoms and describe the basic composition of an atom.
- Differentiate between protons, neutrons, and electrons.
- Explain electric charges and static electricity.
- Understand that "opposites attract" and "like charges repel."
- Define ions and describe the attraction of ions to other electrically charged particles or substances (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Ask students if they have experienced static electricity from clothing or blankets. Discuss what materials seem to generate the greatest electric charges, and test their predictions by using different materials to charge the balloon. Likewise, move the charged balloon toward different materials, such as small pieces of aluminum foil or rubber bands, to explore whether those substances behave differently than the puffed rice. Discuss the results.

REAL-WORLD APPLICATIONS

- If you rub your shoes on a carpet, your body may collect extra electrons. These electrons will remain on your body until they can be released. When you touch certain objects, you will feel a shock, which is simply a release of excess electrons.
- Long before GPS (global positioning systems) and other high-tech navigational aids, the compass provided humans with an easy way to determine direction. A compass is composed of a magnet that is attracted toward the North Pole. The magnet interacts with the earth's magnetic field and aligns itself to point to the magnetic poles. These directions are called magnetic north and magnetic south. If you turn the compass toward the South Pole, the needle will repel from the South Pole and turn back to face the North Pole.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 18 ACTIVITY SHEET: Puffed Rice Fleas

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element		
Atom		
Proton		
Neutron		
Electron		
Electrically neutral		
Static electricity		

4. Consider how the puffed rice cereal will react to an electrically charged balloon and why.

▶ **Write your hypothesis.** ______________________________

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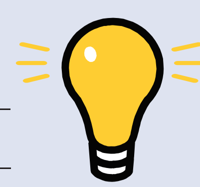


LESSON 18 ACTIVITY SHEET: Puffed Rice Fleas

PERFORM YOUR EXPERIMENT

1. Sprinkle several kernels of puffed rice cereal on a plate.
2. Rub an inflated balloon on a carpet or wool material to charge the balloon.
3. Slowly bring the charged balloon near the puffed rice cereal, and observe what happens.
4. Now hold the balloon motionless, and watch what occurs.

ANALYZE & CONCLUDE

1. What happens when you rub the inflated balloon on a carpet or wool material? (Can you see a change?)

____

____

____

2. What happens when you bring the charged balloon toward the puffed rice cereal? Why? ______________________

____

____

3. What happens when you hold the balloon motionless for a while after some kernels of puffed rice cereal collect on the balloon? Why? ____

____

____

4. What will happen if you place the balloon near the puffed rice cereal without rubbing it on something first? Why?

____

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________

____

____

LESSON 18 ACTIVITY SHEET: Puffed Rice Fleas

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Ion		
Electricity		

2. Have you ever experienced static electricity? If so, when? If not, can you give some examples of static electricity?

____

____

____

3. Static electricity occurs most often in what type of climate? Why? ____________________

____

____

LESSON 18 ACTIVITY SHEET: Puffed Rice Fleas

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. A plate, puffed rice cereal, balloons, a charging cloth …

2. Predict how these materials may be used. A plate may be used to hold various substances. Puffed rice cereal may be eaten for breakfast. Balloons may be used for decoration. A cloth may be used to clean. Together, these materials may be used to show the effects of static electricity.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down further by normal chemical means; elements are the building blocks of matter.	
Atom	The fundamental unit of an element; the smallest particle of an element that maintains the chemical properties of that element.	
Proton	A subatomic particle that carries a positive charge and is found in the nucleus of an atom.	
Neutron	A subatomic particle that carries no electric charge and is found in the nucleus of an atom.	
Electron	A subatomic particle that carries a negative charge and occupies the space outside the nucleus of an atom.	
Electrically neutral	An atomic state in which the number of protons in an atom equals the number of electrons, thus the positive and negative charges are balanced.	
Static electricity	The buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material.	

4. Consider how the puffed rice cereal will react to an electrically charged balloon and why.

▶ **Write your hypothesis.** Puffed rice cereal will appear to jump to and from the balloon as a result of static electricity (the movement of electric charges between materials and the interactions between different charges).

LESSON 18 ACTIVITY SHEET: Puffed Rice Fleas

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Sprinkle several kernels of puffed rice cereal on a plate.
2. Rub an inflated balloon on a carpet or wool material to charge the balloon.
3. Slowly bring the charged balloon near the puffed rice cereal, and observe what happens.
4. Now hold the balloon motionless, and watch what occurs.

ANALYZE & CONCLUDE

1. What happens when you rub the inflated balloon on a carpet or wool material? (Can you see a change?)

Rubbing the inflated balloon on a carpet or wool material transfers electrons (negative electric charges) to the balloon. You cannot actually see this change occur until the balloon comes in contact with other materials.

2. What happens when you bring the charged balloon toward the puffed rice cereal? Why? The electric charge on the surface of the balloon (negative charge) will attract the puffed rice cereal because the puffed rice has a more positive charge. Opposite charges attract.

3. What happens when you hold the balloon motionless for a while after some kernels of puffed rice cereal collect on the balloon? Why? The puffed rice cereal will eventually gather some of the excess electrons from the balloon. Then, the similar charges between the puffed rice cereal and the balloon will repel each other, causing the kernels to "jump" from the balloon.

4. What will happen if you place the balloon near the puffed rice cereal without rubbing it on something first? Why?

Nothing will happen if you do not rub the balloon on something first because both substances will remain electrically neutral.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 18 ACTIVITY SHEET: Puffed Rice Fleas

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Ion	An atom or group of atoms that has lost or gained one or more of its outer electrons; an ion will have either a positive or a negative charge.	
Electricity	A form of energy that results from the flow of charged particles, such as electrons or ions.	

2. Have you ever experienced static electricity? If so, when? If not, can you give some examples of static electricity?

Static electricity can occur from dragging your feet across a carpet, rubbing two types of fabric together, or pulling a fleece sweatshirt over your head (and hair!). The friction between the two substances causes a buildup of electric charges on one substance.

3. Static electricity occurs most often in what type of climate? Why? Static electricity occurs most often in dry climates because electrons stay on surfaces longer in dry air. Moist air conducts electricity better than dry air, so charges wear off quickly.

LESSON 19: Liquid Rainbow

ESTIMATED TIME **Setup:** 10–15 minutes | **Procedure:** 10 minutes

• DESCRIPTION

Challenge students to layer five liquids of different densities in clear drinking straws and determine the order of the solutions based on density.

• OBJECTIVE

This lesson will allow students to explore the properties of density and solubility. Students will attempt to layer solutions of different densities on top of one another in order to identify the solutions from most dense to least dense. This lesson can be simplified to address the importance of measurement.

• CONTENT TOPICS

Scientific inquiry; measurement; properties of matter (density); mixtures (solutions)

This experiment can be scaled down from gallons of water and cups of salt to cups of water and teaspoons of salt to accommodate different class sizes or group work. See the ***Experimental Procedure*** section of this lesson for the conversions.

• MATERIALS

- ❑ Five pitchers, milk jugs, or other large containers
- ❑ Food coloring (yellow, green, red, and blue)
- ❑ Transparent drinking straws
- ❑ Pickling salt or table salt
- ❑ Six cups for each student or group
- ❑ Measuring cups
- ❑ Measuring spoons

Pickling salt is preferred for this activity because it does not have any additives and will not make cloudy solutions. Clear or translucent drinking straws must be used so that the colors of the different solutions can be observed when in the straw.

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 234–235 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from “A Framework for K–12 Science Education,” established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion)***

OBSERVATION & RESEARCH

BACKGROUND

Mass and volume are common units of measure. **Mass** is a measure of the amount of matter in a substance. **Volume** is the amount of space an object occupies. Mass and volume can be used to determine a useful physical property of matter—density.

Density is an important concept in chemistry that is defined as the mass of an object per unit volume.

Density is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are. The formula used to calculate density is **d = m/v**, where d is the density, m is the mass of the object, and v is the volume of the object. Scientists use density in different ways. They use it to identify unknown substances and to separate different liquids.

LESSON 19: Liquid Rainbow

The approximate density of pure water is 1.0 gram per milliliter (g/mL). This means that one milliliter of water will have a mass of one gram on the earth. In general, a substance that is less dense than water will rest on top of the water, and a substance that is denser than water will sink below the surface.

A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved into another substance (solvent). In this experiment, salt is dissolved in water to create a saltwater solution. The density of the resulting solution is greater than the density of water. Likewise, the density of the solution will increase as more solute is dissolved in the solution. As more salt is dissolved in the solution, the mass of the solution increases. Since the volume of the solution remains relatively the same, the density of solutions with more dissolved salt will be greater than the density of solutions with less dissolved salt.

Using a specific technique, a solution with a lower density can rest on top of a denser solution. Essentially, the denser solutions have more mass concentrated within a specific volume and will fall beneath solutions with lower densities.

In addition, **solubility** is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent and create a uniform solution. A substance that dissolves in another substance is **soluble**. For example, salt is soluble in water. If a substance does not dissolve, it is **insoluble**. For instance, butter is insoluble in water. Because salt is soluble in water, different saltwater solutions can be mixed together. As a result, if a solution with a greater density is added to a solution with a lower density, the higher density solution will naturally fall to the bottom. However, because salt is soluble in water, as the denser solution moves through the less dense solution, the two may mix.

FORMULAS & EQUATIONS

The density of an object is the amount of mass per unit of volume. It can be calculated using the following equation:

$$d = m/v$$

Density is measured in grams per milliliters or grams per cubic centimeters. One cubic centimeter (cm^3 or cc) is equal to one milliliter (mL).

Tap water is a mixture of pure water, minerals, and other substances. The density of pure water is 1.0 g/mL.

The chemical formula for pure water is **H_2O**.

Ordinary table salt is made primarily of sodium chloride.

The chemical formula for sodium chloride is **NaCl**.

Most table salts are made of about 97–99% NaCl with the rest being small amounts of iodine and other ingredients.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of physical measurements can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on properties of matter and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶ Adding different amounts of salt to containers of water will cause each solution to have a different density. Those solutions can be layered on top of one another from most to least dense using a specific technique.

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Practice performing different measurements to reinforce the importance of measurement and explain the difference between accuracy and precision. Calculate the mass, volume, and density of different saltwater solutions.

OBJECTIVE

This lesson reinforces the importance of measurement and allows students to practice measuring mass, volume, and density.

OBSERVATION & RESEARCH

Measurement is perhaps one of the most fundamental concepts in science. It is the process of determining the ratio of a physical quantity, such as length or mass, to a unit of measurement. Without the ability to measure, it would be difficult for scientists to conduct experiments or form theories. Not only is measurement important in science, but it is also essential in industry, farming, engineering, construction, manufacturing, commerce, and our everyday lives!

Scientists have two goals when they take measurements. They want their measurements to be **accurate** by getting as close as possible to the true measurement of something. They also want their measurements to be **precise** so that they can take the same measurement and get the same result over and over.

Measurement is never 100% accurate, so the true value of a measurement is never exactly known. This uncertainty is a result of error, a concept which is associated with measuring because measurement is always a comparison to a standard. Manually measuring something always involves uncertainty because it is based on judgment: if two people use a ruler to measure how tall a plant is, it may look like 20 cm to one person and 18 cm to the other. To increase the accuracy of a measurement, therefore reducing error, an object should always be measured more than once. Taking multiple measurements and then determining the average measurement increases the likelihood that you have the exact measurement.

Mass and volume are common units of measure. **Mass** is a measure of the amount of matter in a substance. **Volume** is the amount of space an object occupies. **Density** is another important measurement in chemistry, defined as the mass of a substance per unit volume. Density is a physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are.

In this experiment, the density of each saltwater solution depends on the amount of salt added to the water. As more salt is dissolved in the water, the density of the liquid increases. In order to layer the different liquids, they must have different densities. Therefore, it is important to measure the salt to be added to each solution carefully. The difference in scale between the gallons of water and cups of salt measurements (or the cups of water and teaspoons of salt measurements) is important to produce the desired results in the experiment.

Using this background information, you may want to allow the students to create the different saltwater solutions to practice measurement. They should use *Experimental Procedure* Option 2 (cup of water and teaspoons of salt) and work in small groups. Once they have prepared the solutions, you can have them close their eyes as you go around the room and add the dye to each group's solutions. You'll want to make sure that they have the cups lined up in order of least to most dense, so you add the dye consistently for each group. Then, you will mix up the order of the cups while their eyes are still closed.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on measurement can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 19: Liquid Rainbow

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described below, but spend more time on solubility and miscible substances. A **miscible** liquid is a liquid that will mix in all proportions to form a homogeneous solution. All of the saltwater solutions are miscible, and therefore, when a denser solution is layered on top of a less dense solution, the denser solution will fall through the "lighter" one, and the two solutions may mix in the process. On the other hand, oil and water are **immiscible**; they will not mix.

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: As the amount of solute changes, does the density of the solution change? Likewise, as the density of the solution changes, does its position in relation to the other solutions change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Prepare five salt solutions. Use the appropriate measurements below based on your class size and whether students will perform this experiment individually or in groups.

OPTION 1: For large classes

A. Prepare five salt solutions as described below, each with a different density. Use the following measurements:

Pitcher #1: 1 gallon of water, 0 cups of salt, and 1 bottle of yellow coloring

Pitcher #2: 1 gallon of water, ½ cup of salt, and 1 bottle of green coloring

Pitcher #3: 1 gallon of water, 1 cup of salt, and no coloring (clear)

Pitcher #4: 1 gallon of water, 1 ½ cups of salt, and 1 bottle of red coloring

Pitcher #5: 1 gallon of water, 2 cups of salt, and 1 bottle of blue coloring

B. Line up five cups in front of each student (or group). Pour one cup of solution 1 (Pitcher #1) into the first cup. Pour one cup of solution 2 (Pitcher #2) into the second cup. Continue this process with the other three solutions and cups.

OPTION 2: For small classes or small groups

A. Prepare five salt solutions as described below, each with a different density. Use the following measurements:

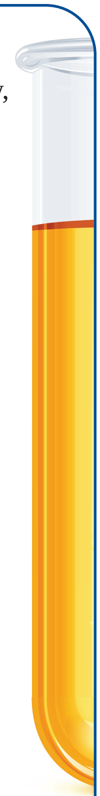
Cup #1: 1 cup of water, 0 teaspoons of salt, and 10 drops of yellow food coloring

Cup #2: 1 cup of water, 1 ½ teaspoons of salt, and 10 drops of green food coloring

Cup #3: 1 cup of water, 3 teaspoons of salt, and no food coloring (clear)

Cup #4: 1 cup of water, 4 ½ teaspoons of salt, and 10 drops of red food coloring

Cup #5: 1 cup of water, 6 teaspoons of salt, and 10 drops of blue food coloring



LESSON 19: Liquid Rainbow

EXPERIMENTAL PROCEDURE

2. Each student or group should have one empty cup to serve as a waste container. When comparing different solutions, students should empty their straw into the waste cup to avoid contaminating the other solutions.

Be sure that each cup has at least 5 centimeters of solution. This level of depth will allow for the different solutions to enter the straw and form layers of color.

3. Press your thumb over the opening at the top of the straw, and place the straw straight down into one solution until the end of the straw touches the bottom of the cup. The straw must be perpendicular to the bottom of the cup.

4. With the straw touching the bottom of the cup, lift your thumb off the top of the straw for one second; then cover the straw again. This process should allow you to draw some of the solution into the straw. (This may take some practice.)

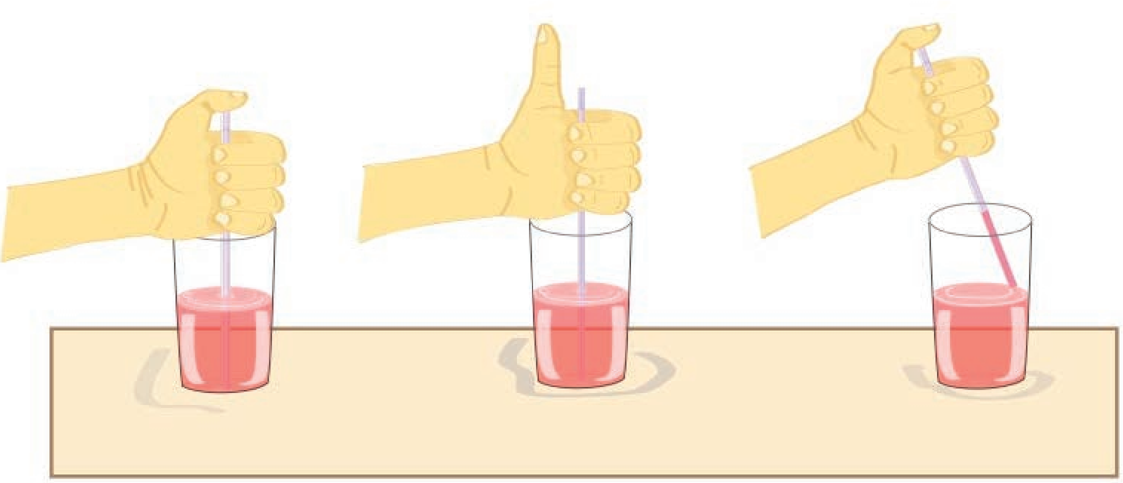
5. With your thumb still over the opening, lift the straw straight out of the solution.

6. Repeat steps 3–5 by submerging the straw into a second solution. (Remind the students to place the end of the straw straight down to the bottom of the cup before lifting their thumbs.)

7. Observe. (If the second solution is less dense, it is likely to mix with the first solution as it attempts to move to the top.)

8. Continue by challenging the students to layer all five solutions in a straw. To layer all five solutions, they should begin layering by starting with the least dense solution and ending with the densest solution. Hint: They should test 2 or 3 solutions at a time, and use those comparisons to determine the order of the solutions from least to most dense.

Each layer pulled into the straw will be smaller than the first, because the pressure of the layers already in the straw will only allow a small amount of the next solutions to enter the straw.



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is a solution? What order of the solutions did you observe? You can use the table in the activity sheet (or a similar one of your own) for students to record the order of the solutions from least to most dense.

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the importance of measuring the correct quantities to obtain desired results.
- Define and identify solutions, solutes, and solvents.
- Explain the concept of density and the relation of the amount of solute to the density of a solution.
- Use analytical thinking skills to develop a technique for solving a problem.
- Define and identify different types of measurement (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lessons or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- To help illustrate the concept of density, explain that the classroom would become denser if more people were to enter the room. You may also use the concept of a car. Explain that a car with one person in it is less dense or “crammed” than the same car with 10 people in it.
- Prepare the solutions prior to class, and do not tell the students that the solutions are all saltwater solutions. Following the experiment, ask them why they were able to rest some solutions on top of others. Lead them toward the concept of density. Then, explain that all of the solutions were saltwater solutions. Propose the question that if all the solutions were made of just salt and water, why would they have different densities?
- Take the challenge one step further! If the students were able to layer all five solutions, have the students turn the straw upside down while keeping their thumbs pressed tightly over the top opening. When the straw is inverted, the colors will change position according to their densities. They will appear to mix, but may then separate out into different layers of color. This demonstrates that the densest solutions will fall to the bottom, while the least dense will rise to the top!

K-4 See **Lesson 12: Density Totem** for a simplified density experiment.

5-8 See **Lesson 4: Buoyant Butter** for an introductory lesson on density.

REAL-WORLD APPLICATIONS

- Density is used to identify substances. For example, someone may claim that he/she found gold. To determine if the shiny substance is actually pure gold, the person can begin by calculating its density. If the density of the substance is 19.3 g/mL, the substance is most likely pure gold. However, if the density is not 19.3 g/mL, the person might have found pyrite. Pyrite is known as fool’s gold because it resembles gold. However, pyrite is much lighter; it has a density of about 5 g/mL.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 19 ACTIVITY SHEET: Liquid Rainbow

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

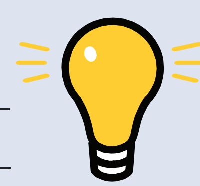
Term	Definition	Example (write or add image)
Mass		
Volume		
Density		
Solution		
Soluble		
Insoluble		

4. Consider what may happen when solutions of different densities are combined and why.

▶**Write your hypothesis.** ______________________________

____

____



LESSON 19 ACTIVITY SHEET: Liquid Rainbow

PERFORM YOUR EXPERIMENT

1. Obtain five cups from your teacher. Each cup will contain a different solution. Get one empty cup as well to serve as a waste container.

2. Observe the five solutions, and make a hypothesis about each solution's relative density. (Which solution is the densest? Which solution is least dense?) Then, test your hypotheses by using a straw to experiment with the solutions.

3. Select two solutions, and try to layer them in the straw following steps 4–7.

4. Press your thumb over the opening at the top of the straw. Then, place the end of the straw straight down into one solution until the end of the straw touches the bottom of the cup. The straw must be perpendicular to the bottom of the cup.

5. With the straw touching the bottom of the cup, lift your thumb off the top of the straw for one second. Then, cover the straw with your thumb again. This process should allow you to draw about two centimeters of the first solution into the straw. (Holding your thumb over the end of the straw acts as an air valve.) This may take some practice.

6. Keep your thumb pressed on the top of the straw, and lift the straw straight out of the solution.

7. Continue to keep your thumb pressed on the top of the straw so the first solution stays inside. Then, repeat steps 4–6 with the second solution. Remember to place the end of the straw directly on the bottom of the cup. Then, lift your thumb off the straw for one second, and place your thumb back on top. Lift the straw straight out of the second solution, and observe. If the second solution is denser, it will remain separated from the first at the bottom of the straw. If the second solution is less dense, it may mix with the first solution as it attempts to move to the top.

8. Place your straw into the waste cup, and remove your thumb. This process will empty your straw into the waste cup.

9. Try to layer all five solutions in the straw. Continue by testing two solutions at a time, using steps 4–7. Then, try to layer three, and then four, until you are able to layer all five solutions. Compare the densities of all the solutions to determine the order of their densities from least to greatest.

Each layer pulled into the straw will be smaller than the first. The pressure of the layers already in the straw will only allow a small amount of the next solutions to enter the straw.

LESSON 19 ACTIVITY SHEET: Liquid Rainbow

ANALYZE & CONCLUDE

1. Record your observations of each solution. Note whether a specific color is always on the top, if the solution rests on top of one color but mixes with another, if a color is always on the bottom, etc. Use these observations to draw conclusions about the relative density of each solution. Then, rank each solution based on its density (1 being the least dense, 5 being the most dense) using the table below.

Color of the Solution	Observations	Density Ranking

2. Color the blocks below to show the order of the colored solutions collected in your straw.

Bottom				**Top**

3. Are the densest solutions at the bottom or top of the straw? Why? ______________________________

____

____

4. What makes some solutions denser than others? ______________________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

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LESSON 19 ACTIVITY SHEET: Liquid Rainbow

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Measurement		
Accuracy		
Precision		

2. What device can you use to measure mass? What device can you use to measure volume? ______________________

____

____

3. How could you increase the density of a solution? ______________________________

____

____

LESSON 19 ACTIVITY SHEET: Liquid Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Pitchers or gallon containers (such as empty and cleaned milk jugs), food coloring, clear drinking, straws, salt, cups …

2. Predict how these materials may be used. Gallon containers and cups may be used to hold substances, such as liquids. Food coloring may be used to dye substances. Straws may be used for drinking. Salt may be used for flavoring. These materials may be used to create solutions of different colors and with different densities. The different solutions can be layered in the straw.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Density	A physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are; the mass of an object per unit of volume ($d = m/v$).	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Soluble	The ability of a substance to dissolve in another substance.	
Insoluble	The inability of a substance to be dissolved into another substance.	

4. Consider what may happen when solutions of different densities are combined and why.

▶ **Write your hypothesis.** Adding different amounts of salt to containers of water will result in each solution having a different density. The solutions can be made to form layers when combined in a clear straw, because the solutions with lower densities will rest on top of solutions with higher densities.

LESSON 19 ACTIVITY SHEET: Liquid Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Obtain five cups from your teacher. Each cup will contain a different solution. Get one empty cup as well to serve as a waste container.

2. Observe the five solutions, and make a hypothesis about each solution's relative density. (Which solution is the densest? Which solution is least dense?) Then, test your hypotheses by using a straw to experiment with the solutions.

3. Select two solutions, and try to layer them in the straw following steps 4–7.

4. Press your thumb over the opening at the top of the straw. Then, place the end of the straw straight down into one solution until the end of the straw touches the bottom of the cup. The straw must be perpendicular to the bottom of the cup.

5. With the straw touching the bottom of the cup, lift your thumb off the top of the straw for one second. Then, cover the straw with your thumb again. This process should allow you to draw about two centimeters of the first solution into the straw. (Holding your thumb over the end of the straw acts as an air valve.) This may take some practice.

6. Keep your thumb pressed on the top of the straw, and lift the straw straight out of the solution.

7. Continue to keep your thumb pressed on the top of the straw so the first solution stays inside. Then, repeat steps 4–6 with the second solution. Remember to place the end of the straw directly on the bottom of the cup. Then, lift your thumb off the straw for one second, and place your thumb back on top. Lift the straw straight out of the second solution, and observe. If the second solution is denser, it will remain separated from the first at the bottom of the straw. If the second solution is less dense, it may mix with the first solution as it attempts to move to the top.

8. Place your straw into the waste cup, and remove your thumb. This process will empty your straw into the waste cup.

9. Try to layer all five solutions in the straw. Continue by testing two solutions at a time, using steps 4–7. Then, try to layer three, and then four, until you are able to layer all five solutions. Compare the densities of all the solutions to determine the order of their densities from least to greatest.

Each layer pulled into the straw will be smaller than the first. The pressure of the layers already in the straw will only allow a small amount of the next solutions to enter the straw.

LESSON 19 ACTIVITY SHEET: Liquid Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

ANALYZE & CONCLUDE

1. Record your observations of each solution. Note whether a specific color is always on the top, if the solution rests on top of one color but mixes with another, if a color is always on the bottom, etc. Use these observations to draw conclusions about the relative density of each solution. Then, rank each solution based on its density (1 being the least dense, 5 being the most dense) using the table below.

Color of the Solution	Observations	Density Ranking
Yellow	The yellow solution is always above the other colors.	1
Green	The green solution stays below yellow, but moves above the rest of the solutions.	2
Clear	The clear solution stays below yellow and green, but moves above red and blue.	3
Red	The red solution moves above blue, but stays below the rest of the solutions.	4
Blue	Blue always stays on the bottom or falls through to the bottom.	5

2. Color the blocks below to show the order of the colored solutions collected in your straw.

Bottom **Top**

3. Are the densest solutions at the bottom or top of the straw? Why? The densest solutions are at the bottom of the straw because dense solutions have more mass per unit of volume.

4. What makes some solutions denser than others? A solution with a greater mass in a given space (volume) will have a greater density. In this case, as more salt is added (more mass), the solution becomes denser.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 19 ACTIVITY SHEET: Liquid Rainbow

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Measurement	A figure, extent, or amount obtained by measuring.	
Accuracy	The closeness of a given measurement to the actual (true) value for that quantity of substance; to measure a quantity as close as possible to the true measurement (true value) of that quantity.	
Precision	The degree to which repeated measurements under unchanged conditions show the same results.	

2. What device can you use to measure mass? What device can you use to measure volume? A balance can be used to measure mass. A graduated cylinder can be used to measure the volume of a liquid.

3. How could you increase the density of a solution? To increase the density of a solution, increase the amount of mass per unit of volume. For example, add more solute to increase the mass of the solution.

LESSON 20: Hold the Salt

ESTIMATED TIME **Setup:** 10 minutes | **Procedure:** Allow for observations over 4 hours.

DESCRIPTION

Apply the process of distillation to produce fresh, drinkable water from a saltwater solution.

OBJECTIVE

This lesson demonstrates the process of distillation and how it is used to separate substances in a solution. Students create a simple distillation device to remove pure water from a saltwater solution. The lesson can be simplified to address the states of matter and illustrate physical changes.

CONTENT TOPICS

Scientific inquiry; states of matter; physical changes (condensation, vaporization); mixtures (solutions); separation processes (distillation)

If able, check the progress of the experiment every hour.

Do not exceed 4 hours as mold may grow in the container.

MATERIALS

- ❑ Large bowl
- ❑ Heavy glass cup (shorter than the bowl is deep)
- ❑ Teaspoon
- ❑ Clear plastic food wrap
- ❑ Any coin
- ❑ Clear cellophane tape
- ❑ Blue food coloring
- ❑ Water
- ❑ Table salt
- ❑ Ruler

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 248 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Most of the things around us are mixtures—air, bronze metal, lemonade, pizza, and more! Mixtures are made of two or more substances that are combined physically. A solution is a uniform mixture in which one or more substances (solutes) are dissolved into another substance (solvent). In this experiment, salt is dissolved in water to create a saltwater solution. However, salt water, like ocean water, is not drinkable water.

Humans need fresh drinking water to survive. We can only last a couple of days without it, but not any type of water will do. Drinking salt water from the ocean can be dangerous. Although small amounts of salt water will not cause major problems, the human body acts to remove excess salt, specifically sodium, from the body. If a person drinks a glass of salt water, the body will work to get rid of the excess salt. Water will move out of every cell in an effort to dilute the salt and establish a balance in the body. However, cells need water, so the diffusion of water out of the cells leaves them dangerously dehydrated. In addition, kidneys and cells in the blood may absorb more salt than they can handle, becoming overworked and shutting down. Likewise, other sources of water may be contaminated with other harmful substances. Therefore, finding ways to produce fresh drinking water is crucial to our survival.

To separate unwanted chemical substances from water, scientists use different separation processes. A **separation process** is a means of separating any mixture of substances into two or more distinct products. A separation process uses the different properties of a mixture's parts to get them to separate.

A commonly used separation process is called distillation. **Distillation** is a method of separating a liquid mixture based on the differences between the boiling points of the mixture's parts. During distillation, a liquid mixture is heated to the boiling point of one part. As a result, that part of the mixture vaporizes. The vaporized gas can be collected in a separate part of the distillation device and cooled. As the gas cools, it condenses into its pure liquid form. The purified liquid is called the **distillate**.

In this experiment, a distillation process is used to collect fresh drinking water from the saltwater solution. Pure water has a much lower boiling point than salt. Therefore, when the salt water is heated, the water reaches its boiling point sooner and begins to vaporize, leaving the salt behind. The gas that vaporizes is water vapor, or more important, it is pure water vapor.

To convert this pure water vapor back into a liquid, the vapor must be collected and condensed. **Condensation** is a change in state from a gas to a liquid. As the water vapor cools, it condenses back into liquid form. At this point, the liquid is now pure, drinkable water.

FORMULAS & EQUATIONS

The blue saltwater solution created in the experiment is comprised of water, table salt, and food coloring. The distillation process separates the water from the salt, food coloring, and any other substances that were contained in the solution.

Tap water is a solution as well. It is a mixture of pure water, minerals, and other substances.

The chemical formula for pure water is $\mathbf{H_2O}$.

Ordinary table salt is made primarily of sodium chloride.

The chemical formula for sodium chlorde is **NaCl**.

Most table salts are made of about 97– 99% NaCl and small amounts of iodine and other ingredients.

Distillation involves the physical changes of vaporization and condensation. During a physical change, the chemical makeup of the structure does not change. The water vapor and liquid water are both H_2O, just in different physical states.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on solutions can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on states of matter and physical changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on distillation can be found in the Laboratory Separations section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

HYPOTHESIS

▶ As the temperature of a saltwater solution rises and reaches the boiling point of water, pure water will vaporize, leaving the salt and other parts of the mixture behind.

LESSON 20: Hold the Salt

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Use a saltwater solution to illustrate a separation process, and discuss states of matter and physical changes.

OBJECTIVE

This lesson demonstrates a separation process and physical changes, particularly vaporization and condensation.

OBSERVATION & RESEARCH

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, glasses, and trees. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and oil. **Gases** have no definite shape and no definite volume. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Matter can change from one state to another, generally as a result of a change in temperature. **Melting** is a change in state from a solid to a liquid. The opposite change is freezing. **Freezing** is a change in state from a liquid to a solid. A change in state from a liquid to a gas is known as **vaporization**, and a change in state from a gas to a liquid is known as **condensation**. Changes directly between the solid and gaseous states, without going through the liquid state first, are lesson common. **Sublimation** is a change in state from a solid directly to a gas. The opposite is **deposition**, which ocurs when a gas changes into a solid.

Changes between these states of matter are physical changes. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. For example, tearing or cutting a piece of paper is an example of a physical change. The paper is in smaller pieces, but the chemical makeup of the paper has not changed. Likewise, ice, water, and water vapor are all H_2O in different physical states. The chemical formula remains H_2O regardless of whether it is in the solid, liquid, or gaseous state.

In this experiment, pure water is separated from a solution, using vaporization and condensation. The sunlight causes the temperature of the solution to increase. When the temperature reaches the boiling point of water, the water will begin to vaporize. As the water vapor touches the cooler plastic wrap, it will condense into a liquid and roll down the wrap into the cup. Because water has a lower boiling point than the salt in the solution, it vaporizes sooner than the salt. As a result, the pure water is separated from the salt. A **separation process** is a means of separating any mixture of substances into two or more distinct products, in this case, salt and water.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Conduct the experiment as described on page 248, but spend more time on types of mixtures and solubility. Discuss the differences between homogeneous and heterogeneous mixtures. Use pictures to provide examples of these types of mixtures. Then, discuss solubility and why some substances dissolve in some solvents, but others do not.

Another option is to explore the desalination of water. The process of obtaining pure, drinkable water from a saltwater solution is called **desalination**, which literally means to take the salt out of water. Distillation is one method. Have the students research other methods of desalination.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states of matter, physical changes, and types of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on distillation and desalination can be found in the Laboratory Separations section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 20: Hold the Salt

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: As the temperature changes, does the composition of the solution change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

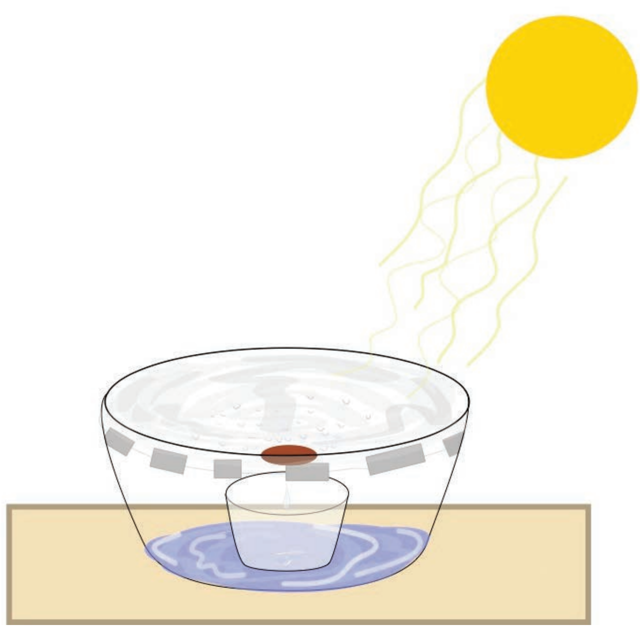
1. Pour tap water in a bowl to a depth of about 5 centimeters (2 inches).
2. Add 10 drops of blue food coloring and 2–3 teaspoons of salt to the water. Mix well until the salt is dissolved.
3. Place the heavy glass cup (with the opening facing up) in the center of the bowl, so it is surrounded by the blue saltwater solution. Make sure that the cup sits flat on the bottom of the bowl.
4. Put a loose covering of plastic food wrap over the top of the bowl. Tape the plastic wrap to the sides of the bowl so that air cannot get in or out. Make sure the plastic wrap is *not* pulled tightly across the top of the bowl.
5. Place a coin on the outside of the plastic wrap directly over the center of the glass. Make sure that the weight of the coin makes the plastic wrap slant down toward the center of the glass.
6. Put the bowl on a flat surface outside or on a windowsill where it will get a lot of sunshine.
7. Leave the bowl in the sun for four hours. (You can also use a heat lamp if you wish to conduct this experiment inside.)
8. After four hours, take off the plastic wrap and lift the glass out of the saltwater solution. Measure the height of the saltwater solution left in the bowl, and compare to the original measurement.

When moving the bowl, be sure that none of the blue saltwater solution splashes into the glass.

If possible, check the bowl every hour for four hours. Do not leave the bowl in the sun for more than four hours because mold may eventually begin to grow in the water.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is a mixture? What is a solution? What changes did you observe during the experiment? You can use the table in the activity sheet (or a similar one of your own) for students to record the initial height of the solution in the bowl and the final height of the solution in the bowl.



LESSON 20: Hold the Salt

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Describe the difference between salt water and freshwater and explain the dangers of drinking salt water.
- Compare and contrast mixtures and solutions.
- Describe the process of distillation.
- Explain and give examples of physical changes, specifically vaporization and condensation.
- Define a separation process and describe the process of distillation (see ***Differentiation in the Classroom***).
- Define and give examples of the different states of matter (see ***Differentiation in the Classroom***).
- Distinguish between various phase changes/changes between states of matter (see ***Differentiation in the Classroom***).

Fun Fact

The water in swimming pools and the ocean appears to be blue. This color can only be seen in tremendous quantities of water. The water looks blue because of the reflection of light.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, ask the students if they know how to make freshwater from salt water. Tell them that this can be done by using the sun, and then ask how they can make this happen. (You can even challenge them to come up with their own experimental setup.)
- After the bowl has been in the sun a while, ask the students to explain what they are observing. Have them describe (and record!) what they see during each stage of the experimental setup. Be sure that the students are able to observe each step of the distillation process.

REAL-WORLD APPLICATIONS

- Evaporation and condensation are essential parts of the earth's water cycle. The water cycle describes the continuous movement of water on, above, and below the surface of the earth. Throughout this process, the water passes through the gaseous, liquid, and sometimes even the solid states.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 20 ACTIVITY SHEET: Hold the Salt

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Solution		
Separation process		
Distillation		
Vaporization		
Condensation		

4. Consider what might happen to a saltwater solution when the temperature is increased and why.

▶**Write your hypothesis.** ______________________________

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LESSON 20 ACTIVITY SHEET: Hold the Salt

PERFORM YOUR EXPERIMENT

1. Fill a bowl with tap water to a depth of about 5 centimeters (2 inches).
2. Add 10 drops of blue food coloring and 2–3 teaspoons of salt. Mix well until the salt is dissolved.
3. Place the heavy glass cup (opening facing up) in the center of the bowl so it is surrounded by the blue saltwater solution. Make sure that the glass sits flat on the bottom of the bowl.
4. Put plastic wrap loosely over the top of the bowl. Tape the plastic wrap to the sides of the bowl so that air cannot get in or out. Make sure the plastic wrap is *not* pulled tightly across the top of the bowl.
5. Place a coin on the outside of the plastic wrap directly over the center of the glass. Make sure that the weight of the coin makes the plastic wrap slant down toward the center of the glass.
6. Put the bowl on a flat surface outside or on a windowsill where it will get a lot of sunshine.
7. After four hours, take off the plastic wrap, and lift the glass out of the saltwater solution. Then, measure the height of the saltwater solution in the bowl.

ANALYZE & CONCLUDE

1. What do you see forming on the plastic wrap? What is causing this to form? ______________________________

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2. What color is the liquid that collected in the cup? What does this tell you? ______________________________

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____

3. How do you think the liquid in the cup would taste? Why? (**Never** actually taste any substance in the lab.)

____

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LESSON 20 ACTIVITY SHEET: Hold the Salt

4. After a few hours, what is left in the bowl? Explain. ____

____

____

5. Measure the amount of liquid in the bowl, and record below. Remember to include units.

Time	Height of the Solution in the Bowl
Start (0 hours)	
Finish (__ hours)	

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________

____

____

LESSON 20 ACTIVITY SHEET: Hold the Salt

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid		
Liquid		
Gas		
Melting		
Freezing		
Sublimation		
Deposition		
Physical change		

2. How might the process of distillation be useful to people? ______________________________

____

____

LESSON 20 ACTIVITY SHEET: Hold the Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. A large bowl, a glass cup, plastic wrap, a coin, tape, blue food coloring, salt, water …

2. Predict how these materials may be used. A large bowl may hold a liquid. A glass cup may be used for drinking. Plastic wrap may be used to cover and wrap leftover food. Blue food coloring may be used to dye a substance. Salt may be used in cooking. These materials can be used to construct a system that will demonstrate vaporization and condensation, as well as a distillation process.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Separation process	A process that divides a mixture into two or more distinct substances.	
Distillation	A method of separating a liquid mixture based on the differences between the boiling points of the mixture's parts.	
Vaporization	A physical change in which a substance changes states from a liquid to a gas.	
Condensation	A physical change in which a substance changes states from a gas to a liquid.	

4. Consider what might happen to a saltwater solution when the temperature is increased and why.

▶**Write your hypothesis.** Pure water will evaporate (vaporize) from the blue saltwater solution because water has a lower boiling point than salt. If the water vapor touches a cool surface, it may condense as pure liquid water.

LESSON 20 ACTIVITY SHEET: Hold the Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill a bowl with tap water to a depth of about 5 centimeters (2 inches).
2. Add 10 drops of blue food coloring and 2–3 teaspoons of salt. Mix well until the salt is dissolved.
3. Place the heavy glass cup (opening facing up) in the center of the bowl so it is surrounded by the blue saltwater solution. Make sure that the glass sits flat on the bottom of the bowl.
4. Put plastic wrap loosely over the top of the bowl. Tape the plastic wrap to the sides of the bowl so that air cannot get in or out. Make sure the plastic wrap is *not* pulled tightly across the top of the bowl.
5. Place a coin on the outside of the plastic wrap directly over the center of the glass. Make sure that the weight of the coin makes the plastic wrap slant down toward the center of the glass.
6. Put the bowl on a flat surface outside or on a windowsill where it will get a lot of sunshine.
7. After four hours, take off the plastic wrap, and lift the glass out of the saltwater solution. Then, measure the height of the saltwater solution in the bowl.

ANALYZE & CONCLUDE

1. What do you see forming on the plastic wrap? What is causing this to form? Droplets of liquid are forming on the plastic wrap. The droplets are water droplets that have evaporated (vaporized) from the solution and condensed on the plastic wrap.

2. What color is the liquid that collected in the cup? What does this tell you? The water in the cup is clear, which indicates that the food coloring does not evaporate. Only pure water evaporates.

3. How do you think the liquid in the cup would taste? Why? (**Never** actually taste any substance in the lab.)

   The water in the cup will taste like freshwater because the process separated the salt from the water.

LESSON 20 ACTIVITY SHEET: Hold the Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. After a few hours, what is left in the bowl? Explain. The salt and the food coloring will be left in the bowl if all the water evaporates. However, since only some of the water evaporates, a blue saltwater solution remains. The remaining solution is more concentrated than the original solution (has more solute and less solvent).

5. Measure the amount of liquid in the bowl, and record below. Remember to include units.

Time	Height of the Solution in the Bowl
Start (0 hours)	5 centimeters (2 inches)
Finish (__ hours)	Answers will vary

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 20 ACTIVITY SHEET: Hold the Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid	A state of matter characterized by a definite volume and a definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	
Melting	A physical change in which a substance changes states from a solid to a liquid.	
Freezing	A physical change in which a substance changes states from a liquid to a solid.	
Sublimation	A physical change in which a substance changes states from a solid to a gas.	
Deposition	A physical change in which a substance changes states from a gas to a solid.	
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	

2. How might the process of distillation be useful to people? A distillation process can be used to make clean, drinkable water for people in areas where freshwater is not readily available.

LESSON 21: Sewer Leeches

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5–10 minutes

DESCRIPTION

Place raisins in soda pop to observe the motion caused by the buildup of carbon dioxide bubbles on the raisins' surface.

OBJECTIVE

This lesson introduces solubility of gases and buoyancy. Students observe as carbon dioxide gas bubbles form on raisins that are added to soda pop. The lesson can be extended to address polarity and carbonation.

CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; mixtures (solutions); attractive forces

MATERIALS

- ❑ Tall glass or clear plastic cylinder
- ❑ Clear or translucent carbonated soda pop
- ❑ Raisins

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 262 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Many liquids that we drink are solutions. A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved into another substance (solvent). For example, in a saltwater solution, the solute is salt, and the solvent is the water. In soda pop, sugar (or other sweeteners), flavorings, and carbon dioxide (CO_2) gas are solutes, and water, again, is the solvent. These additives are dissolved into the water giving soda pop its taste, color, and carbonation (fizz!).

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. Several factors can affect solubility, including temperature, pressure, and the nature of the solute or solvent. Under normal temperature and pressure conditions, CO_2 does not easily dissolve in water. However, as pressure increases, the solubility of gases increases. (More solute can be dissolved in a liquid.) Therefore, increasing pressure allows the CO_2 to be dissolved into the soda pop. When you open a can or bottle of soda pop, you are releasing pressure and allowing some of the CO_2 gas to escape. The escaping gas creates the distinctive hissing sound.

Raisins have a density that is greater than the density of water (and soda pop). **Density** is an important concept in chemistry that is defined as the mass of an object per unit volume. Density is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are. In general, a substance that is less dense than a particular liquid will rest on top of the liquid, and a substance that is denser than the liquid will sink. Therefore, because the raisins have a greater density than the soda pop, they will initially sink to the bottom.

Density, however, is not the only consideration. Think about a ship made of steel. Although steel has a density greater than water, the shape of the boat spreads the weight of the steel over a larger space. In addition, some of that space is filled with air, which has a much lower density than water. Therefore, whether an object sinks or floats also has to do with displacement and buoyancy.

Displacement occurs when one substance takes the place of another. When an object is placed in water, it will displace some of the water. Think about sitting in a bathtub. When you sit down, the water will rise as your body takes the place of some of the water. In general, if an object weighs more than the water it displaces, the object will sink. If an object weighs less than the water it displaces, it will float. **Buoyancy** is the upward force that a fluid exerts on an object that enables the object to float. The buoyant force on an object is equal to the weight of the fluid displaced by the object.

In this experiment, the rough surface of a raisin allows bubbles of CO_2 gas to form out of the solution. Those bubbles attach to the surface of the raisin, increasing the volume of the raisin and displacing more of the soda pop. When enough bubbles are attached to the surface, the overall weight of the raisin with attached bubbles becomes less than the weight of the soda pop that is displaced. As a result, the buoyant force of the liquid pushes the raisin with attached bubbles to the top.

Once the raisin reaches the top, the bubbles pop upon exposure to the air. As a result, the weight of the raisin by itself is greater than the soda pop displaced, so the buoyant force of the liquid can no longer hold the raisin on the surface. Therefore, the raisin once again sinks to the bottom, and the process begins again. The raisin may also turn and roll as bubbles burst on one side or the other while the raisin floats to the top. All of these motions make the raisin appear to be alive and "swimming" in the liquid!

FORMULAS & EQUATIONS

Density is the amount of mass per unit of volume. It can be calculated using the following equation:

$$d = m/v$$

Density is measured in grams per milliliters or grams per cubic centimeters. One cubic centimeter (cm^3 or cc) is equal to one milliliter (mL).

Soda pop is a solution made of various solutes, such as high-fructose corn syrup (or other sweeteners), flavorings, and carbon dioxide gas, dissolved in water (the solvent).

The chemical formula for carbon dioxide is $\mathbf{CO_2}$.

The chemical formula for pure water is $\mathbf{H_2O}$.

Raisins are made primarily by sun drying certain types of grapes. The drying process removes water from the grapes and concentrates the sugar. As a result, raisins taste much sweeter than grapes. They are also lighter than grapes because of the removal of water, which allows them to be lifted by the CO_2 bubbles and buoyant force of the liquid.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and solutions can be found in the Classification of Matter section in CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on density can be found in the Measurement section in CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on displacement can be found in the Laboratory Equipment section in CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶Raisins placed in a glass of soda pop will move around in the liquid because of the formation of carbon dioxide bubbles on the surface of the raisin.

LESSON 21: Sewer Leeches

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 262, but focus on classification of matter. Any substance that has mass and takes up space is considered **matter**. Matter is generally found in three states on the earth—solid, liquid, or gas. Matter is often classified as either a pure substance or a mixture. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of two hydrogen atoms and one oxygen atom joined together.

A **mixture** is made of two or more substances that are combined physically. The different parts of a mixture have different properties. The chemical structure of each part of the mixture remains the same when they are combined. Solutions are a type of mixture.

Use pictures of different substances or state the name of the substance out loud, and then have students identify whether the substance is an element, compound, or mixture. Discuss why.

Another option is to discuss solids, liquids, and gases. Use the bottle, the soda pop, and the CO_2 gas to illustrate the differences between each state of matter or to simply have students practice describing different substances and identifying differences.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and solutions can be found in the Classification of Matter section in CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on solubility and polarity can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on displacement can be found in the Laboratory Equipment section in CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on food preservation, such as drying processes, can be found in the Applications of Chemistry in Everyday Life section in CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

Fun Fact

Scientists discovered that the bubbles found naturally in mineral water resulted from carbon dioxide gas. The naturally occurring carbonation led scientists and inventors to develop carbonated drinks.

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Place raisins in soda pop to observe the motion caused by the buildup of carbon dioxide bubbles on the raisins' surface.

OBJECTIVE

This lesson introduces solubility of gases, polarity, carbonation, and buoyancy as students watch carbon dioxide gas bubbles form on raisins that are added to soda pop.

OBSERVATION & RESEARCH

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. A substance that dissolves in another substance is **soluble.** For example, salt is soluble in water. If a substance does not dissolve, it is **insoluble.** For instance, butter is insoluble in water.

Several factors can affect solubility, including temperature, pressure, and the nature of the solute or solvent. Under normal temperature and pressure conditions, carbon dioxide (CO_2) is relatively insoluble in water, which causes the gas to form bubbles and escape from the liquid. However, changing pressure conditions allows us to control the solubility of gases. As pressure increases, solubility increases. (More solute can be dissolved in a liquid.) Therefore, increasing pressure causes the CO_2 to be dissolved in the soda pop.

In soda pop processing plants, carbonation takes place under high pressure. **Carbonation** is the process of dissolving CO_2 gas in water. The can or bottle is then sealed under high pressure as well. When you open a can or bottle of soda pop, you are releasing pressure and allowing some of the CO_2 gas to escape. The escaping gas creates the distinctive hissing sound.

Water molecules are strongly attracted to one another because of their polarity. **Polarity** refers to the distribution of electrons in an atom. **Polar substances** are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. In a water molecule, the oxygen atom has a partial negative charge, and the hydrogen atoms have partial positive charges. Because "opposites attract," the negatively charged oxygen atoms attract the positively charged hydrogen atoms in other water molecules. When the molecules interact, they form strong hydrogen bonds. These strong attractions help to hold the dissolved carbon dioxide gas inside the soda pop.

When an object is placed in a liquid, displacement will occur. **Displacement** occurs when one substance takes the place of another. In general, if an object weighs more than the water it displaces, the object will sink. If an object weighs less than the water it displaces, it will float. **Buoyancy** is the upward force that a fluid exerts on an object that enables the object to float. The buoyant force on an object is equal to the weight of the fluid displaced by the object. Raisins have a density that is greater than the density of water (and soda pop), and they weigh more than the soda pop they will displace. Therefore, raisins will initially sink in the soda pop.

In this experiment, the rough surface of the raisins allows bubbles of CO_2 gas to form out of the solution. In order for a bubble to form or expand, the water molecules must be pushed away from one another. When raisins are added to the soda pop, the rough surfaces disrupt the polar attractions between water molecules, allowing bubbles to form. Those bubbles attach to the surface of the raisin, increasing the volume of the raisin and displacing more of the soda pop. When enough bubbles are attached to the surface, the overall weight of the raisin with attached bubbles becomes less than the weight of the soda pop that is displaced. As a result, the buoyant force of the liquid pushes the raisin with attached bubbles to the top.

Once the raisins reach the top, the bubbles pop upon exposure to the air. As a result, the weight of the raisin by itself is greater than the soda pop displaced, so the buoyant force of the liquid can no longer hold the raisin on the surface. Therefore, the raisin once again sinks to the bottom, and the process begins again. The raisin may also turn and roll as bubbles burst on one side or the other while the raisin floats to the top. All of these motions make the raisin appear to be alive and "swimming" in the liquid!

LESSON 21: Sewer Leeches

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the type of liquid, do the raisins react differently?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill a tall, transparent glass or cylinder with clear or translucent soda pop.
2. Drop a few raisins into the cylinder.
3. Observe the raisins' lifelike movements.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens when raisins are added to the soda pop? Why do the raisins rise and then fall in the soda pop? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

Fun Fact

Most raisins you see are a dark, purple color; however, some raisins are yellow in color because they are produced from a different variety of grape.

NOTES

LESSON 21: Sewer Leeches

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Describe and identify solutions, solutes, and solvents.
- Explain solubility and the relationship between pressure and the solubility of gases.
- Understand density, displacement, and buoyancy as they relate to whether an object will sink or float in a liquid.
- Define and provide examples of matter, elements, compounds, and mixtures (see ***Differentiation in the Classroom***).
- Explain how the polarity of water affects the carbonation of soda pop (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Prepare the raisins and soda pop mixture just before the start of class. Cover the cylinder with a towel, and tell the students that you have collected sewer leeches! Students will not be able to identify the raisins from a distance. Tell the students that the leeches are in their larval stage and are preparing to transform. Then, take one of the raisins out and hold it in your hand. Allow the students to come up and closely examine the sewer leeches to determine what they really are. Ask them what causes the raisins to move.
- Try this experiment using different solutions other than soda pop. Try adding the raisins to fruit juice or plain water. Ask the students why the raisins only move around when added to carbonated drinks.
- Instead of raisins, try this experiment with M&Ms® or other small candies. Bubbles will form on these candies, but they will not float. Ask the students why this happens? Consider the substances' densities and surface textures in your discussion.

5-8 See **Lesson 16: Fountain of Soda Pop** for an exciting demonstration of gas solubility.

REAL-WORLD APPLICATIONS

- Water contains dissolved oxygen from which fish and other aquatic animals extract the oxygen they need as the water flows past their gills. Humans lack the ability to breathe underwater and have developed oxygen tanks to allow them to stay underwater for long periods. People are able to breathe underwater by using pressurized gas tanks that provide oxygen for divers to breathe.
- The same concepts of density, displacement, and buoyancy can be observed at a community pool. Young children often wear "floaties." The air in the floaties increases the overall volume of the child, so that the child weighs less than the water he/she displaces. As a result, the child is able to float more easily in the water.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 21 ACTIVITY SHEET: Sewer Leeches

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution		
Solute		
Solvent		
Solubility		
Displacement		
Buoyancy		

4. Consider what will happen when raisins are added to carbonated soda pop and why.

▶ **Write your hypothesis.** ____

____

____

LESSON 21 ACTIVITY SHEET: Sewer Leeches

PERFORM YOUR EXPERIMENT

1. Fill a tall, transparent glass or cylinder with a clear or translucent soda pop.
2. Drop a few raisins into the cylinder.
3. Observe.

ANALYZE & CONCLUDE

1. Describe the movement of the raisins when they are dropped in the soda pop. ________________________________

____

____

2. What are the components of soda pop? ____

____

____

3. What forms on the surface of the raisins? Explain. ____

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4. Will the same movement occur if you use water instead of soda pop? Why or why not? ____________________

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____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ____________________

____

____

LESSON 21 ACTIVITY SHEET: Sewer Leeches

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Carbonation		
Polarity		
Polar substances		
Nonpolar substances		

2. What happens when you open a bottle of soda pop? What do you see and hear? ____________________________

____

____

3. What helps keep the CO_2 dissolved within the soda pop? ____________________________

____

____

LESSON 21 ACTIVITY SHEET: Sewer Leeches

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Tall glass or cylinder, clear or translucent soda pop, raisins …

2. Predict how these materials may be used. A tall glass may be used to hold a liquid. Soda pop is a beverage for drinking. Raisins may be eaten as a snack. These materials may be used to demonstrate the interaction between the raisins and the carbon dioxide (CO_2) gas in the soda pop.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Solute	A substance that is dissolved in a solution.	
Solvent	A substance capable of dissolving another substance.	
Solubility	A measure of the amount of solute that can be dissolved in a solvent.	
Displacement	The act of moving something out of its original position or of one substance taking the place of another.	
Buoyancy	An upward force that a fluid exerts on an object, enabling the object to float.	

4. Consider what will happen when raisins are added to carbonated soda pop and why.

▶**Write your hypothesis.** Raisins dropped in soda pop will move around in the liquid because of the formation of carbon dioxide bubbles on the surface of the raisin.

LESSON 21 ACTIVITY SHEET: Sewer Leeches

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill a tall, transparent glass or cylinder with clear or translucent soda pop.
2. Drop a few raisins into the cylinder.
3. Observe.

ANALYZE & CONCLUDE

1. Describe the movement of the raisins when they are dropped in the soda pop. The raisins move all around the glass of soda pop. They move up and then fall back down.

2. What are the components of soda pop? Soda pop is a solution made up of high-fructose corn syrup (or other sweeteners), flavorings, and CO_2 gas dissolved in water.

3. What forms on the surface of the raisins? Explain. Tiny bubbles containing CO_2 form on the surface of the raisins. These bubbles come from the dissolved CO_2 gas in the soda pop.

4. Will the same movement occur if you use water instead of soda pop? Why or why not? No, the same movement will not occur. Water does not contain dissolved CO_2, so there won't be any bubbles to move the raisin. The raisins will remain at the bottom of the glass.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 21 ACTIVITY SHEET: Sewer Leeches

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Carbonation	The process of dissolving carbon dioxide gas in water or an aqueous solution under pressure.	
Polarity	The state of having a positive or a negative charge.	
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	
Nonpolar substance	Substances made up of particles that have an even distribution of electrons; the charges on these particles are neutralized.	

2. What happens when you open a bottle of soda pop? What do you see and hear? When you open a bottle of soda pop, you hear a hissing sound. This sound indicates that some CO_2 gas is being released from the soda pop. Bubbles form at the top of the bottle as some of the CO_2 gas bubbles move toward the surface.

3. What helps keep the CO_2 dissolved within the soda pop? The strong attractions between the oxygen and hydrogen atoms in water help to hold the dissolved CO_2 inside the soda pop.

LESSON 22: Mysterious Mixtures

ESTIMATED TIME **Setup:** 5–10 minutes | **Procedure:** 10–15 minutes

• DESCRIPTION

Use the process of chromatography to separate mixed dyes into the different colors that make up the dye.

• OBJECTIVE

This lesson examines mixtures and demonstrates the separation process of chromatography. Students will use food coloring and filter paper to observe chromotagraphy in action. The lesson can be extended to discuss dyes and pigments.

• CONTENT TOPICS

Scientific inquiry; measurement; properties of matter; mixtures (solutions); separation processes (chromatography)

• MATERIALS

- ❑ 8-oz paper or plastic cups
- ❑ White coffee filters
- ❑ Metric ruler
- ❑ Scissors
- ❑ Food coloring (red, blue, yellow)
- ❑ Water
- ❑ Pencils
- ❑ Clear plastic tape
- ❑ Tablespoon

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 273 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Most of the things around us are mixtures, like the air, the ocean, and food coloring! A **mixture** is made of two or more substances that are combined physically. A mixture can be classified as either homogeneous or heterogeneous.

A **homogeneous mixture** is a type of mixture that is considered to be the same throughout. Homogeneous mixtures are mixed evenly. Therefore, each part of the mixture seems to be the same. A **solution** is a homogeneous mixture in which one or more substances (the solutes) are dissolved into another substance (the solvent). Solutions are made up of elements or compounds mixed together at the molecular level. On the other hand, a **heterogeneous mixture** is a type of mixture in which the makeup is not the same throughout. Heterogeneous mixtures are not mixed evenly, so they do not appear uniform.

In a mixture, the chemical structure of each part of the mixture remains the same. Therefore, scientists are able to separate mixtures into their original parts. Separating a mixture of substances into two or more distinct products is called a **separation process**. A separation process uses the different properties of a mixture's parts to get them to separate. A mixture can be separated either through physical or chemical means.

A physical separation process uses physical properties to separate the parts of a mixture. This separation occurs without changing the chemical properties of the parts. Common physical separation processes include filtration and distillation. Another way chemists can separate parts of a mixture is through a process called chromatography. **Chromatography** is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.

During chromatography, a mixture is moved over a stationary material, called the **stationary phase**. The mixture that flows over the material is called the **mobile phase**. The different parts that make up the mobile phase flow through the stationary phase at different rates. As a result, the components separate, generally leaving behind distinct bands of the different components.

In this experiment, different solutions are made by mixing water with different colors and amounts of food coloring. Next, a chromatography process is used to separate the different parts of the different solutions. When the end of the filter paper is placed in a solution, the paper will begin to absorb the liquid. As the solution moves up the paper, the different color components move through the paper at different rates. As a result, the colors separate, leaving bands of color along the paper based on how far that color component can travel through the paper. (The cup with red, yellow, and blue may only separate into two colors, red and green. In this case, the red separated out, but the yellow and blue stayed mixed and migrated up the paper at the same rate.)

FORMULAS & EQUATIONS

Food coloring is a type of food additive that makes the food a certain color (or makes the color more vibrant). People have been adding color to food for thousands of years to enhance the appeal of the food, either by making it appear more familiar, or simply for decoration. Food colorings were initially developed using spices, crushed seeds, or even crushed insects! However, more recently, chemists have developed synthetic food colorings to create even brighter colors and colors that are hard to find in nature. Different colors and food-coloring products contain a variety of chemical compounds, so there is not one exact formula.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and basic separation processes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chromatography can be found in the Laboratory Separations section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

HYPOTHESIS

▶Different food colorings and water can be combined to create uniform solutions. When the edge of a strip of filter paper is placed in the solution, the different colors of the solution will flow through the paper at different rates and separate into different bands of color on the paper.

LESSON 22: Mysterious Mixtures

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

For younger students, this lesson can demonstrate that most things are made up of parts, and some parts we cannot see.

DESCRIPTION

Create colored solutions and then use a separation process to identify the different colored parts in each solution.

OBJECTIVE

This lesson introduces different types of mixtures and a separation process that can be used to identify the different parts of a mixture.

OBSERVATION & RESEARCH

Most of the things around us are mixtures, like the air, the ocean, and food coloring! A **mixture** is made of two or more substances that are combined physically. A mixture can be classified as either homogeneous or heterogeneous.

A **homogeneous mixture** is a type of mixture that is considered to be the same throughout. Homogeneous mixtures are mixed evenly. Therefore, each part of the mixture seems to be the same. Examples of homogeneous mixtures are apple juice and brass. In liquid form, homogeneous mixtures are generally called solutions. A **solution** is a homogeneous mixture in which one or more substances (the solutes) are dissolved into another substance (the solvent). Solutions are made up of elements or compounds mixed together at the molecular level. Apple juice is a solution. The juice looks (and tastes) the same whether it is poured from the top, middle, or bottom of the bottle. Similarly, brass is a mixture of metals that looks the same throughout.

On the other hand, a **heterogeneous mixture** is a type of mixture in which the makeup is not the same throughout. Heterogeneous mixtures are not mixed evenly, so they do not appear uniform. Examples of heterogeneous mixtures include pizza and peanut butter and jelly sandwiches. The different parts of these mixtures can be clearly seen.

In this experiment, different solutions are made by mixing water with different colors and amounts of food coloring. Students should notice that once the water and colors are mixed together, the liquid looks the same throughout. It is a solution—a homogeneous mixture.

Next, a special **separation process** is used to separate the different parts of the different solutions. A separation process uses the different properties of a mixture's parts to get them to separate. In the experiment, when the end of the filter paper is placed in a solution, the paper will begin to absorb the liquid. As the solution moves up the paper, the different color components move through the paper at different rates. As a result, the colors separate, leaving bands of color along the paper based on how far that color component can travel through the paper. (The cup with red, yellow, and blue may only separate into two colors, red and green. In this case, the red separated out, but the yellow and blue stayed mixed and migrated up the paper at the same rate.)

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 273, but explore different separation processes further. Discuss other separation processes and how they are used (distillation, precipitation, etc.).

Another option is to discuss dyes in more details. What are the differences between natural and synthetic dyes? What are the differences between food colorings and other dyes? Discuss regulations that help to ensure food colorings are safe to eat.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and basic separation processes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 22: Mysterious Mixtures

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the colors in the solution change, do the colors on the paper change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill each cup with three tablespoons of water.
2. Put three drops of red and three drops of blue food coloring into one cup. Put three drops of red and three drops of yellow in a second cup, and put three drops of each color—red, blue, and yellow—in a third cup.
3. Write the color combinations in each cup on a piece of masking tape, and tape it to the bottom of the corresponding cup where students cannot see it.
4. Take an unused coffee filter, and cut three strips about 10 cm long and 2 cm wide. Wrap one end of a strip around a pencil, and lower the other end so that it goes about 1 cm into the water. Tape the filter paper to the pencil, and place the pencil on the rim of the cup.
5. Repeat step 4 for your two other cups.
6. Have the students observe and then guess (if they don't already know) which cup contains which food coloring. If green appears on the filter strips, ask the students how this is possible.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is a solution? What colors were separated from each solution? You can use the table in the activity sheet (or a similar one of your own) for students to record their data.

NOTES

LESSON 22: Mysterious Mixtures

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypothesis. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and provide examples of different types of mixtures.
- Compare and contrast homogeneous and heterogeneous mixtures.
- Define and identify a solution and the parts of a solution.
- Understand the process of chromatography and how it is used to separate mixtures.

Fun Fact

In the 16th century, Spanish explorers observed the Aztecs collecting tiny cochineal insects that fed on red cactus berries. These insects were crushed to produce a red pigment for coloring food.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Prepare the solutions before class. When the students arrive, tell them that the cups contain mixtures of different colors and that you need to figure out what colors are in the cups. Ask them if they know any methods you could use. Challenge them to predict what colors are in the solutions based on their physical observations. Introduce chromatography as a separation process, but do not tell them how it works to separate the colors. Then perform the experiment, and have students compare their predictions against the actual results.
- If green appears, ask students if they notice anything odd about their results. They may produce a number of answers, but eventually remind students that green is not a primary color. Green is a mixture of blue and yellow. Ask students to consider why those two colors did not separate.

REAL-WORLD APPLICATIONS

- The separation process of chromatography is used in conducting forensics for crime scene investigations, by pharmaceutical companies in analyzing the amounts of specific chemicals in their products, by hospitals in determining the alcohol in patients' blood, and by environmentalists studying the level of pollutants in our water supply.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

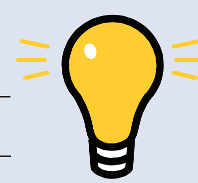
____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Separation process		
Chromatography		
Stationary phase		
Mobile phase		

4. Consider how colors can be separated from a solution of food coloring and water using filter paper and why that process would work.



▶**Write your hypothesis.** ______________________________

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LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

PERFORM YOUR EXPERIMENT

1. Fill each cup with three tablespoons of water.
2. Put three drops of red and three drops of blue food coloring into one cup. Put three drops of red and three drops of yellow in a second cup. Put three drops of each color—red, blue, and yellow—in a third cup.
3. Write the color combinations in each cup on a piece of masking tape. Tape it to the bottom of the corresponding cup where you cannot see it.
4. Take an unused coffee filter, and cut three strips about 10 cm long and 2 cm wide. Wrap one end of a strip around a pencil, and lower the other end so that it goes about 1 cm into the water. Tape the filter paper to the pencil, and place the pencil on the rim of the cup.
5. Repeat step 4 for your two other cups. Observe.

Always be careful when using scissors and other sharp objects.

ANALYZE & CONCLUDE

1. In the table below, record your observations of the colors in each cup. Then make a prediction about which colors you think will appear on the paper. After completing the experiment, record the colors that did appear on the paper.

Cup Number	Color(s) in Cup	Color(s) on Paper: Predictions *(what you think will appear)*	Color(s) on Paper: Actual *(what actually appears)*
1			
2			
3			

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

2. In what order do the colors appear on the different papers? In what order are the colors of the rainbow? Compare.

____

____

____

3. Does green appear on your filter paper? If so, why? What colors make green? ______________________

____

____

4. Why do the colors separate? ____

____

____

5. If you use black ink, what do you think will happen? Why? ________________________

____

____

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ________________

____

____

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

SHARE YOUR KNOWLEDGE

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Homogeneous mixture		
Solution		
Heterogeneous mixture		

2. List the colors of the rainbow. ____

____

____

3. Which of those colors are made by mixing two other colors together? Explain. ____________________

____

____

4. List other substances that are mixtures. Explain why they are mixtures, and write what types they are.

____

____

____

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Plastic cups, coffee filters, ruler, scissors, food coloring, water, pencils, tape, tablespoon ...

2. Predict how these materials may be used. Plastic cups may be used to hold a liquid. Coffee filters may be used to separate a solid from a liquid. A ruler may be used to measure. Food coloring may be used to dye a substance. Water may be used to drink, bathe, or clean. These materials may be combined to demonstrate a separation process.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Separation process	A process that divides a mixture into two or more distinct substances.	
Chromatography	A group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.	
Stationary phase	A stationary material over which a mixture flows during a chromatography separation process.	
Mobile phase	The mixture that flows over the stationary material in a chromatography separation process.	

4. Consider how colors can be separated from a solution of food coloring and water using filter paper and why that process would work.

▶**Write your hypothesis.** Filter paper placed in a solution of mixed-color dyes will absorb the solution and separate the colors based on the rate at which the different components can move through the paper.

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill each cup with three tablespoons of water.
2. Put three drops of red and three drops of blue food coloring into one cup. Put three drops of red and three drops of yellow in a second cup. Put three drops of each color—red, blue, and yellow—in a third cup.
3. Write the color combinations in each cup on a piece of masking tape. Tape it to the bottom of the corresponding cup where you cannot see it.
4. Take an unused coffee filter, and cut three strips about 10 cm long and 2 cm wide. Wrap one end of a strip around a pencil, and lower the other end so that it goes about 1 cm into the water. Tape the filter paper to the pencil, and place the pencil on the rim of the cup.
5. Repeat step 4 for your two other cups. Observe.

Always be careful when using scissors and other sharp objects.

ANALYZE & CONCLUDE

1. In the table below, record your observations of the colors in each cup. Then make a prediction about which colors you think will appear on the paper. After completing the experiment, record the colors that did appear on the paper.

Cup Number	Color(s) in Cup	Color(s) on Paper: Predictions *(what you think will appear)*	Color(s) on Paper: Actual *(what actually appears)*
1	Red, blue	Answers will vary	Red, blue
2	Red, yellow	Answers will vary	Red, yellow
3	Red, blue, yellow	Answers will vary	Red, green or Red, yellow, green, blue

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. In what order do the colors appear on the different papers? In what order are the colors of the rainbow? Compare.

In cup one, the colors that appeared were red and then blue. In cup two, the colors were red and then yellow. In cup three, the colors were red and then green. The colors of the rainbow are red, orange, yellow, green, blue, and violet. The order of the colors reflects the order of the colors in the rainbow.

3. Does green appear on your filter paper? If so, why? What colors make green? Yes, green appears on the filter paper from cup three. The red separated out, but the yellow and blue dyes mixed and migrated up the paper at the same rate. Blue and yellow make green.

4. Why do the colors separate? The colors separate because they have different molecular sizes and weights and move through the paper at different rates. The color particles will separate and form distinct bands of color according to their size.

5. If you use black ink, what do you think will happen? Why? Black ink is made of all colors. If you were to use black ink, the different colors that make up black will show up on the coffee filter paper. It should look like a rainbow.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 22 ACTIVITY SHEET: Mysterious Mixtures

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

SHARE YOUR KNOWLEDGE—BEGINNERS

Have students complete this section if you used the beginners' differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Homogeneous mixture	A type of mixture that is considered to be the same throughout; the substances are evenly mixed.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Heterogeneous mixture	A type of mixture in which the makeup is not the same throughout; the substances are not evenly mixed.	

2. List the colors of the rainbow. Red, orange, yellow, green, blue, violet.

3. Which of those colors are made by mixing two other colors together? Explain. Orange is made by mixing red and yellow. Green is made by mixing yellow and blue. Violet is made by mixing red and blue.

4. List other substances that are mixtures. Explain why they are mixtures, and write what types they are.

Other substances that are mixtures include apple juice and brass. They are mixtures because they are made up of two or more substances that are combined physically. Apple juice and brass are homogeneous mixtures. They appear the same throughout. Heterogeneous mixtures include pizza and chicken noodle soup. These mixtures are not the same throughout.

LESSON 23: Exploding Bags

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5 minutes

• DESCRIPTION

Combine vinegar and baking soda within a plastic bag to initiate a chemical reaction.

• OBJECTIVE

This lesson demonstrates the formation of products from reactants during a chemical reaction. Students use two common household materials to observe how a chemical reaction produces new substances. The lesson can be extended to cover acids and bases.

• CONTENT TOPICS

Scientific inquiry; properties of matter; chemical reactions; acids and bases; energy

• MATERIALS

- ❑ Vinegar
- ❑ Baking soda
- ❑ Water
- ❑ Plastic bag (zipper lock, quart size)
- ❑ Toilet paper
- ❑ Measuring cups
- ❑ Spoons

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 286 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from “A Framework for K–12 Science Education,” established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Scientists sort matter by its physical and chemical properties. We use our senses or take measurements to identify **physical properties**. Some examples of physical properties are color, shape, boiling point, melting point, and density. **Chemical properties** can be identified by observing how a chemical reacts with other substances. Some examples of chemical properties include acidity, toxicity, and flammability. During the experiment, students can observe the different physical (and chemical) properties of the substances.

When the vinegar and baking soda are combined, a change occurs. Matter often changes, and these changes can be either physical or chemical. A **physical change** is any change in a substance’s form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. Chemical reactions occur around us all the time. They even take place inside of our bodies. When we breathe, we take in oxygen from the air, which combines with glucose (a sugar) in our bodies. These substances react to produce carbon dioxide and water vapor, which we exhale.

LESSON 23: Exploding Bags

When a chemical reaction is complete, the resulting substance(s) is/are different from the original substance(s). The substance or substances that start a chemical reaction are called **reactants**. The new substance(s) that are produced as a result of the reaction are called **products**.

In this experiment, adding baking soda to vinegar starts a chemical reaction. The reaction produces sodium acetate and carbonic acid. The carbonic acid is unstable and instantly falls apart into carbon dioxide and water. The rapidly forming bubbles that appear during the reaction are carbon dioxide gas escaping from the mixture. Because the mixture is sealed within a bag, pressure created from the rapidly forming gas will cause the bag to burst.

FORMULAS & EQUATIONS

Vinegar is a mixture made up of very dilute acetic acid. Therefore, vinegar contains acetic acid and water.

The chemical formula for acetic acid is $\mathbf{C_2H_4O_2}$.

The chemical formula for pure water is $\mathbf{H_2O}$.

The chemical name of baking soda is sodium bicarbonate. It is commonly used in baking, hence its name.

The chemical formula for baking soda is $\mathbf{NaHCO_3}$.

When vinegar and baking soda are combined, an acid-base reaction occurs between the acetic acid and baking soda.

$$\mathbf{CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2CO_3}$$

This reaction produces sodium acetate ($\mathbf{CH_3COONa}$ or $\mathbf{NaCH_3CO_2}$) and carbonic acid ($\mathbf{H_2CO_3}$).

The carbonic acid is unstable and quickly decomposes into carbon dioxide gas ($\mathbf{CO_2}$) and water ($\mathbf{H_2O}$).

$$\mathbf{H_2CO_3 \rightarrow H_2O + CO_2}$$

The carbon dioxide gas forms bubbles that can be seen as the reaction takes place.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on physical and chemical properties and changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

▶When baking soda and vinegar are combined in a sealed plastic bag, a chemical reaction will occur, releasing carbon dioxide gas and causing the bag to pop open.

Fun Fact

Dry ice easily sublimates directly into carbon dioxide gas at standard temperature and pressure.

LESSON 23: Exploding Bags

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 286, but focus the lesson on classifying matter. Discuss physical properties in more detail and the different uses of different substances.

Another option is to spend more time on the differences between physical and chemical changes. For example, show a picture of a pencil. Then show a picture of the pencil broken—that's a physical change. Next, show a picture of cake batter and then a baked cake—that's a chemical change!

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Combine vinegar (an acid) and baking soda (a base) within a plastic bag to initiate a chemical reaction.

OBJECTIVE

This lesson demonstrates the formation of products from reactants during a chemical reaction. Students explore acids and bases and use two common household substances to observe a chemical reaction.

OBSERVATION & RESEARCH

To describe certain chemical compounds, chemists use the terms "acid" and "base." You can determine whether a solution is an acid or a base by determining the concentration of hydrogen ions (H^+) in the solution. An **ion** is an atom or molecule that has lost or gained one or more of its outer electrons. Therefore, the total number of electrons is not equal to the total number of protons, so an ion will have either a negative or a positive electric charge.

In general, a solution that contains a concentration of hydrogen ions (H^+) greater than the concentration in pure water is called an **acid**. Likewise, a solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than that of pure water is called a **base**. Solutions containing an H^+ concentration equal to that of pure water are **neutral**.

Acids, bases, and all types of matter can undergo different changes. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials change. Chemical reactions occur around us all the time.

When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). The substance or substances that start a chemical reaction are called **reactants**. The new substance(s) that are produced as a result of the reaction are called **products**.

In this experiment, students work with common household vinegar and baking soda, which forms a basic solution when dissolved in water. Adding baking soda to vinegar starts a chemical reaction that produces sodium acetate and carbonic acid. The carbonic acid is unstable and instantly falls apart into carbon dioxide and water. The rapidly forming bubbles that appear during the reaction are carbon dioxide gas escaping from the mixture. Pressure created from the rapidly forming gas will cause the bag to burst. In addition, the starting temperature is higher than the ending temperature, so the reaction is considered to be endothermic. An **endothermic change** is a change that needs energy to be added.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on ions can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on acids and bases can be found in the Acids, Bases, and pH section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections.*

LESSON 23: Exploding Bags

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the substance added to the vinegar changes, will the reaction change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Tear off two squares of toilet paper from a toilet paper roll.
2. Add a large spoonful of baking soda to the center of one of the toilet paper squares, and carefully wrap the toilet paper around it. Wrap the second toilet paper square around the first.
3. Have one student hold the plastic bag open as another student adds ¼ cup of vinegar and ¼ cup of warm water to the bag.
4. Place the wrapped baking soda in the bag, and quickly seal it. Gently swirl the liquid around so that it soaks the toilet paper.
5. Place the bag down and watch it inflate and eventually pop. (If the bag does not pop, allow the students to gently touch the bag to see if they can feel a temperature change.)

Protective eyewear should be worn for this experiment.

This experiment should be conducted outside or within a sink or large bowl/pan to minimize the mess.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is a physical change? What is a chemical change? What occurs when the vinegar and baking soda are combined? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 23: Exploding Bags

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the S***cientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define physical and chemical properties and give examples of each.
- Differentiate between physical and chemical changes.
- Identify the reactants and products of a chemical reaction.
- Explain the chemical reaction that occurs during the experiment and what gas is being produced.
- Identify common household acids and bases (see ***Differentiation in the Classroom***).

Fun Fact

The reaction between baking soda and vinegar is the reaction used to create miniature "volcanoes."

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Ask the students what they would expect to happen if the amount of baking soda added to vinegar was increased. Try testing different amounts of baking soda, and have the students record the results.
- Add less baking soda to the vinegar, so the bag will inflate but not pop. Have students touch the inflated bag. Students should notice that that bag feels colder, indicating that an endothermic reaction took place.
- Try combining other substances to create a chemical reaction within the bag. For example, try combining lemon juice and baking soda or baking powder and vinegar to see if there is a reaction.

Be sure to research the reaction of different products and read the safety precautions on product labels before combining them. Randomly mixing chemical substances is dangerous.

REAL-WORLD APPLICATIONS

- Baking soda and vinegar are known for their cleaning capabilities. Baking soda can be used to remove stains on pots, appliances, and clothing. It is also used as a deodorizer. Diluted vinegar is a disinfectant and deodorizer that can be used to clean various surfaces.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 23 ACTIVITY SHEET: Exploding Bags

OBSERVE & RESEARCH

1. Write down the materials you observe.

2. Predict how these materials may be used.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical property		
Chemical property		
Physical change		
Chemical reaction		
Reactant		
Product		

4. Consider the effects of combining vinegar and baking soda inside a plastic bag and why you expect such results.

▶**Write your hypothesis.**

LESSON 23 ACTIVITY SHEET: Exploding Bags

PERFORM YOUR EXPERIMENT

1. Tear off two squares of toilet paper from a toilet paper roll.
2. Add a large spoonful of baking soda to the center of one of the toilet paper squares, and carefully wrap the toilet paper around the baking soda. Wrap the second toilet paper square around the first.
3. Have a partner hold the plastic bag open for you. Add ¼ cup of vinegar and ¼ cup of warm water to the bag.
4. Place the wrapped baking soda in the bag, and quickly seal it. Gently swirl the liquid around so that it soaks the toilet paper.
5. Place the bag down and observe.

ANALYZE & CONCLUDE

1. Describe the baking soda. ____

____

2. Describe the vinegar. ____

____

3. What happens when the baking soda and vinegar interact? ____________________

____

____

4. What gas forms during the chemical reaction? Explain. ______________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________

____

____

LESSON 23 ACTIVITY SHEET: Exploding Bags

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Acid		
Base		
Neutral		

2. The following equation represents the combined chemical reaction that occurred. Label the reactants and the products.

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2CO_3 \rightarrow H_2O + CO_2$$

__________ __________ __________ __________ ______ ______

3. Give examples of other everyday chemical reactions. ______________________________________

____

____

LESSON 23 ACTIVITY SHEET: Exploding Bags

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Vinegar, baking soda, plastic bags, toilet paper, measuring spoons, spoons ...

2. Predict how these materials may be used. Vinegar and baking soda may be used in cooking or cleaning. Plastic bags may be used to hold materials. Toilet paper may be used to clean up a mess. These materials may be combined to create a chemical reaction.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical property	A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance.	
Chemical property	A property of an object characterized by reactions that change the object's identity; describe an object's "potential" to undergo some chemical change or reaction due to its composition.	
Physical change	A change that alters the form or appearance of a substance but does not change the chemical makeup of the substance or create a new substance.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances.	
Reactant	A starting material for a chemical reaction.	
Product	A substance formed as a result of a chemical reaction.	

4. Consider the effects of combining vinegar and baking soda inside a plastic bag and why you expect such results.

▶ **Write your hypothesis.** When baking soda and vinegar are combined in a sealed plastic bag, a chemical reaction will occur, releasing carbon dioxide gas and causing the bag to pop open.

LESSON 23 ACTIVITY SHEET: Exploding Bags

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Tear off two squares of toilet paper from a toilet paper roll.
2. Add a large spoonful of baking soda to the center of one of the toilet paper squares, and carefully wrap the toilet paper around the baking soda. Wrap the second toilet paper square around the first.
3. Have a partner hold the plastic bag open for you. Add ¼ cup of vinegar and ¼ cup of warm water to the bag.
4. Place the wrapped baking soda in the bag, and quickly seal it. Gently swirl the liquid around so that it soaks the toilet paper.
5. Place the bag down and observe.

ANALYZE & CONCLUDE

1. Describe the baking soda. The baking soda is a white, dry powder.

2. Describe the vinegar. The vinegar is translucent.

3. What happens when the baking soda and vinegar interact? The baking soda and vinegar undergo a chemical reaction, which releases a gas that produces bubbles. These bubbles form quickly, creating a foamy mass inside the bag.

4. What gas forms during the chemical reaction? Explain. One of the initial products of the reaction breaks down further into carbon dioxide (CO_2) and water. The gas bubbles seen forming inside the bag are made of CO_2.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?
Answer 1: Valid because the data support my hypothesis.
Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 23 ACTIVITY SHEET: Exploding Bags

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Acid	A solution that contains an excess of hydrogen ions (H^+); acids have a higher concentration of hydrogen ions than pure water.	
Base	A solution that has an excess of hydroxide ions (OH^-); bases have a lower concentration of hydrogen ions than pure water.	
Neutral	A solution that contains a concentration of hydrogen ions (H^+) that is equal to that of pure water.	

2. The following equation represents the chemical reaction that occurred. Label the reactants and the products.

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2CO_3 \rightarrow H_2O + CO_2$$

CH_3COOH	$NaHCO_3$	CH_3COONa	H_2CO_3	H_2O	CO_2
reactant	reactant	product	product (then reactant)	product	product

3. Give examples of other everyday chemical reactions. The ingredients in toothpaste react when you brush your teeth. When you eat, the acids in your stomach break down the foods so they can be used in various processes and to generate energy.

LESSON 24: Grasping for Air

ESTIMATED TIME Setup: 5 minutes | **Procedure:** 5 minutes

DESCRIPTION

Use a trash can and a trash bag to explore the concept of pressure.

OBJECTIVE

This lesson introduces pressure, specifically air pressure. Students experience the strong force of air pressure that usually goes unnoticed as they try to remove a trash bag that is sealed to a trash can. The lesson can be extended to discuss vacuums.

CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; force (pressure)

MATERIALS

- ❑ Small plastic trash can
- ❑ Clean plastic trash bag
- ❑ Duct tape

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 297 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Scientists use the term "matter" to describe the things around you. Matter is anything that has mass and takes up space, such as paper, food, skin, and water. Matter exists primarily as a solid, liquid, or gas on the earth. Solids have a definite volume and a definite shape. Examples of solids are chairs, books, and trees. Liquids have a definite volume but no definite shape. Examples of liquids are water and orange juice. Gases have no definite shape and no definite volume. An example of a gas is the air around you! Although we can't see the air, there are ways we can tell it exists.

The particles that make up a gas (the air) move around freely. When the air is trapped within a certain space or container, the particles bounce around and collide with one another, creating pressure on the container. Pressure is the amount of force exerted on an area. For example, when you blow up a balloon, you are filling the balloon with gas particles (mainly carbon dioxide). The gas particles move freely within the balloon, colliding with one another and exerting pressure on the inside layer of the balloon.

Fun Fact

Although vacuums exist, they are not perfect. A perfect vacuum would have nothing in it at all.

LESSON 24: Grasping for Air

Air pressure, or atmospheric pressure, is the force exerted on a surface by the weight of the air above that surface. The average air pressure at sea level is about 14.7 pounds per square inch (101.325 kPa). That's almost 15 pounds of air pushing on every inch of our bodies! Fortunately, we're so used to this pressure that we don't even notice it.

A trash can experiences air pressure from outside air, as well as from the air that is inside the can. The air pressure inside and outside of the trash can is equal. When you put an empty trash bag into a trash can, the bag displaces some of the air that was originally in the trash can. **Displacement** is the act of moving something out of its original position or of one substance taking the place of another. The air that was displaced can easily escape outside of the trash can. Once you seal the trash bag to the trash can, no more air can get between the bag and the can or escape outside. In addition, you have pushed most of the air out from between the trash bag and trash can, so very few air particles are left in this space.

When you try to pull the bag out of the trash can, you increase the amount of space between the bag and the can. As the amount of space for the air particles trapped between the bag and can increases, the air pressure in that space decreases. This means that the air pressure on the other side of the bag is greater than the air pressure between the bag and the can. As a result, you cannot pull the bag out of the can. The more you pull, the greater the air pressure pushes in the opposite direction.

Fun Fact

Outer space is considered to be a partial vacuum. While the space between the planets and stars seems empty, it still has heat, light, sound, and cosmic radiation.

FORMULAS & EQUATIONS

Air is a mixture of gases. A mixture is made of two or more substances that are combined physically. The air around us is made up of mainly nitrogen and oxygen gas.

The formula for nitrogen gas is $\mathbf{N_2}$.

The formula for oxygen gas is $\mathbf{O_2}$.

Approximately 78% of the air is $\mathbf{N_2}$, and about 21% is $\mathbf{O_2}$. The remaining 1% is made up of trace gases such as argon (**Ar**), carbon dioxide ($\mathbf{CO_2}$), water vapor ($\mathbf{H_2O}$), and other gases.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on properties and states of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on pressure can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on displacement can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶When air is removed from the space between a trash can and the trash bag inside it, the pressure between the can and the bag will be much lower than the pressure outside. The difference in air pressure will make it difficult to pull the bag from the can.

LESSON 24: Grasping for Air

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 297, but focus on the states and properties of matter. Ask students how they know that certain gases exist if they cannot see them. Talk about the wind (how they can feel the air) or blowing up a balloon (how they can "see" a gas). Then discuss properties of matter, such as volume and pressure. **Volume** is the amount of space an object occupies. Discuss that gases do not have a specific volume or shape. You can use the plastic bag to illustrate this concept. If you put a solid object in the bag, the shape and volume of the object stays the same. However, if you hold the bag closed at different points, the gas acts differently. It fills the entire space available.

Likewise, you can discuss the concept of pressure in more detail. Ask them if someone stepped on their foot, would they feel more pressure if the person was wearing a flat-soled shoe or a high heel? You can use an object with different surface areas on different sides, such as a bottle of water, to demonstrate pressure. Have them hold it in the palm of their hand with the bottom against their palm. Then have them flip the bottle over so the little cap is pressing against the palm of their hand. Did they feel more pressure from the smaller cap side of the bottle?

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on volume and pressure can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on displacement can be found in the Laboratory Equipment section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Use a trash can and a trash bag to explore the concepts of pressure and vacuums.

OBJECTIVE

This lesson introduces pressure, specifically air pressure, and vacuums. Students experience the strong force of air pressure and the creation of a vacuum using only a trash can and trash bag.

OBSERVATION & RESEARCH

Matter is all around us, mainly in the form of solids, liquids, and gases. The air around us is a mixture of gases. The gas particles that make up the air move around freely. When the air is trapped within a certain space or container, the particles bounce around and collide with one another, creating pressure on the container. **Pressure** is the amount of force exerted on an area.

Air pressure, or atmospheric pressure, is the force exerted on a surface by the weight of the air above that surface. The average air pressure at sea level is about 14.7 pounds per square inch (101.325 kPa). That's almost 15 pounds of air pushing on every inch of our bodies! Fortunately, we're so used to this pressure that we don't even notice it.

A trash can experiences air pressure from the outside air, as well as from the air that is inside the can. The air pressure inside and outside of the trash can is equal. When you put an empty trash bag into a trash can, the bag displaces some of the air that was originally in the trash can. **Displacement** is the act of moving something out of its original position or of one substance taking the place of another. The air that was displaced can easily escape outside of the trash can. Once you seal the trash bag to the trash can, no more air can get between the bag and the can or escape outside.

In addition, you have pushed most of the air out from between the trash bag and trash can, so very few air particles are left in this space. You basically create a partial vacuum between the bag and the can. A **vacuum** (partial vacuum) is a volume of space that has essentially no matter. Most scientists agree that spaces without any

LESSON 24: Grasping for Air

DIFFERENTIATION IN THE CLASSROOM

matter or energy at all, referred to as pure vacuums or perfect vacuums, do not exist.

Because there are so few particles, the gaseous pressure in a partial vacuum is much lower than standard atmospheric pressure. When you try to pull the bag out of the trash can, you increase the amount of space between the bag and the can. As the amount of space for the air particles trapped between the bag and the can increases, the air pressure in that space decreases even more. This means that the air pressure on the other side of the bag is much greater than the air pressure between the bag and the can. As a result, you cannot pull the bag out of the can. The more you pull, the greater the air pressure pushes in the opposite direction.

In addition, you may notice that the sides of the trash can will begin to cave in as you attempt to pull the trash bag out of the trash can. As you pull the bag, a suction is created. A **suction** is a force that attracts a substance or object to a region of lower pressure when there is a difference in pressure. Thus, the trash can is pulled in toward the low pressure area between the bag and can.

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you do not push all the air out from between the trash bag and the trash can, will it be easier to pull the bag out of the space?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Place a trash bag into a trash can. Fold the top of the bag over the can. Press all around the inside of the bag so that you push as much air as possible out from between the can and the bag.
2. Use duct tape to seal the bag tightly around the rim of the can.
3. Reach into the can and grab the center of the bottom of the bag. Try to pull the trash bag straight up and out of the can.
4. Have one student hold the trash can sideways or upside down, as another student tries to pull the bag out. They can also try pulling the bag from other parts of the can.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is pressure? What happens when the pressure inside a container is much lower than the pressure outside of the container? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

LESSON 24: Grasping for Air

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and identify different types of measurements, such as volume and pressure.
- Differentiate between the different states of matter.
- Describe the effects of differences in air pressure.
- Explain vacuums and suction (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Conduct the experiment in a similar manner, but use a jar and small plastic sandwich bag instead. You can also use rubber bands instead of duct tape to seal the bag to the jar in this setup.
- Try the opposite action first. Fill the trash bag with air and tie it so the air cannot escape. Then try to push the air-filled bag into the trash can. You can also blow up the bag with air and quickly seal it to the mouth of the trash can. Have students try to push the bag into the trash can. Discuss that the air pressure inside the trash can is preventing them from pushing the bag inside. There is already something inside the can—air takes up space! (Again, you can use a jar and a small plastic sandwich bag instead of the trash bag and trash can for this experiment as well.)

REAL-WORLD APPLICATIONS

- Air pressure varies with altitude. At higher elevations, the air pressure is lower than at sea level. When you fly in a plane or travel up a mountain, your ears may "pop." As you travel higher in the atmosphere, outside air pressure decreases. As a result, the air pressure exerted by the air trapped in your inner ear is no longer balanced with the air pressure outside. The trapped air will begin to push outward toward the lower pressure area, which can cause discomfort. The pressure can equalize when some air from your inner ear escapes through the Eustachian tubes, the small channel in each ear that connects the inner ear to the throat. When they open, you feel the pressure release—the "pop."
  You can hear this change because it is happening in your ear. However, before the pop, you may notice that your hearing ability decreases. The buildup of pressure inside your ear makes it more difficult to transmit sound.
- Likewise, as you descend, the atmospheric pressure increases, but your inner ear is still at the lower pressure. Now, the extra pressure from the outside air pushes into your ear. Eventually, the pressure will equalize again, but many people don't wait for the pressure to balance naturally. Instead, they close their mouth, hold their nose, and "blow." Since the air from their lungs has nowhere else to go, it is forced into the inner ear through the Eustachian tubes, "popping" their ears.
- Toilet plungers utilize a suction to unclog pipes. When a plunger is inserted into the toilet bowl, the rubber "cup" covers the toilet drain that leads to the pipes. The shape of the plunger cup creates a seal. Therefore, when you push down on the plunger, the air is forced out of the cup and into the pipe, increasing the air pressure in the pipe. As the plunger is pulled back, suction is created, pulling air and water from the pipe back toward the toilet drain. This quick and strong force of air and water pressure helps to loosen a clog in the pipes.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 24 ACTIVITY SHEET: Grasping for Air

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

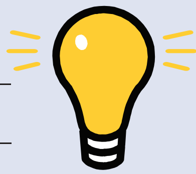
Term	Definition	Example (write or add image)
Matter		
Solid		
Liquid		
Gas		
Pressure		
Air pressure		
Displacement		

4. Consider why differences in air pressure, caused by the removal of air between a trash bag and a trash can, create difficulty in removing the bag.

▶ **Write your hypothesis.** ____

____

____



LESSON 24 ACTIVITY SHEET: Grasping for Air

PERFORM YOUR EXPERIMENT

1. Place a trash bag into a trash can. Fold the top of the bag over the can. Press all around the inside of the bag so that you push as much air as possible out from between the can and the bag.
2. Use duct tape to seal the bag tightly around the rim of the can.
3. Reach into the can, and grab the center of the bottom of the bag. Try to pull the trash bag straight up and out of the trash can.
4. Have a partner hold the trash can sideways or upside down. Observe what happens when you try to pull the bag out again. Try pulling the bag from other locations in the can.

ANALYZE & CONCLUDE

1. What happens when you try to pull the trash bag out of the trash can? ______________________________

____

____

2. Why do you think the trash bag reacts this way? ______________________________

____

____

3. What happens when you hold the trash can sideways or upside down and try to pull out the bag? Why? __________

____

____

4. What might happen if there were holes in the trash bag or trash can? Why? ______________________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 24 ACTIVITY SHEET: Grasping for Air

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Volume		
Vacuum		
Suction		

2. Give examples of other times you may have experienced a vacuum. ______________________________

____

____

3. Outer space is considered to be a vacuum, but it is not a perfect one. Why? ______________________

____

____

LESSON 24 ACTIVITY SHEET: Grasping for Air

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. A small trash can, a plastic trash bag, duct tape ...

2. Predict how these materials may be used. A trash can lined with a plastic trash bag may be used as a trash recepticle. Duct tape may be used to hold a material in place. These materials may be combined to demonstrate the concepts of air pressure and vacuums.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter	Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth.	
Solid	A state of matter characterized by a definite volume and definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container	
Pressure	The amount of force exerted on an area.	
Air pressure	The cumulative force exerted on a surface by the weight of the air particles above that surface.	
Displacement	The act of moving something out of its original position or of one substance taking the place of another.	

4. Consider why differences in air pressure, caused by the removal of air between a trash bag and a trash can, create difficulty in removing the bag.

▶ **Write your hypothesis.** When air is removed from the space between a trash can and the trash bag inside it, a pressure difference will be created. With the bag sealed inside the can, this difference in pressure will make it difficult to pull the bag from the can.

LESSON 24 ACTIVITY SHEET: Grasping for Air

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Place a trash bag into a trash can. Fold the top of the bag over the can. Press all around the inside of the bag so that you push as much air as possible out from between the can and the bag.
2. Use duct tape to seal the bag tightly around the rim of the can.
3. Reach into the can, and grab the center of the bottom of the bag. Try to pull the trash bag straight up and out of the trash can.
4. Have a partner hold the trash can sideways or upside down. Observe what happens when you try to pull the bag out again. Try pulling the bag from the other locations in the can.

ANALYZE & CONCLUDE

1. What happens when you try to pull the trash bag out of the trash can? When you try to pull the trash bag out of the trash can, it seems stuck. It is difficult to pull.

2. Why do you think the trash bag reacts this way? The bag reacts this way because of the difference in pressure that is created between the outside air and the air inside of the trash can. The pressure is lower between the bag and the can, so the outside air puts more pressure on the bag as you try to pull it.

3. What happens when you hold the trash can sideways or upside down and try to pull out the bag? Why? The bag still cannot be removed because the pressure difference stays the same in each position.

4. What might happen if there were holes in the trash bag or trash can? Why? If holes were cut into the trash bag or trash can, then air could enter the space between the bag and the can. You would then be able to lift the bag from the inside of the can.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 24 ACTIVITY SHEET: Grasping for Air

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Volume	A physical property that measures the amount of space a substance occupies.	
Vacuum	A volume of space that has essentially no matter; also known as a partial vacuum.	
Suction	A force that attracts a substance to a region of lower pressure when there is a difference in pressure.	

2. Give examples of other times you may have experienced a vacuum. Using a suction cup or a toilet plunger are examples of when a vacuum is created.

3. Outer space is considered to be a vacuum, but it is not a perfect one. Why? Outer space is considered to be a partial vacuum. While the space between the planets and stars seems empty, it still has heat, light, sound, and cosmic radiation.

LESSON 25: Capillary Carnations

ESTIMATED TIME Setup: 5–10 minutes | **Procedure:** Allow at least 24 hours to make periodic observations.

• DESCRIPTION

Place white carnations in colored water to make the flower petals change color.

• OBJECTIVE

This lesson demonstrates capillary action in plants and introduces the forces involved in the process. Students use food coloring to help visualize the movement of water into and through a plant. The lesson can be extended to discuss the molecular structure and properties of water.

• CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; attractive forces (surface tension, adhesion, cohesion)

• MATERIALS

- ❑ White carnation flowers
- ❑ Clear plastic cups
- ❑ Water
- ❑ Food coloring
- ❑ Scissors and/or a knife

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 308 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- LS1.A: Structure and Function
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, books, and trees. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and orange juice. **Gases** have no definite shape and no definite volume. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Along with differences in shape and volume, the different states of matter have other unique properties. For example, capillary action and surface tension are unique properties of liquids.

Capillary action, or capillarity, is the movement of liquids upward through a narrow tube, cylinder, or permeable substance because of the cohesive and adhesive forces interacting between the liquid and the surface. **Cohesion** is the attractive force that exists between like particles in a certain liquid. (It's the attraction that causes like molecules to stick together.) Thus, water molecules are attracted to other water molecules.

Likewise, **surface tension** is a property of liquids that describes the attraction of liquid particles at the surface. The strong attraction (cohesion) of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Surface tension is also the reason liquids tend to keep a low surface area. For example, water droplets will tend to form into a sphere rather than spreading out flat.

Conversely, **adhesion** is the force of attraction between unlike molecules. It's the force that causes water molecules to stick to the inside of a glass. The forces of capillary action are strong enough to move the liquid upward against the force of gravity.

Fun Fact

In ancient Greece, carnations were used to make ceremonial crowns.

All plants need water to survive, and most plants get that water from the soil. Capillary action helps to move water, and the nutrients dissolved in the water, up into the plant's roots and through all parts of the plant. The water gets into the plant's roots and adheres to the plant tissue. The plant tissue attracts the water molecules (because of adhesion), pulling the water up into the plant. As one water molecule climbs, the cohesive attraction to other water molecules pulls those molecules up the stem as well. Why does all the water move upward in the entire stem, rather than just some water molecules moving upward along the edges? The surface tension of the water keeps the surface intact, so the whole liquid surface is dragged upward, pulling the rest of the water molecules upward behind it.

In this experiment, the adhesive and cohesive forces pull the water up into the carnation against the force of gravity. This action can be proven by using food coloring. The food coloring is drawn upward into the plant and its petals with the water.

FORMULAS & EQUATIONS

Water is a liquid substance that is essential to the survival of plants and animals.

The chemical formula for water is $\mathbf{H_2O}$.

This formula illustrates that a molecule of water is comprised of two hydrogen atoms and one oxygen atom.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶When the stems of white carnation flowers are placed in colored water, the colored water will move up through the plant, causing the petals to change color.

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 308, but spend more time on the states and properties of matter. Show pictures of different items—a chair, milk, a balloon. (A balloon is a solid, but what's inside?) Ask the students to identify the states of matter, and describe the differences between the states.

Likewise, focus more on the different properties of matter, specifically the properties of liquids. Pour a little water on a desk to illustrate the cohesive attraction of water molecules. The water will form droplets. Then tilt the desk slowly so that the water flows off the edge. Does it linger at the side of the desk before falling to the ground? Discuss how cohesion and adhesion play a part.

LESSON 25: Capillary Carnations

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Place white carnations in colored water to make the flower petals change color.

OBJECTIVE

This lesson demonstrates capillary action in plants and explores the structure of plants and properties of water. Students use food coloring to help visualize the movement of water into and through a plant.

OBSERVATION & RESEARCH

Matter exists primarily in three states on the earth—solid, liquid, or gas. Each state of matter has unique properties. The properties of matter are characteristics that describe a particular substance. For example, solids have a definite shape. Likewise, liquids are often described by certain unique properties, such as surface tension.

Capillary action, or capillarity, is the movement of liquids upward through a narrow tube, cylinder, or permeable substance because of the cohesive and adhesive forces interacting between the liquid and the surface. **Cohesion** is the attractive force that exists between like particles in a certain liquid. (It's the attraction that causes like molecules to stick together.)

Water molecules are strongly attracted to one another. Water molecules are polar molecules. **Polar substances** are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. The oxygen atom in a water molecule has a partial negative charge, and the hydrogen atoms have partial positive charges. Because "opposites attract," the negatively charged oxygen atom attracts the positively charged hydrogen atoms in other water molecules. When the molecules interact, they form strong hydrogen bonds.

Surface tension is another property of liquids that results from cohesion. The strong attraction (cohesion) of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Surface tension is also the reason liquids tend to keep a low surface area. For example, water droplets will tend to form into a sphere rather than spreading out flat.

Conversely, **adhesion** is the force of attraction between unlike molecules. It's the force that causes water molecules to stick to the inside of a glass. The forces of capillary action are strong enough to move the liquid upward against the force of gravity.

All plants need water to survive, and most plants get that water from the soil. Capillary action helps to move water, and the nutrients dissolved in the water, up into the plant's roots and through all parts of the plant. The water is attracted to the plant's roots as a result of adhesion. It then moves across the root cells to a certain type of plant tissue called xylem. **Xylem** is a complex plant tissue made up of vessels (or small hollow tubes) that transport water and dissolved minerals through the plant. Xylem also provides structural support to the plant.

The attraction of the water molecules to the xylem causes the water to adhere to the sides of these tiny tubes, climbing up the sides as more water molecules move toward the tissue. The water, however, does not just move upward along the sides of the xylem. It moves up through the entire tube. The surface tension of the water keeps the surface intact, so the whole liquid surface is dragged upward. Cohesion then causes the rest of the water molecules below the surface to be pulled upward as well.

In this experiment, the adhesive and cohesive forces pull the water up into the carnation against the force of gravity. This action can be seen by using food coloring. The food coloring is drawn upward into the plant and its petals with the water.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states and properties of matter, including surface tension, can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on polar substances can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

LESSON 25: Capillary Carnations

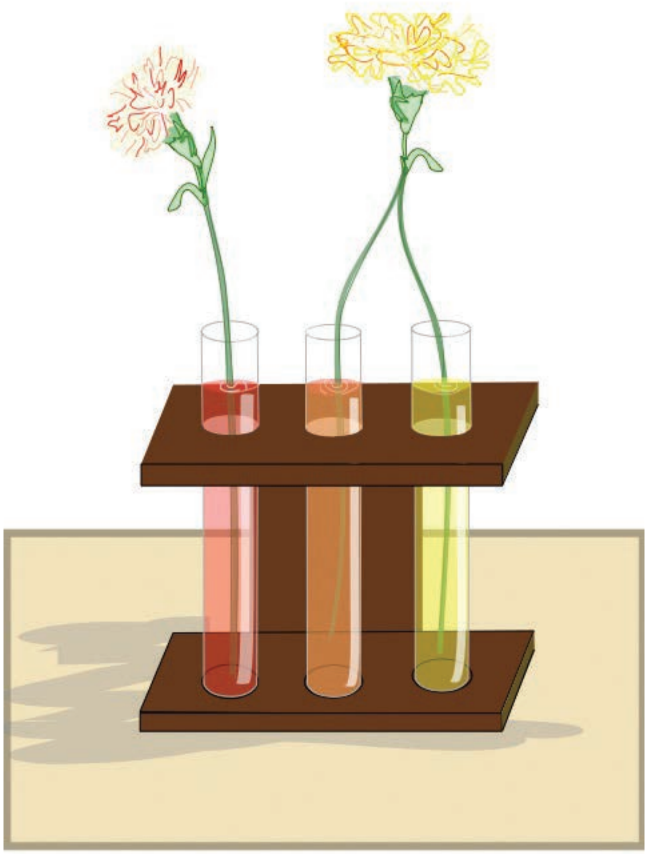
EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the color of the water, will the color of the petals change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill a cup halfway with water and add 20–30 drops of food coloring.
2. Cut two inches off the bottom of each carnation stem. Then, place the carnations' stems in the colored water.
3. Wait several hours or even until the next day to observe the results.
4. To dye one carnation's petals two different colors, use a knife or scissors to split the stem lengthwise into two pieces. Do not split the entire stem; stop about 2–3 inches from the top of the stem.
5. Place the separated sections of the stem in different colored water solutions, and wait several hours or even until the next day to observe the results.

Always be careful when using scissors and other sharp objects. When splitting the carnations' stems in half, it is best to do this for the students.



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. How do plants move water from the soil into all parts of the plant? How quickly does the water move through the plant? You can use the table in the activity sheet (or a similar one of your own) for students to record their data.

LESSON 25: Capillary Carnations

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Differentiate between the different states of matter.
- Describe capillary action and the attractive forces of cohesion, adhesion, and surface tension.
- Explain the importance of capillary action in nature.
- Differentiate between polar and nonpolar substances and describe why water is classified as a polar substance (see ***Differentiation in the Classroom***).
- Explain the purpose of xylem in plants (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the experiment, take a paper towel and hold the bottom of it in a cup of water. Have the students watch as water rises up the paper towel. Ask your students if they know how this is possible. Discuss how water can rise up against the force of gravity. Most will know that the water is being absorbed by the paper towel, but they may not know that it is because of capillary action. The water adheres to the fibers in the paper towel and climbs up the paper towel, pulling other water molecules upward as well because of cohesion.
- After the experiment, cut the stems of the carnations and have the students observe the tiny tubes in the plant. Magnifying glasses may help them to see the tubes.

REAL-WORLD APPLICATIONS

- Most plants get the water they need to survive through their roots. While some plants can absorb water through their leaves, water from the ground generally contains other nutrients that are useful to the plant. By obtaining water from the ground, the minerals and nutrients dissolved in the groundwater are pulled up into the plant as well. As a result, it is important to water the ground where plants grow. If you only water the leaves or top of the plant, the plant will not get enough water to survive.
- Blood is mostly water, so the forces of adhesion, cohesion, and surface tension, and therefore capillary action, can be observed in blood. If you prick your finger, the blood will form droplets. Likewise, if the edge of a sterile gauze pad touches the blood, the blood will quickly move up through the fibers of the gauze.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 25 ACTIVITY SHEET: Capillary Carnations

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid		
Liquid		
Gas		
Capillary action		
Cohesion		
Surface tension		
Adhesion		

4. Consider what will occur if white carnations are placed in colored water and why.

▶ **Write your hypothesis.** ______________________________

____

____

LESSON 25 ACTIVITY SHEET: Capillary Carnations

PERFORM YOUR EXPERIMENT

1. Fill a cup halfway with water. Add 20–30 drops of food coloring to the cup of water.
2. Use scissors to cut two inches off the bottoms of the stems. Then, place the carnations' stems in the colored water.
3. Wait several hours or until the next day. Observe the results.
4. Try dyeing one carnation different colors. Your teacher will provide a carnation with the stem split lengthwise in two pieces. Place the separated parts of the stem in different colored water solutions. Wait several hours or until the next day. Observe the results.

Always be careful when using scissors and other sharp objects.

ANALYZE & CONCLUDE

1. Record your observations of the carnations' appearance in the table below. Record the day and time of your observation. For example, Monday, 10:00 a.m.

Day and Time	Observations (color, healthy/wilted, etc.)

LESSON 25 ACTIVITY SHEET: Capillary Carnations

2. What does the carnation look like before it is placed in the colored water? ______________________________

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3. Describe the carnation after it has been in the colored water for a few hours. ______________________________

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____

4. What do you think caused the change? ____

____

____

5. What forces do you think are causing this to occur? ____

____

____

6. After you split the stem of a carnation, what do you see? ____

____

____

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? __________________________

____

____

LESSON 25 ACTIVITY SHEET: Capillary Carnations

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance		
Nonpolar substance		
Xylem		

2. When you water a plant, why would you soak the soil around the plant instead of sprinkling water on the plant's leaves? ______________________________

____

____

3. The water absorbed by plant roots is used in a process by which plants make their own food. What is this process called? Write the chemical equation for the reaction. Where does this process take place within the plant?

____

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____

LESSON 25 ACTIVITY SHEET: Capillary Carnations

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. White carnations, plastic cups, water, food coloring, scissors ...

2. Predict how these materials may be used. White carnations may be used as decorations. Plastic cups may be used to hold a liquid. Water may be used to drink or feed plants. Food coloring may be used to dye a substance. These materials may be used to change the color of white carnations and demonstrate capillary action.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid	A state of matter characterized by a definite volume and definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container	
Capillary action	The ability of a substance to be drawn (possibly upward) through a tiny tube or vessel due to adhesive and cohesive forces; also known as capillarity.	
Cohesion	An attractive force that holds atoms or ions of a single body together; an attraction between particles of the same kind.	
Surface tension	A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface “film."	
Adhesion	An attractive force that holds atoms or ions of different substances together.	

4. Consider what will occur if white carnations are placed in colored water and why.

▶**Write your hypothesis.** White carnation petals will turn the color of the dyed water because of capillary action within the plant.

LESSON 25 ACTIVITY SHEET: Capillary Carnations

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill a cup halfway with water. Add 20–30 drops of food coloring to the cup of water.
2. Use scissors to cut two inches off the bottoms of the stems. Then, place the carnations' stems in the colored water.
3. Wait several hours or until the next day. Observe the results.
4. Try dyeing one carnation different colors. Your teacher will provide a carnation with the stem split lengthwise in two pieces. Place the separated parts of the stem in different colored water solutions. Wait several hours or until the next day. Observe the results.

Always be careful when using scissors and other sharp objects.

ANALYZE & CONCLUDE

1. Record your observations of the carnations' appearance in the table below. Record the day and time of your observation. For example, Monday, 10:00 a.m.

Day and Time	Observations (color, healthy/wilted, etc.)
Answers will vary	Answers will vary

LESSON 25 ACTIVITY SHEET: Capillary Carnations

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. What does the carnation look like before it is placed in the colored water? The carnation looks healthy. It is upright in the cup, and the petals are white.

3. Describe the carnation after it has been in the colored water for a few hours. The bottoms of the petals begin to show the color of the water.

4. What do you think caused the change? Capillary action drew the colored water up into the carnation, which dyed the petals.

5. What forces do you think are causing this to occur? The forces of cohesion and adhesion cause the capillary action to occur.

6. After you split the stem of a carnation, what do you see? The inside of the carnation stem shows tiny strands of color. These strands of color are the xylem that are transporting the colored water through the plant.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 25 ACTIVITY SHEET: Capillary Carnations

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	
Nonpolar substance	A substance made up of particles that have an even distribution of electrons; the charges on these molecules are neutralized.	
Xylem	A complex plant tissue made up of networks of vessels (or small hollow tubes) that transport water and dissolved minerals through the plant; provides structural support to the plant.	

2. When you water a plant, why would you soak the soil around the plant instead of sprinkling water on the plant's leaves? You soak the soil around the plant with water because plants absorb water through their roots, which are in the ground. The water is then transported throughout the plant by tiny vessels. If you just sprinkled the water on the plants leaves, the plant may not absorb enough water to survive.

3. The water absorbed by plant roots is used in a process by which plants make their own food. What is this process called? Write the chemical equation for the reaction. Where does this process take place within the plant?

Photosynthesis is the process by which plants make their own food. The chemical equation for the reaction is $6CO_2 + 6H_2O$ + sunlight (energy) $\rightarrow C_6H_{12}O_6 + 6O_2$. The process occurs within the chloroplasts found in the plant cells.

LESSON 26: Melting Ice with Salt

ESTIMATED TIME **Setup:** 3–5 minutes | **Procedure:** 15–30 minutes

DESCRIPTION

Use salt to melt ice and demonstrate the effects of salt on the freezing point of water.

OBJECTIVE

This lesson explores the physical changes of melting and freezing. Students observe the effect that salt has on the freezing point of water. The lesson can be extended to introduce solutions and nonvolatile solutes.

CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; physical changes (freezing, melting); elements and compounds; mixtures (solutions)

MATERIALS

- ❑ Ice
- ❑ Table salt
- ❑ Two clear cups
- ❑ Metric ruler
- ❑ Tablespoon

If possible, observe the changes every 5 minutes.

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 321 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O.

However, the water that comes out of a sink is not a pure substance. It is a mixture, generally called tap water. Tap water usually contains dissolved minerals and other substances. The water that is considered to be a pure substance is called distilled water (or pure water).

Common table salt is mainly made up of the compound sodium chloride (NaCl). Calcium chloride ($CaCl_2$) and potassium iodide (KI) are also salts. While common table salt is used in this experiment, other salts may work just as well, or possibly better.

As temperature changes, matter may change from one state to another. Changes between states of matter are physical changes. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays

LESSON 26: Melting Ice with Salt

the same before and after the change. For example, ice (solid), water (liquid), and water vapor (gas) are all H_2O in different physical states. The chemical formula remains H_2O regardless of whether it is in the solid, liquid, or gaseous state.

Freezing is a change in state from a liquid to a solid. The temperature at which a liquid begins to form a solid is known as the **freezing point**. The freezing point of water is 0 °C or 32 °F. However, the freezing point of water can be lowered by adding salt to the water. With the salt added, the water will no longer freeze or stay frozen at 0 °C. Thus, the ice will begin to melt back into liquid form. **Melting** is a change in state from a solid to a liquid. It is the opposite of freezing.

Keep in mind that salt can only lower the freezing point of water by a certain amount, and this amount depends on how much salt is used. If the temperature is extremely cold, such as -20 °C or 0 °F, the ice will not melt, and water will still freeze even with salt present.

FORMULAS & EQUATIONS

Pure water is comprised of two hydrogen atoms and one oxygen atom.

The chemical formula for pure water is $\mathbf{H_2O}$.

Tap water is a mixture of pure water, dissolved minerals, and other substances.

During a physical change, the structure or chemical formula of the substance does not change. As energy (in the form of heat) is added or removed from the substance, it changes from one state of matter to another. The following equation illustrates the process of melting.

$$\mathbf{H_2O\ (s) + energy \rightarrow H_2O\ (l)}$$

Keep in mind, enough energy has to be added to cause this change. The temperature of the solid substance must reach its melting point. The **melting point** is the temperature at which a substance begins changing its state from a solid to a liquid. The melting point and freezing point of a substance are generally the same.

Common table salt is mainly made up of the compound sodium chloride.

The chemical formula for sodium chloride is **NaCl**.

Most table salts are made of about 97–99% NaCl. The remaining 1–3% is usually iodine and other ingredients.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, compounds, states of matter, and physical changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶ A combination of salt and ice will melt faster than pure ice because the salt lowers the freezing point of water.

Fun Fact

In Florida, the temperature rarely drops below freezing. When it does, however, it threatens Florida's orange crops. To protect the oranges from a freeze, farmers may spray the crops with water. As the water freezes, it releases heat. The heat is transferred to the orange, protecting the crop.

LESSON 26: Melting Ice with Salt

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 321, but focus on states of matter and physical changes. Show students the salt, and ask them in which state of matter it is and how they know. Show students the ice, and again ask them its state and how they know. Then, show them liquid water, and have them identify its state of matter. Is it the same substance as the ice? How do they know? Ask them what is different, and discuss physical changes. Use the experiment to show that temperature changes can cause a substance to change from one state to another, but other substances can impact those changes as well.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Use salt to melt ice and demonstrate the effects of salt on the freezing point of water.

OBJECTIVE

This lesson explores the physical changes of melting and freezing and demonstrates the effect that salt, a nonvolatile solute, has on the freezing point of water.

OBSERVATION & RESEARCH

Matter can be classified into pure substances and mixtures. All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O. However, the water that comes out of a sink is not a pure substance. It is a mixture, generally called tap water.

Mixtures are two or more substances that are combined physically. A **solution** is a uniform mixture in which one or more substances (solutes) are dissolved into another substance (solvent). Tap water usually contains dissolved minerals and other substances.

Likewise, common table salt is a mixture mainly made up of the compound sodium chloride (NaCl). Water and salt can be easily combined to form a saltwater solution. Salt is the solute, and water is the solvent. Salt is considered to be a nonvolatile solute. **Volatility** describes the tendency of a substance to vaporize (change into a gaseous state). A **nonvolatile solute** is a solute which has little tendency to escape from the solution. When heated, a solution with a nonvolatile solute will produce a vapor of the pure solvent. Solutions with volatile solutes will produce a vapor that is a mixture of the solvent and solute.

Nonvolatile solutes can be used to lower the freezing point of a liquid. Therefore, salt can be used to lower the freezing point of water. The temperature at which a liquid begins to form a solid is known as the **freezing point**. The freezing point of water is 0 °C or 32 °F. When salt is added to water, the water will no longer freeze. If salt is added to ice, the ice can no longer stay frozen at 0 °C, so the ice will begin to melt back into liquid form. **Melting** is a change in state from a solid to a liquid. It is the opposite of freezing.

Keep in mind that salt can only lower the freezing point of water by a certain amount, and this amount depends on how much salt is used. Additionally, if the temperature is extremely cold, such as -20 °C or 0 °F, the ice will not melt, and water will still freeze even with salt present.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, compounds, states of matter, physical changes, and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 26: Melting Ice with Salt

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you add salt, will the rate at which the ice melts change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Fill one cup halfway with ice only.
2. Fill another cup halfway with the same amount of ice, and add one tablespoon of salt.
3. Observe the two cups every five minutes for 15–30 minutes. Look to see which cup is melting faster. This can be observed by looking at how much water is collecting at the bottom of the cups. Use a ruler to measure the amount of water in each cup.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What causes water to change from one state to another? What happens when salt is added to the ice? You can use the table in the activity sheet (or a similar one of your own) for students to record their data.

NOTES

LESSON 26: Melting Ice with Salt

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and provide examples of matter, elements, compounds, and mixtures.
- Explain and give examples of physical changes, specifically melting and freezing.
- Understand that salt lowers the freezing point of water.
- Describe and identify solutions, solutes, and solvents (see ***Differentiation in the Classroom***).
- Describe volatility and nonvolatile solutes (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Use the concepts in this experiment to introduce how ice cream is made. You can even research a recipe, gather the necessary materials, and try making ice cream with your class.
- Have the students test other solutes, such as sugar. Sugar is also a nonvolatile solute. Does the sugar cause the ice to melt faster than the pure ice? Does the sugar cause the ice to melt as quickly as the salt does? Discuss these differences as a class.

REAL-WORLD APPLICATIONS

- When snow or ice covers the ground, trucks spread salt on roads to prevent water from freezing and/or to cause the snow and ice to melt. You may also notice people buying containers of salt to use on their sidewalks or driveways for the same purpose.
- Nonvolatile solutes, such as salt, also raise the boiling point of water. In high altitudes, there is a decrease in air pressure. As a result of the pressure decrease, water boils at a lower temperature. Therefore, the temperature at which the water boils may not be high enough to cook the food properly. Salt is added to raise the boiling point to a higher temperature and make sure that the food is cooked properly.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 26 ACTIVITY SHEET: Melting Ice with Salt

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element		
Compound		
Physical change		
Freezing		
Freezing point		
Melting		
Melting point		

4. Consider how adding salt to ice will affect the rate at which the ice melts.

▶ **Write your hypothesis.** ______________________________

____

____

LESSON 26 ACTIVITY SHEET: Melting Ice with Salt

PERFORM YOUR EXPERIMENT

1. Fill a cup halfway with ice only.
2. Fill another cup halfway with the same amount of ice, and add one tablespoon of salt.
3. Observe the two cups every five minutes for 15–30 minutes. Look to see which cup is melting faster by observing the amount of water that is collecting at the bottom of the cups.
4. Use a ruler to measure the amount of water in each cup every five minutes.

ANALYZE & CONCLUDE

1. Measure the amount of water in the cups, and record below.

Time	Amount of Water (cm) in the Cup of Ice	Amount of Water (cm) in the Cup of Ice and Salt
5 minutes		
10 minutes		
15 minutes		
20 minutes		
25 minutes		
30 minutes		

2. Does the ice melt faster in the regular cup or in the cup with salt? Why? ______________________________

____

____

3. What is your control in this experiment? Explain. ______________________________

____

____

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________

____

____

LESSON 26 ACTIVITY SHEET: Melting Ice with Salt

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution		
Volatility		
Nonvolatile solute		

2. How can salt be used in freezing temperatures? ____

____

____

3. Salt is also placed in water when water is boiled at high altitudes. Why? ______________________________

____

____

LESSON 26 ACTIVITY SHEET: Melting Ice with Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Ice, salt, cups, ruler ...

2. Predict how these materials may be used. Ice may be used as a way to cool down a substance. Salt may be used in cooking. Cups may be used to hold a substance. A ruler may be used to measure a substance. These materials may be used together to demonstrate the effects of salt on ice.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom.	
Compound	A pure substance made up of two or more elements joined in a defined ratio.	
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Freezing	A physical change in which a substance changes states from a liquid to a solid.	
Freezing point	The temperature at which a substance begins to change from a liquid to a solid.	
Melting	A physical change in which a substance changes states from a solid to a liquid.	
Melting point	The temperature at which a substance begins to change from a solid to a liquid.	

4. Consider how adding salt to ice will affect the rate at which the ice melts.

▶**Write your hypothesis.** A combination of salt and ice will melt faster than pure ice because the salt lowers the freezing point of water.

LESSON 26 ACTIVITY SHEET: Melting Ice with Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Fill a cup halfway with ice only.
2. Fill another cup halfway with the same amount of ice, and add one tablespoon of salt.
3. Observe the two cups every five minutes for 15–30 minutes. Look to see which cup is melting faster by observing the amount of water that is collecting at the bottom of the cups.
4. Use a ruler to measure the amount of water in each cup every five minutes.

ANALYZE & CONCLUDE

1. Measure the amount of water in the cups, and record below.

Time	Amount of Water (cm) in the Cup of Ice	Amount of Water (cm) in the Cup of Ice and Salt
5 minutes	Answers will vary	Answers will vary
10 minutes		
15 minutes		
20 minutes		
25 minutes		
30 minutes		

2. Does the ice melt faster in the regular cup or in the cup with salt? Why? Ice melts faster in the cup with salt because salt lowers the freezing point of the ice, causing the ice the melt faster than it normally would.

3. What is your control in this experiment? Explain. The control is the cup with pure ice because no changes are made to the ice in this cup.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 26 ACTIVITY SHEET: Melting Ice with Salt

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Volatility	The tendency of a substance to vaporize (change into a gaseous state).	
Nonvolatile solute	A solute which has little tendency to escape from a solution.	

2. How can salt be used in freezing temperatures? Salt is used to melt ice and snow on sidewalks and roads so that it is safer to walk and drive during freezing conditions.

3. Salt is also placed in water when water is boiled at high altitudes. Why? In high altitudes, water boils at a lower temperature. The lower temperature might not be high enough to cook food properly, so salt is added to raise the boiling point and make sure the food is properly cooked.

LESSON 27: Separating Salt & Pepper

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 15–20 minutes

- ## DESCRIPTION

Test different methods to separate a mixture of salt and pepper.

- ## OBJECTIVE

This lesson demonstrates various separation processes. Students explore different techniques for separating a mixture of salt and pepper based on physical properties. The lesson can be simplified to reinforce their understanding of different properties of matter.

- ## CONTENT TOPICS

Scientific inquiry; properties of matter; mixtures; separation processes; elements and compounds; atomic structure

- ## MATERIALS

- ❑ Salt
- ❑ Pepper
- ❑ Beakers, glass jars, or plates
- ❑ A miscellaneous assortment of items for separating the mixture (spoons, paper towels, tweezers, straws, balloons, magnifying glasses, water, etc.)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 332 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.B: Types of Interactions
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Often the chemical substances used in science are not found in their pure or usable form. Instead, they are found mixed or combined with other substances. For example, pure iron is found in the form of iron ore.

Mixtures are made of two or more substances that are combined physically, and chemists often need to separate a specific chemical substance (a specific part) from a mixture. Separating a mixture of substances into two or more distinct products is called a **separation process**. A separation process uses the different properties of a mixture's parts to get them to separate. Common separation processes include filtration, distillation, and precipitation.

In this experiment, students will use the physical properties of salt and pepper to separate the mixture. **Physical properties** can be observed by using our senses and taking measurements. Some examples of physical properties are color, texture, weight, shape, boiling point, melting point, and density. **Chemical properties** can be identified by observing how a chemical reacts with other substances. Some examples of chemical properties include acidity, toxicity, and flammability.

During the experiment, students can observe the different physical properties of the substances, and test methods for using those properties to separate the mixture. For example, in this lesson, students can use differences in weight to separate a salt and pepper mixture. Shaking the mixture will

LESSON 27: Separating Salt & Pepper

cause the lighter pepper to move above the salt, which can then be scooped off the top. Likewise, lightly blowing on the mixture will cause the lighter pepper to move away from the heavier salt (though students should be reminded to make sure other students are out of the way when testing this method). The mixture can also be separated by simply picking out the crystals or flakes one by one.

Another physical property that can be used to separate the mixture is electric charge. Substances can gain or lose electrons, becoming positively or negatively charged. **Static electricity** is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material. Some materials tend to give up electrons easily and become positively charged. Other materials tend to collect electrons from other materials.

In addition, like charges repel one another, while opposite charges attract one another. Therefore, a positively charged object will attract a negatively charged object, but two negatively charged objects will repel one another.

In the experiment, students can rub a balloon against their hair, causing the balloon to collect electrons from their hair. Because the balloon is collecting extra electrons, it becomes negatively charged. After charging the balloon, students can hold it above the salt and pepper mixture and slowly bring it closer. The positively charged pepper will "jump" up quickly and stick to the balloon, leaving the salt behind. The salt remains on the table because it is heavier than the pepper. However, if you move the balloon too close, the salt will also jump up and attach to the balloon.

FORMULAS & EQUATIONS

Pepper is known as piper nigrum and comes from a plant. The piperine molecule gives the pepper its spicy taste.

Piperine is an alkaloid, and its chemical formula is **$C_{17}H_{19}NO_3$**.

Common table salt is mainly made up of the compound sodium chloride.

The chemical formula for sodium chloride is **NaCl**.

Most table salts are made of about 97–99% NaCl. The remaining 1–3% is usually iodine and other ingredients.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on properties of matter and physical separations can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*

HYPOTHESIS

▶ A mixture of salt and pepper can be separated by making use of different physical properties, such as weight, color, and electric charge.

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 332, but focus on classifying matter. Discuss physical properties in more detail and the different uses of different substances. Ask students what the physical differences are between salt and pepper—color, texture, weight, etc.

Another option is to emphasize the different types of mixtures all around you. Point out different substances in the room, or use pictures of different substances, such as soup, pizza, and apple juice. What do they have in common? What makes them all mixtures? Discuss as a class.

LESSON 27: Separating Salt & Pepper

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

A salt and pepper mixture is separated using various separation processes.

OBJECTIVE

This lesson encourages students to explore different techniques for separating the salt and pepper by making use of the differences in the substances' properties.

OBSERVATION & RESEARCH

Matter is often classified as either a pure substance or a mixture. **Elements** are pure substances that cannot be broken down further by normal chemical means. All matter is made up of basic elements. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together to give water the chemical formula H_2O.

Mixtures are made of two or more substances that are combined physically, and chemists often need to separate a specific chemical substance (a specific part) from a mixture. Separating a mixture of substances into two or more distinct products is called a **separation process**. A separation process uses the different properties of a mixture's parts to get them to separate. During the experiment, students test methods for separating the mixture. For example, students can use differences in weight to separate the mixture. Another physical property that can be used to separate the mixture is electric charge.

Atoms are the fundamental units of an element and of all matter! Atoms are made up of even smaller parts—protons, neutrons, and electrons. **Protons** and **neutrons** are held together tightly in the nucleus, or core, of an atom, while **electrons** occupy the space outside of the nucleus. Protons have a positive electric charge, neutrons have no electric charge, and electrons are negatively charged. When the number of protons in an atom equals the number of electrons, the positive and negative charges are balanced, and the atom is **electrically neutral**. However, atoms can gain or lose electrons, leaving them with a positive or a negative charge.

Likewise, larger objects can gain or lose electrons becoming positively or negatively charged.

Static electricity is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material. Some materials tend to give up electrons easily and become positively charged. Other materials tend to collect electrons from other materials. In addition, like charges repel one another, while opposite charges attract one another. Therefore, a positively charged object will attract a negatively charged object, but two negatively charged objects will repel one another.

In the experiment, students can rub a balloon against their hair, causing the balloon to collect electrons from the hair. Because the balloon is collecting extra electrons, it becomes negatively charged. After charging the balloon, students can hold it above the salt and pepper mixture and slowly bring it closer. The positively charged pepper will "jump" up quickly and stick to the negatively charged balloon, leaving the salt behind. The salt remains on the table because it is heavier than the pepper. However, if you move the balloon too close, the salt will also jump up and attach to the balloon.

When the students have completed the experiment, they should either wipe the balloon with a damp cloth or wash the balloon off over a sink to remove the pepper. They should be careful not to pop the balloon, or pepper will fly everywhere!

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on properties of matter and physical separations can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on atoms and the parts of an atom can be found in the Atomic Structure section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 27: Separating Salt & Pepper

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If different separation processes are used, will the salt and pepper behave differently?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Instruct the students to look at the mixture in a jar or on a plate. Have them write down the physical properties of the mixture and of the individual components.
2. As a class, identify physical properties that may help you separate the mixture.
3. Instruct the students to choose two or three methods that they could use to separate the mixture using whatever tools are necessary. (Possible methods include lightly shaking the mixture, blowing on it, using a balloon charged with static elecricity, or picking out the different particles piece by piece.) Have the students test these methods.
4. While testing their methods, students should record their results with specific details on how effective their method was. If they have time, they can do more testing.

Pepper will sting the eyes. Students should wear protective eyewear during this experiment and be warned not to touch their faces. If students test the technique of blowing to separate the mixture, they must do it away from other students.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What technique did you try? What was the result? You can use the table in the activity sheet (or a similar one of your own) for students to record their data.

NOTES

LESSON 27: Separating Salt & Pepper

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Identify and understand different properties of matter.
- Describe and provide examples of different types of mixtures.
- Differentiate between physical and chemical separation processes.
- Explain electric charges and static electricity.
- Define and provide examples of matter, elements, compounds, and mixtures (see ***Differentiation in the Classroom***).
- Differentiate between protons, neutrons, and electrons (see ***Differentiation in the Classroom***).

Fun Fact

During the Middle Ages, salt was extremely valuable for its role in food preservation. However, during this time, pepper was even more expensive than salt.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Develop a silly story to explain how the salt and pepper got mixed together and why you need to separate them again. After the experiment, have students analyze their results and hold a class discussion about the different methods. Identify which methods worked the best and why.
- Have the students try using water to separate the mixture. The lighter pepper will remain on top of the water, and the salt will sink to the bottom. The pepper can be scooped from the top, but what about the salt? A distillation process can be used to recover the salt.

REAL-WORLD APPLICATIONS

- Separation processes are important in a variety of industries. Various separation processes are used in recycling, food chemistry, refining, water treatment, and much more. Students can look in books or online to figure out which separation processes are used in which industries, as well as how those separation processes are used.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

OBSERVE & RESEARCH

1. Write down the materials you observe.

2. Predict how these materials may be used.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Separation process		
Physical property		
Chemical property		
Static electricity		

4. Consider how making use of physical properties can help separate a salt and pepper mixture and why.

▶ **Write your hypothesis.**

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

PERFORM YOUR EXPERIMENT

1. Observe the mixture of salt and pepper in a jar or on a plate. Record the physical properties of the mixture and the individual components below.
2. Identify the physical properties of the substances that may help to separate the mixture.
3. Experiment with different separation methods using the different tools supplied by your teacher. Record your results to determine which method works best to separate the parts of the mixture.

ANALYZE & CONCLUDE

1. Describe the salt and pepper mixture. ______________________________

____

____

2. Describe the physical properties of the salt. ______________________________

____

____

3. Describe the physical properties of the pepper. ______________________________

____

____

4. Consider what methods can be used to separate the mixture and test them. Record the results below, noting how much of the mixture was separated using that method.

Method Tested	Results

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

5. Which method worked the best? Explain. ____

____

____

6. Based on your experiment, can you think of any other methods that may work well to separate the mixture?

____

____

____

7. How is this experiment similar to recycling?____

____

____

8. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________

____

____

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element		
Compound		
Atom		
Proton		
Neutron		
Electron		
Electrically neutral		

2. Why would scientists need to separate mixtures? (Provide at least one example.) ______________________________

____

____

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Salt, pepper, plates, spoons, paper towels, tweezers, balloons, magnifying glass ...

2. Predict how these materials may be used. Salt and pepper may be used to add flavor to food. Plates may be used to hold a substance. Spoons may be used to scoop or measure a substance. Paper towels may be used to clean up messes. Tweezers may be used to pick up small objects. These materials may be used to separate a salt and pepper mixture based on the substances' properties.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Separation process	A process that divides a mixture into two or more distinct substances.	
Physical property	A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance.	
Chemical property	A property of an object characterized by reactions that change the object's identity; describes an object's "potential" to undergo some chemical change or reaction due to its composition.	
Static electricity	The buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material.	

4. Consider how making use of physical properties can help separate a salt and pepper mixture and why.

▶**Write your hypothesis.** A mixture of salt and pepper can be separated by making use of physical properties, such as weight, color, and electric charge, because these different properties cause the salt and pepper to behave differently.

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Observe the mixture of salt and pepper in a jar or on a plate. Record the physical properties of the mixture and the individual components below.
2. Identify the physical properties of the substances that may help to separate the mixture.
3. Experiment with different separation methods using the different tools supplied by your teacher. Record your results to determine which method works best to separate the parts of the mixture.

ANALYZE & CONCLUDE

1. Describe the salt and pepper mixture. The salt and pepper mixture is black/brown and white ...

2. Describe the physical properties of the salt. Salt is a small, rough, crystalline solid ...

3. Describe the physical properties of the pepper. Pepper is a small, black/brown, light solid ...

4. Consider what methods can be used to separate the mixture and test them. Record the results below, noting how much of the mixture was separated using that method.

Method Tested	Results
Shaking the plate	Answers will vary
Picking out the different parts with tweezers	Answers will vary
Using static electricity	Answers will vary

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

5. Which method worked the best? Explain. Answers will vary depending on the methods used.

6. Based on your experiment, can you think of any other methods that may work well to separate the mixture?

Because salt and pepper have different weights, they could be placed in water. The pepper is more likely to remain suspended on the surface, while the salt will fall to the bottom and may begin to dissolve.

7. How is this experiment similar to recycling? Recycling uses a similar separation process in order to separate different types of products, such as plastic, glass, or paper, from the rest. Recycling processes will make use of certain characteristics of the products to separate them from the trash. For example, a magnet is used to separate out some metals.

8. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 27 ACTIVITY SHEET: Separating Salt & Pepper

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom.	
Compound	A pure substance made up of two or more elements joined in a defined ratio.	
Atom	The fundamental unit of an element; the smallest particle of an element that maintains the chemical properties of that element.	
Proton	A subatomic particle that carries a positive charge and is found in the nucleus of an atom.	
Neutron	A subatomic particle that carries no electric charge and is found in the nucleus of an atom.	
Electron	A subatomic particle that carries a negative charge and occupies the space outside the nucleus of an atom.	
Electrically neutral	An atomic state in which the number of protons in an atom equals the number of electrons, thus, the positive and negative charges are balanced.	

2. Why would scientists need to separate mixtures? Scientists need to separate mixtures in order to obtain the parts that make up these mixtures. Often, the components of a mixture are unknown, and a separation process can show what makes up that mixture. Separation processes are used to purify water for drinking and to produce different types of fuels from crude oil.

LESSON 28: Antigravity Water

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 5–10 minutes

- ## DESCRIPTION

Flip a cup of water upside down to demonstrate the effects of attractive forces and air pressure.

- ## OBJECTIVE

This experiment demonstrates the effects of pressure and attractive forces. Students observe as these forces work together to keep water inside an inverted cup. The lesson can also be extended to discuss the polarity of water molecules.

- ## CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter; force (pressure); attractive forces (surface tension, adhesion, cohesion)

- ## MATERIALS

- ❑ Clear plastic cups (high strength) or glass cups
- ❑ Large bowl or dish (to catch falling water)
- ❑ Index cards (large enough to cover the rim of the cup)
- ❑ Mason jar or similar jar with a screw-on top (optional)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 345 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS2.A: Forces and Motion
- PS2.B: Types of Interactions
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Scientists use the term "matter" to describe the things around you. **Matter** is anything that has mass and takes up space, such as paper, food, skin, and water. Matter primarily exists in three states on the earth—solid, liquid, or gas. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, books, and cups. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and orange juice. **Gases** have no definite shape and no definite volume. An example of a gas is the air around you! In addition to differences in shape and volume, solids, liquids, and gases have other unique properties.

Particles in a liquid move around freely, but still experience forces of attraction. **Cohesion** is the attractive force that exists between like particles in a liquid. Water molecules are strongly attracted to one another. **Surface tension** is another property of liquids that results from cohesion. The strong attraction of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Conversely, **adhesion** is the force of attraction between unlike molecules. It's the force that causes water molecules to stick to the inside of a glass or an index card.

In the experiment, the water molecules in the cup stick together because of cohesion. The water molecules also stick to the sides of the cup and index card because of adhesion. These attractive forces pull all the water molecules in the cup tightly together. In addition, when the index card is held to the rim of the inverted cup, the tightly held water molecules along the rim of the cup and walls of the cup form a "film" or seal around the rim of the cup. This seal prevents air from entering the cup and displacing the water. **Displacement** is the act of moving something out of its original position or of one substance taking the place of another. The seal isn't perfect, and there is a slight gap between the cup and index card. However, this gap is too small for air to break the surface tension of the water molecules.

In addition, the particles that make up a gas (the air) move around freely in rapid random motion. They do not have strong bonds or attractions between them. The air particles bounce around and collide with one another, creating pressure. **Pressure** is the amount of force exerted on an area. **Air pressure**, or atmospheric pressure, is the force exerted on a surface by the weight of the air above that surface. Yet because the particles move in all directions, air pressure is exerted from all angles, not just down. The average air pressure at sea level is about 14.7 pounds per square inch (101.325 kPa). That's almost 15 pounds of air pushing on every inch of our bodies!

Likewise, air pressure is pushing on the cup from all directions. If the cup is full of water, there is essentially no air pressure in the cup. While the force of gravity is pulling down on the water, the attractive forces of the water and the air pressure are pushing up and holding the index card in place. The greater exertion of these forces keeps the index card sealed to the cup. If the cup is about half to three-quarters full, air and water are inside the cup. When the cup is inverted, a little water will drip out of the cup. With less water, the air pocket in the cup increases. The gas particles will spread out to fill the extra space in the cup, causing the pressure inside the cup to decrease. Therefore, the air pressure outside of the cup is greater than the pressure inside, again exerting a greater upward force.

FORMULAS & EQUATIONS

Tap water is a mixture of pure water and dissolved minerals.

The chemical formula for pure water is $\mathbf{H_2O}$.

This formula illustrates that a molecule of water is comprised of two hydrogen atoms and one oxygen atom.

Air is a mixture of gases. The air around us is made up mainly of nitrogen and oxygen gas.

The chemical formula for nitrogen gas is $\mathbf{N_2}$.

The chemical formula for oxygen gas is $\mathbf{O_2}$.

Approximately 78% of the air is $\mathbf{N_2}$, and about 21% is $\mathbf{O_2}$. The remaining 1% is made up of trace gases, such as argon (**Ar**), carbon dioxide ($\mathbf{CO_2}$), water vapor ($\mathbf{H_2O}$), and other gases.

Pressure is the amount of force exerted on an area. This relationship is described by the following equation:

$$p = F/A$$

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states and properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on pressure can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶ Water will remain in an inverted cup with only an index card covering the opening because of air pressure and the forces of attraction experienced by the water molecules.

LESSON 28: Antigravity Water

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 345, but spend more time on the states and properties of matter. Show images of matter in different states, and have students identify the state of matter.

Likewise, you can discuss the concept of pressure in more detail. If the students move around the room like gas particles, will they feel more pressure if more students enter the room? If there were less students in the room, will it be easier to move around without bumping into anyone? Use this example to discuss why the pressure in the cup decreases when some of the water escapes from the glass.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Flip a cup of water upside down to demonstrate the effects of attractive forces and air pressure.

OBJECTIVE

This experiment demonstrates how air pressure and attractive forces, including the polarity of water molecules, work together to keep water inside an inverted cup.

OBSERVATION & RESEARCH

Matter exists primarily in three states on the earth—solid, liquid, or gas. The difference between solids, liquids, and gases is in the motion of the particles within the substance. For example, the molecules of H_2O move differently in the form of ice than they do in the form of water vapor.

The particles in a **solid** are generally locked into place by strong attractive forces giving the solid substance a definite shape and volume. Particles in a **liquid** are not as close as particles in a solid, and they move more freely. The particles roll over each other but still experience weak forces of attraction. The particles in a **gas** are spaced far apart. They do not have strong bonds or attractions between them. Therefore, they move about freely and rapidly in random directions.

Cohesion is the attractive force that exists between like particles in a liquid. (It's the attraction that causes like molecules to stick together.) Water molecules are strongly attracted to one another. They are polar molecules. **Polar substances** are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. The oxygen atom in a water molecule has a partial negative charge, and the hydrogen atoms have partial positive charges. Because "opposites attract," the negatively charged oxygen atom attracts the positively charged hydrogen atoms in other water molecules. When the molecules interact, they form strong hydrogen bonds.

Surface tension is another property of liquids that results from cohesion. The strong attraction (cohesion) of particles at the surface of the liquid creates a surface "film" that makes moving an object through the surface of a liquid more difficult than moving the object when it is completely submerged in the liquid. Conversely, **adhesion** is the force of attraction between unlike molecules. It's the force that causes water molecules to stick to the inside of a glass or an index card.

In the experiment, the water molecules stick to the cup and each other because of adhesion and cohesion. When the index card is held to the rim of the inverted cup, the tightly held water molecules along the rim of the cup and walls of the cup form a "film" or seal around the rim. The seal prevents air from entering the cup and displacing the water. The seal isn't perfect, and there is a slight gap between the cup and the index card. However, this gap is too small for air to break the water's surface tension.

In addition, air particles bounce around and collide with one another, creating pressure. **Pressure** is the amount of force exerted on an area. **Air pressure**, or atmospheric pressure, is the force exerted on a surface by the weight of the air above that surface. However, because the particles move in all directions, air pressure pushes on the cup from all directions. If the cup is full of water, there is

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states and properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on pressure can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on polarity can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

DIFFERENTIATION IN THE CLASSROOM

essentially no air pressure in the cup. While the force of gravity is pulling down on the water, the attractive forces of the water and the air pressure are pushing up and holding the index card in place. The greater exertion of these forces keeps the index card sealed to the cup.

If the cup is about half to three-quarters full, air and water are inside the cup. When the cup is inverted, a little water will drip out of the cup. With less water, the air pocket in the cup increases. The gas particles will spread out to fill the extra space in the cup, causing the pressure inside the cup to decrease. Therefore, the air pressure outside of the cup is greater than the pressure inside, again exerting a greater upward force.

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the index card is moved, will water stay in the cup?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

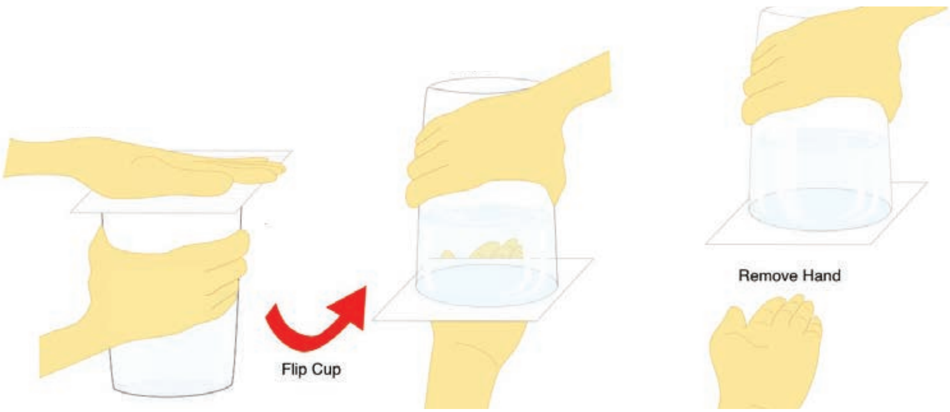
EXPERIMENTAL PROCEDURE

1. Fill a cup with water at least halfway.
2. While the cup is still right-side up, place the index card over the rim. (Wet the rim slightly, and be sure the index card covers the entire opening of the cup.)
3. While holding the index card in place, carefully invert the cup.
4. Let the water settle for a second, make sure the card is touching all the way around the rim, and cautiously let go of the card.

Make sure the cup is turned completely upside down so that the index card is parallel to the ground.

It helps to wet the rim of the cup slightly before placing the index card on it, so there are water molecules on the rim to stick to the index card.

It is best to perform the experiment over a large bowl or sink.



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What forces of attraction cause water molecules to stick to each other and to other substances? What other forces are involved in this activity? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

LESSON 28: Antigravity Water

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Differentiate between the different states of matter.
- Describe the attractive forces of adhesion and cohesion.
- Describe surface tension and its relation to cohesion.
- Define and provide examples of pressure and air pressure.
- Explain the polarity of water (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Take the experiment a step further. Cut out the center of a jar's lid, but be sure you can still screw on the lid. Cover the opening of the jar with a piece of the window screen just large enough to cover the rim. Then screw the lid on the jar. Perform this experiment as a demonstration for the students; however this time, pull the index card slowly away from the inverted jar. The water will not fall out of the jar. The strong attraction of the water molecules to each part of the screen and the high surface tension of the water prevents the water from falling through the tiny holes. However, this stability is very delicate; even if you slightly touch the screen, the water will fall out.

- To illustrate the important role of cohesion and surface tension to the experiment, add soap or detergent to the water. Soap and detergents are surfactants and reduce the surface tension of liquids. Watch what happens when you try the experiment with soap in the cup. (Make sure you perform this demonstration over a sink or large bowl to catch the water!)

- Test other liquids. Water and oil can also be held inside the cup. However, soda pop and other carbonated drinks cannot. The carbon dioxide gas dissolved in these beverages exerts extra pressure inside the glass. Therefore, the attractive forces and air pressure outside the cup are not enough to hold the index card in place.

REAL-WORLD APPLICATIONS

- Generally, when you pour a liquid from a container, air will take the place of the removed liquid. Therefore, when you drink a bottle of soda pop or juice, the bottle does not crush inward when some of the liquid is removed. Air moves into that space to equalize the pressure inside the bottle and outside the bottle. Likewise, gas lawnmowers generally have an air vent. That way, when gasoline is poured into the lawn mower, the air that was filling the space has a place to escape. Otherwise, the gasoline will splash all over as air from inside tries to rush out of the same hole into which you are pouring the gasoline.

- If you drink water from a straw, you may notice that a small amount of the liquid remains in the bottom of the straw if you pull the straw out of the liquid. The water stays in the straw without an index card or small piece of paper because the diameter of the straw is so small that the surface tension of the liquid alone keeps the liquid inside.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 28 ACTIVITY SHEET: Antigravity Water

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

____

____

2. Predict how these materials may be used. ____

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid		
Liquid		
Gas		
Cohesion		
Surface tension		
Adhesion		
Displacement		
Pressure		
Air pressure		

LESSON 28 ACTIVITY SHEET: Antigravity Water

4. Consider what will happen to an index card placed over the opening of a cup filled with water when the cup is inverted and why.

▶**Write your hypothesis.** ______________________________

____

____

PERFORM YOUR EXPERIMENT

1. Fill a cup at least halfway with water.
2. While the cup is still right-side up, place an index card over the rim. (Wet the rim slightly, and make sure the card covers the entire rim of the cup.)
3. While holding the index card in place with your palm, carefully flip the cup upside down. Try to keep the water from leaking out of the cup. Be careful not to squeeze the cup.
4. Let the water settle for a couple of seconds. Make sure the card is touching all the way around the rim, and then cautiously let go of the card. Observe what happens.

ANALYZE & CONCLUDE

1. What do you feel when you flip the cup upside down? ______________________________

____

____

2. What happens once you remove your hand from under the inverted cup? ______________________________

____

____

3. Why do you think this occurs? What forces are present? ______________________________

____

____

____

____

____

LESSON 28 ACTIVITY SHEET: Antigravity Water

4. What might happen if you squeeze the sides of the cup? Why? ______________________________

____

____

5. What do you think will happen if you remove the card while the cup is still upside down? Why? ___________

____

____

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________

____

____

LESSON 28 ACTIVITY SHEET: Antigravity Water

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance		

2. Why are water molecules considered polar substances? ______________________________

____

____

3. Would the experiment work with other liquids? Why or why not? ______________________________

____

____

____

LESSON 28 ACTIVITY SHEET: Antigravity Water

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Plastic cups, large bowl, index card ...

2. Predict how these materials may be used. A plastic cup may be filled with water. A large bowl may be used to hold a large amount of a substance. An index card may be used to take notes. These materials may be used to demonstrate the effects of pressure and surface tension.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid	A state of matter characterized by a definite volume and a definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	
Cohesion	An attractive force that holds atoms or ions of a single body together; an attraction between particles of the same kind.	
Surface tension	A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface "film."	
Adhesion	An attractive force that holds atoms or ions of different substances together.	
Displacement	The act of moving something out of its original position or of one substance taking the place of another.	
Pressure	The force exerted on an area; $p = F/A$	
Air pressure	The cumulative force exerted on a surface by the weight of the air particles above that surface.	

LESSON 28 ACTIVITY SHEET: Antigravity Water

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. Consider what will happen to an index card placed over the opening of a cup filled with water when the cup is inverted and why.

▶ **Write your hypothesis.** Water will remain in an inverted cup with only an index card covering the opening because of air pressure pushing on the card and the attractive forces of water molecules.

PERFORM YOUR EXPERIMENT

1. Fill a cup at least halfway with water.
2. While the cup is still right-side up, place an index card over the rim. (Wet the rim slightly, and make sure the card covers the entire rim of the cup.)
3. While holding the index card in place with your palm, carefully flip the cup upside down. Try to keep the water from leaking out of the cup. Be careful not to squeeze the cup.
4. Let the water settle for a couple of seconds. Make sure the card is touching all the way around the rim, and then cautiously let go of the card. Observe what happens.

ANALYZE & CONCLUDE

1. What do you feel when you flip the cup upside down? You feel movement of the water inside the cup and the increased pressure of the water on the index card.

2. What happens once you remove your hand from under the inverted cup? The index card remains attached to the cup, and the water stays in the cup.

3. Why do you think this occurs? What forces are present? If the cup is completely full of water, there is no air inside the cup. With no air, and therefore no air pressure inside the cup, the air pressure outside of the cup is greater than the air pressure inside. Therefore, the air pressure outside of the cup pushes up on the index card, forcing the card and water to stay in place. In addition, the adhesion of water molecules to the index card and the surface tension of the water molecules hold the index card in place. If the cup is not completely full, some of the water will leak out when the cup is inverted. As a result, the air pressure inside the cup will decrease, and the air pressure outside will push up and hold the index card in place.

LESSON 28 ACTIVITY SHEET: Antigravity Water

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. What might happen if you squeeze the sides of the cup? Why? Squeezing the sides of the cup breaks the surface tension of the water and releases the seal between the card and the cup. As a result, the water pours out.

5. What do you think will happen if you remove the card while the cup is still upside down? Why? The water will pour out of the cup because the card is no longer blocking the air from displacing the water in the cup.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 28 ACTIVITY SHEET: Antigravity Water

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	

2. Why are water molecules considered polar substances? The oxygen atom in a water molecule carries a partial negative charge, and the hydrogen atoms carry partial negative charges.

3. Would the experiment work with other liquids? Why or why not? Some liquids may behave like water because the attractive forces in the liquid are similar to those in water. However, other liquids may not work. Carbonated beverages, such as soda pop, will not stay inside the cup because the dissolved carbon dioxide gas in the liquid exerts extra pressure inside the glass. Therefore, the attractive forces acting on the liquid and the air pressure outside of the cup are not enough to hold the index card in place.

LESSON 29: Solid or Liquid?

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 10–15 minutes

• DESCRIPTION

Mix cornstarch and water to demonstrate the properties of a non-Newtonian fluid.

• OBJECTIVE

This lesson demonstrates the properties of a non-Newtonian fluid. Students experiment with a new substance to determine its state of matter. The lesson can be simplified to address the basic states of matter and the obstacles that can arise when classifying matter.

• CONTENT TOPICS

Scientific inquiry; states of matter; properties of matter (viscosity); mixtures; force

• MATERIALS

- ❑ Box of cornstarch (16 oz)
- ❑ Water
- ❑ Large bowl
- ❑ Large spoon
- ❑ Cake pans
- ❑ Plastic bag (for dispoal)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 358 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, books, dishes, and cornstarch. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and orange juice. **Gases** have no definite shape and no definite volume. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Along with differences in shape and volume, the different states of matter have other unique properties. Liquids and gases are considered fluids. A **fluid** is any substance made up of particles that flow or move freely. A fluid easily changes shape when a force is applied. For example, if you push on a balloon filled with gas, you can easily change its shape. Likewise, if you push on a balloon filled with water, you can change the water balloon's shape as well.

The "thickness" of a fluid is described by a property called viscosity. **Viscosity** is a measure of a fluid's (generally a liquid's) resistance to flow. The higher the viscosity of a fluid, the slower it will flow. For example, honey has a high viscosity; therefore, it flows very slowly when poured out of a container. Honey is considered a viscous liquid—one with a high viscosity.

Most fluids are classified as Newtonian fluids (after the famous scientist and mathematician Sir Isaac Newton). When temperature remains constant, a **Newtonian fluid** has a viscosity that remains constant, regardless of any

LESSON 29: Solid or Liquid?

applied force or the rate of flow. Thus, a Newtonian fluid will continue to flow and act in its usual manner no matter what forces are applied. Water is an example of a Newtonian fluid. No matter how fast you stir, pour, or disturb the water, it will have the same viscosity.

On the contrary, a **non-Newtonian fluid** is one that has a viscosity that varies based on the force applied or how fast an object is moving through the liquid. Depending on the exact non-Newtonian fluid, it may become more or less viscous when a force is applied. When a force is applied to some non-Newtonian fluids, they exhibit properties of a solid. For other non-Newtonian fluids, exerting a force makes it flow quicker or easier. Examples of non-Newtonian fluids are ketchup, yogurt, gravy, and cornstarch "paste."

As you will see in this lesson, a non-Newtonian fluid can be made by mixing cornstarch and water (making a cornstarch paste). This mixture will act as a fluid under normal conditions, but if a force is applied, the mixture will exhibit properties of a solid. Applying a force to the mixture drastically increases its viscosity. If you apply a constant force to the mixture, eventually the pressure will equalize, and the mixture will act like a liquid again.

FORMULAS & EQUATIONS

Pure water is comprised of two hydrogen atoms and one oxygen atom.

The chemical formula for pure water is $\mathbf{H_2O}$.

This formula illustrates that a molecule of water is comprised of two hydrogen atoms and one oxygen atom.

Cornstarch is made up of starch granules separated from the mature grains of corn. It is a very fine white to slightly yellowish powder. Starches are complex sugars (polysaccharides) made up of glucose molecules, and there are many different sizes and structures for these glucose polymers. The two main types of starch are amylose and amylopectin. Generally, cornstarch consists of 25% amylose and 75% amylopectin.

The chemical formula for a basic starch molecule is $\mathbf{(C_6H_{10}O_5)_n}$. *The* n *stands for any number of molecules.*

Therefore, starches are complex polymer chains of carbon, hydrogen, and oxygen.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states and properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶When pressure is applied to a mixture of cornstarch and water, its viscosity will change, causing it to exhibit properties of a solid.

Fun Fact

If a pool is filled with the non-Newtonian cornstarch mixture outlined in this lesson, a person can actually run across it.

LESSON 29: Solid or Liquid?

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Mix cornstarch and water to discuss properties of matter.

OBJECTIVE

This lesson introduces ways to classify matter and discusses some challenges to classifying matter.

OBSERVATION & RESEARCH

Matter exists primarily as a solid, liquid, or gas on the earth. The motion of the particles within a solid, liquid, and gas are different. For example, the molecules of H_2O move differently in the form of ice than they do in the form of water vapor.

The particles in a **solid** are generally locked into place giving the solid substance a definite shape and volume. The particles are held together tightly. However, the particles are not completely still. They do move but not freely. They only vibrate slightly in place. Examples of solids are chairs, books, dishes, and cornstarch.

Particles in a **liquid** are not as close as particles in a solid, and they move more freely. The particles roll over each other, which is why liquids flow. However, liquids still experience weak forces of attraction. These attractive forces make the liquid particles remain fairly close to one another as they slide past one another. Therefore, liquids do not have definite shapes, but they have definite volumes. They take the shape of the vessel that contains them, filling the bottom of the container first. Examples of liquids are water and orange juice.

The particles in a **gas** are spaced far apart. They do not have strong bonds or attractions between them. Therefore, they move about freely and rapidly in random directions. Particles in a gas can move over very large distances and go much farther than liquids without touching another particle. Gases do not have a definite shape or volume. If a gas is put into a container, it will take the shape of the container, filling that container completely. Examples of gases are the oxygen we breathe and the helium that fills balloons.

Liquids and gases are fluids. A **fluid** is any substance made up of particles that flow or move freely. A fluid easily changes shape when a force is applied. For example, if you push on a balloon filled with gas, you can easily change its shape. Likewise, if you push on a balloon filled with water, you can change the water balloon's shape.

Not all matter is easily classified as a solid, liquid, or a gas. Peanut butter, gravy, and the cornstarch mixture made in this experiment are all unique types of matter. They are known as non-Newtonian fluids because they can exhibit different properties based on the amount of force applied. The cornstarch mixture behaves as a liquid under normal conditions, but when a force is applied, it behaves as a solid.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 358, but discuss viscosity in greater detail. For Newtonian fluids, viscosity changes with temperature. In general, increasing the temperature of the fluid decreases its viscosity. At room temperature, honey flows relatively slowly. However, if you heat up the honey, it will flow more easily.

Another option is to discuss the concept of shear stress. **Shear stress** is a pressure or force in the structure of a substance that arises when its layers are shifted horizontally in relation to each other. Students can imagine a flowing liquid as a group of liquid layers sliding past each other. A liquid's resistance to flow arises because of the "friction" between those layers. According to Newton, the slower a layer slides over another layer, the less resistance it experiences. If the speed doubles, so does the resistance. If there was no difference in the speeds of the layers, the liquid would have no resistance to flow. Liquids that follow this model are Newtonian fluids. On the other hand, in some fluids, if the speed of the layers sliding past one another doubles, the resisting force does not double. When this happens, the fluid may experience less resistance (like ketchup) or more than double the resistance (like the cornstarch mixture). These are the non-Newtonian fluids.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on states and properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 29: Solid or Liquid?

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the amount of water in the mixture, does the mixture behave differently?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Mix cornstarch and water in a bowl, using about a quarter of the box of cornstarch at a time, until you have a uniform gooey consistency. If you smack your hand on the mixture and cause significant splashing, the mixture has too much water. Simply add more corn starch. If the mixture is grainy, add more water.
2. Pour the mixture into a cake pan. You are now ready to test the properties of the fluid.
3. Smack the mixture and observe its reaction. It should not splash.
4. Scoop up some of the mixture and hold your hand over the cake pan. Open your fingers and watch as the mixture flows through your fingers. You can also lift some of the mixture in a spoon. Then tilt the spoon to watch the mixture flow out.

It may be easier to mix the cornstarch and water and get a uniform consistency if you use your hands. Gloves should be worn to protect your hands and minimize the mess.

DO NOT pour the mixture down the drain when disposing of it! The cornstarch and water will eventually separate and the thick cornstarch can clog the pipes. Pour the mixture into a plastic bag, and throw it away in a trash can. You can also choose to let the mixture sit until it separates. Then, carefully pour off some of the water, and pour the rest of the mixture into a plastic bag and throw it away.

To reduce waste, you can do the experiment as a demonstration.

NOTES

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. In which state of matter is the cornstarch? In which state of matter is water? In which state of matter is the cornstarch mixture? You can use the chart in the activity sheet (or a similar one of your own) for students to record their data.

LESSON 29: Solid or Liquid?

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Distinguish between the different states of matter.
- Define and give examples of fluids.
- Explain the property of viscosity and provide examples of liquids with high and low viscosities.
- Compare and contrast Newtonian and non-Newtonian fluids.
- Understand the effects of forces on the viscosity of a non-Newtonian fluid.
- Identify ways to change the viscosity of a fluid (see ***Differentiation in the Classroom***).
- Explain the concept of shear stress (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Prepare the mixture before the lesson, and use a pan of water for comparison. Pour both of the fluids into separate containers to show that they behave similarly. Stick your fingers in both to demonstrate the fluid properties. Now ask the students what will happen if you smack each of the fluids. Students will be surprised to see that there is no splatter when you smack the cornstarch mixture! Then, let them touch the water and cornstarch mixture. See if they can figure it out what is occurring.
- Start a discussion about a crowded hallway. Is it more difficult to move through a crowded hallway when other people are moving in different directions? How do they get through the crowd? Do they run or walk slowly? Point out that it is usually easiest to find an open path between all of the people and move through slowly. If you ran straight into the crowd, you would most likely slam into another person and not get very far. Explain that the particles in the cornstarch mixture act like a large crowd of people in a hallway. Pressing your hand into the mixture slowly allows the particles to move out of the way. However, smacking the mixture quickly doesn't allow the particles to slide past one another and move out of the way.

REAL-WORLD APPLICATIONS

- Non-Newtonian fluids like the cornstarch mixture and gravy become more resistant to flow as a force is applied. When you smack the cornstarch mixture, it behaves as a solid. Likewise, stirring gravy more quickly, causes the gravy to thicken. Other non-Newtonian fluids, like ketchup, become less resistant when a force is applied. If you stir or shake a bottle of ketchup, it becomes easier to pour out of the container.
- Quicksand is a non-Newtonian fluid that behaves like ketchup. It will become less viscous when a force is applied. Moving your legs slowly in the quicksand will apply a steady force. This force reduces the resistance of the quicksand and creates a space between your legs and the sand so the water can flow and loosen the sand. Therefore, you can get out by slowly moving toward solid ground.

  The belief that moving in quicksand will make a person sink completely is a myth. Struggling will cause you to sink a bit as the quicksand flows more easily, but it will not cause you to sink completely. People are less dense than quicksand, so they will only sink to about waist level. However, quicksand can still be dangerous. It is often found near the ocean or sea, so a person caught in quicksand can drown as the tides rise, if he or she does not get out in time. Panicking and moving too quickly can create other problems. If you stop moving, the quicksand will behave like a solid, trapping you inside. If someone tugs on you quickly, you could get seriously injured.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 29 ACTIVITY SHEET: Solid or Liquid?

OBSERVE & RESEARCH

1. Write down the materials you observe.

2. Predict how these materials may be used.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid		
Liquid		
Gas		
Fluid		
Viscosity		
Newtonian fluid		
Non-Newtonian fluid		

4. Consider how force applied to a mixture of cornstarch and water may affect how the mixture behaves and why.

▶ **Write your hypothesis.**

LESSON 29 ACTIVITY SHEET: Solid or Liquid?

PERFORM YOUR EXPERIMENT

1. Mix cornstarch and water in a bowl until you have a uniform, gooey consistency. If you smack the mixture with your hand and there is significant splashing, the mixture has too much water. You must add more cornstarch. If the mixture is too dry, add more water.

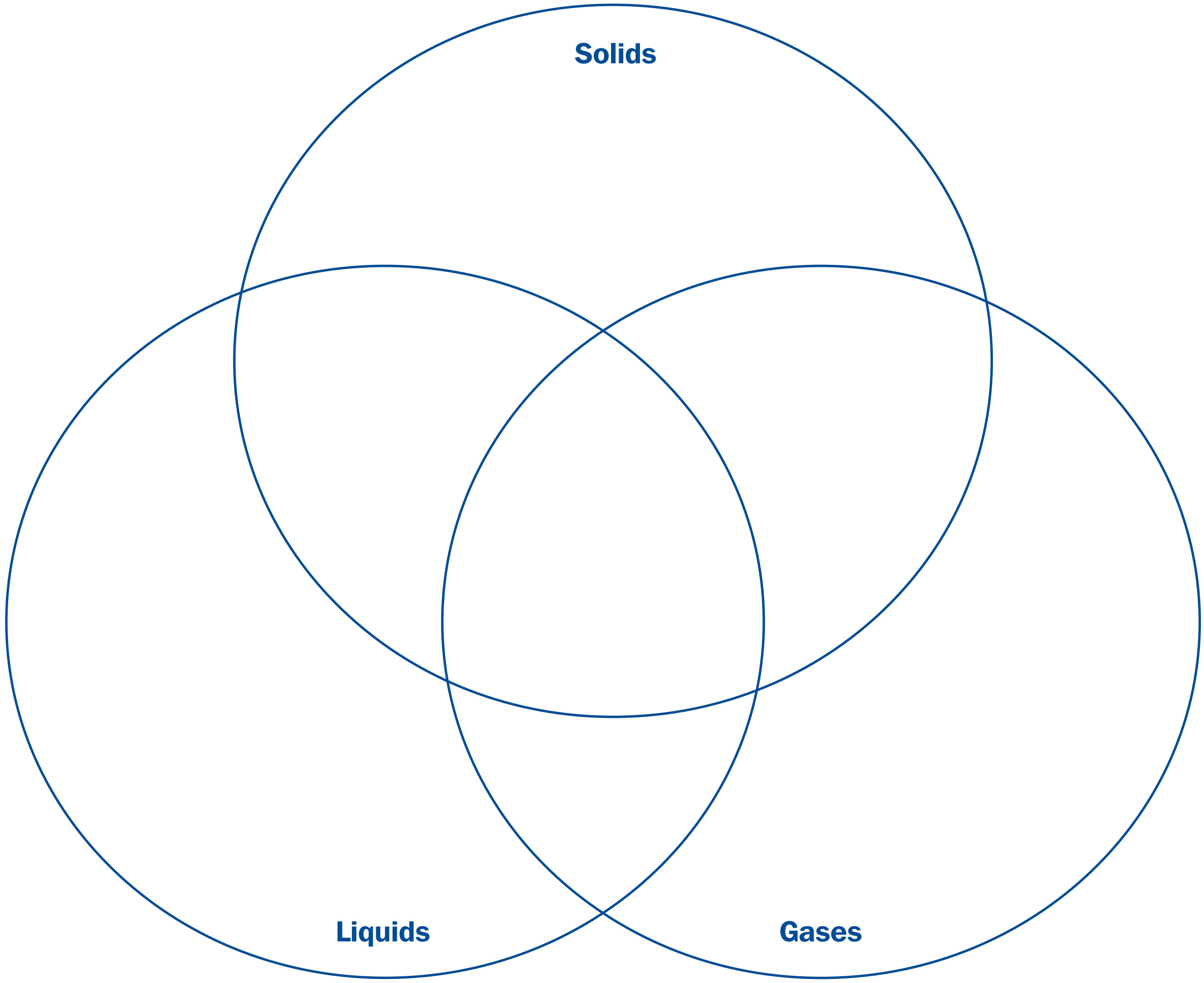
2. Pour the mixture into a cake pan.

3. Smack the mixture, and observe what happens.

4. Scoop up some of the mixture in your hand, and hold it over the cake pan. Then, open your fingers, and watch what happens. You can also lift some of the mixture in a spoon. Then tilt the spoon to watch the mixture flow out.

ANALYZE & CONCLUDE

1. Compare and contrast solids, liquids, and gases using the diagram below.



LESSON 29 ACTIVITY SHEET: Solid or Liquid?

2. Describe the properties of the cornstarch. Is it a solid, liquid, or gas? ______________________________

____

____

3. Describe the properties of the water. Is it a solid, liquid, or gas? ______________________________

____

____

4. Describe the properties of the mixture. How does it feel? ______________________________

____

____

5. What happens when you smack the mixture? ______________________________

____

____

6. Do you think the mixture is a solid, liquid, or gas? Why? ______________________________

____

____

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________________________

____

____

LESSON 29 ACTIVITY SHEET: Solid or Liquid?

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Shear stress		

2. How can the viscosity of a Newtonian fluid change? Provide an example. ______________________________________

____

____

3. Humans have a non-Newtonian fluid that runs throughout their bodies. What do you think it is and why? __________

____

____

LESSON 29 ACTIVITY SHEET: Solid or Liquid?

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Cornstarch, water, bowl, spoon, cake pans, plastic bag ...

2. Predict how these materials may be used. Cornstarch may be used in cooking. Water may be used for drink, clean, or bathe. A bowl and spoon may be used to stir a mixture. Cake pans may be used to hold a substance. Together, these materials may be used to explore states and properties of matter.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Solid	A state of matter characterized by a definite volume and definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	
Fluid	Any substance made up of particles that flow or move freely, such as a liquid or gas.	
Viscosity	The measure of a fluid's thickness or resistance to flow.	
Newtonian fluid	A fluid that has a constant viscosity at a constant temperature, regardless of any applied force or rate of flow.	
Non-Newtonian fluid	A fluid that does not have a constant viscosity; the viscosity of a non-Newtonian fluid varies based on the force applied or how fast an object is moving through the liquid.	

4. Consider how force applied to a mixture of cornstarch and water may affect how the mixture behaves and why.

▶**Write your hypothesis.** When a force is applied to a mixture of cornstarch and water, its viscosity will change, causing it to exhibit properties of a solid.

LESSON 29 ACTIVITY SHEET: Solid or Liquid?

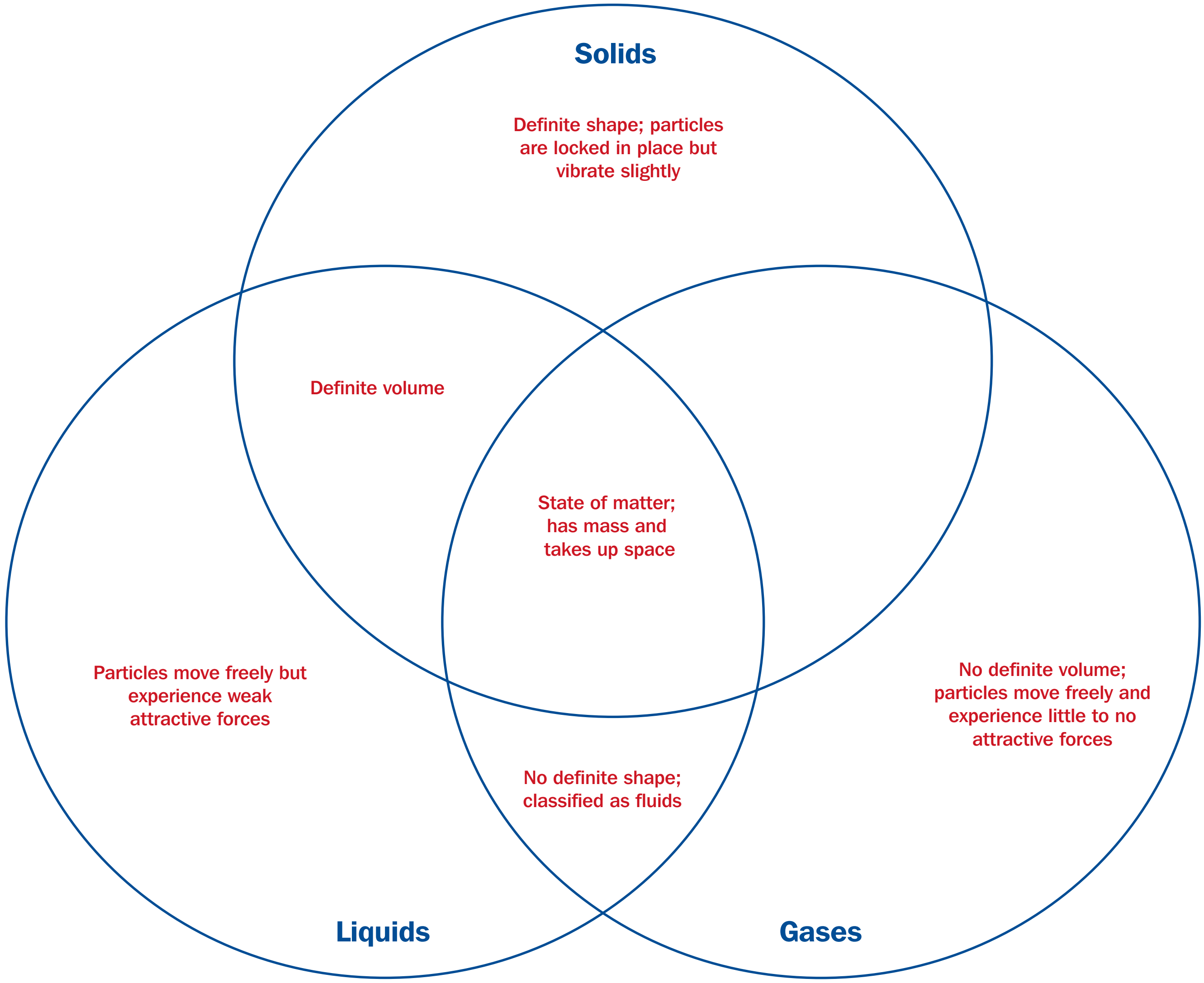
ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Mix cornstarch and water in a bowl until you have a uniform, gooey consistency. If you smack the mixture with your hand and there is significant splashing, the mixture has too much water. You must add more cornstarch. If the mixture is too dry, add more water.
2. Pour the mixture into a cake pan.
3. Smack the mixture, and observe what happens.
4. Scoop up some of the mixture in your hand, and hold it over the cake pan. Then, open your fingers, and watch what happens. You can also lift some of the mixture in a spoon. Then tilt the spoon to watch the mixture flow out.

ANALYZE & CONCLUDE

1. Compare and contrast solids, liquids, and gases using the diagram below.



LESSON 29 ACTIVITY SHEET: Solid or Liquid?

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. Describe the properties of the cornstarch. Is it a solid, liquid, or gas? Cornstarch is a solid. It is a powdery substance with a white or yellowish color.

3. Describe the properties of the water. Is it a solid, liquid, or gas? Water is a liquid that is clear and flows easily.

4. Describe the properties of the mixture. How does it feel? The mixture feels soft but sticky. It flows like a fluid when you move your finger or a spoon through the mixture.

5. What happens when you smack the mixture? The mixture exhibits properties of a solid. Applying pressure will increase the mixture's viscosity.

6. Do you think the mixture is a solid, liquid, or gas? Why? The mixture is not easily classified. It is considered a non-Newtonian fluid, so it is a special type of liquid. This specific mixture exhibits properties of a solid when a force is applied.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 29 ACTIVITY SHEET: Solid or Liquid?

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key term. Then, provide an example of it by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Shear stress	A pressure or force in the structure of a substance that arises when its layers are shifted horizontally in relation to each other.	

2. How can the viscosity of a Newtonian fluid change? Provide an example. The viscosity of a Newtonian fluid can be changed by changing the temperature. For example, if honey is heated, it will flow more easily.

3. Humans have a non-Newtonian fluid that runs throughout their bodies. What do you think it is and why? Blood is a non-Newtonian fluid in the human body. Its viscosity can change with changes in pressure or shear stress.

LESSON 30: Balloon in a Bottle

ESTIMATED TIME **Setup:** 5–10 minutes | **Procedure:** 10–15 minutes

• DESCRIPTION

Place a balloon over a Pyrex® glass bottle or flask to observe the behavior of the balloon in response to changes in temperature.

• OBJECTIVE

This lesson uses a balloon and a Pyrex® glass bottle to demonstrate the relationship between temperature and volume of a gas. Students place a balloon over the opening of a Pyrex® glass bottle or flask and observe the reaction of the balloon to differences in temperature. The lesson can be extended to address the relationship between energy and temperature.

• CONTENT TOPICS

Scientific inquiry; measurement (temperature); states of matter; properties of matter (gas laws); energy

• MATERIALS

- ❑ Pyrex® glass vessel (bottle or flask)
- ❑ Balloon
- ❑ Water
- ❑ Hot plate (a coffee hot plate will work as well)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 371 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter is defined as anything that has mass and takes up space. It is everything around us! People characterize and classify matter by its properties. Two basic properties of matter are mass and volume. **Mass** is a measure of the amount of matter in a substance. The mass of an object can be measured with a balance. To determine the mass of an object, the object is compared to another object with a mass that is known. The unit of measurement that scientists use to measure mass is the kilogram (kg) or gram (g). **Volume** is a measure of the amount of space an object occupies and can be measured in a number of different ways. Volume is measured in liters or cubic units, such as cubic centimeters.

Matter exists primarily as a solid, liquid, or gas on the earth. **Solids** have a definite volume and a definite shape. Examples of solids are chairs, glasses, and trees. **Liquids** have a definite volume but no definite shape. Examples of liquids are water and oil. **Gases** have no definite shape and no definite volume. The volume and shape of a gas are determined by the vessel that contains it. Examples of gases include oxygen, nitrogen, and argon, which along with other gases, make up the air around you.

Likewise, different forms of energy can be identified by different properties as well. **Energy** is a measure of the ability to do work or generate heat. Energy is found in many forms and can change from one form to another. Some forms of energy include kinetic energy, chemical energy, thermal energy, and light.

Temperature is a measure of the average kinetic energy (energy of motion) of particles in a substance. It is a measure of how fast the particles are moving around.

LESSON 30: Balloon in a Bottle

The temperature of a substance is measured using a thermometer.

Gases are defined by a set of laws known as the gas laws, which describe the relationships between volume, temperature, and pressure. One of those laws, **Charles' Law**, explains the relationship between temperature and volume. Charles' Law states that the volume and temperature of a gas are directly proportional. As the temperature of a gas increases, the volume of the gas increases at a proportional rate. (Proportional means that they change at a constant rate. For example, $^{1}/_{2}$ is proportional to $^{2}/_{4}$ and $^{3}/_{6}$.)

In this lesson, a balloon is placed over the opening of a glass vessel. As the air inside the glass vessel is heated, it expands, causing the balloon to inflate. When the hot air is cooled, the volume of the gas decreases and tries to pull more air in from the outside. As this occurs, the balloon is pulled inside the vessel.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on measurement can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on states and properties of matter can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶A balloon placed over the opening of a glass vessel will inflate as the vessel is heated because of the relationship between the temperature and volume of a gas. Likewise, when the heated vessel is cooled, the balloon will be pulled into the bottle because of the decrease in temperature and volume.

FORMULAS & EQUATIONS

Charles' Law: The volume and temperature of a gas are directly proportional. Therefore, the proportion of volume to the temperature of a gas equals a constant.

$V/T = K$, *where* V *is volume,* T *is temperature, and* K *is a constant.*

Because the formula is equal to a constant, it is possible to solve for a change in volume or temperature using the following proportion:

$V_1/T_1 = V_2/T_2$

The other gas laws include the following:

Boyle's Law: At a constant temperature, the product of the pressure and the volume of an ideal gas is constant.

$PV = K$, *where* P *is pressure,* V *is volume, and* K *is a constant.*

Boyle's law can also be used to solve for a change in pressure or volume using the following equation:

$P_1V_1 = P_2V_2$

Gay-Lussac's Law: The pressure exerted on a container by a gas is directly proportional to the temperature of the gas.

$P/T = K$, *where* P *is pressure,* T *is temperature, and* K *is a constant.*

Again, Gay-Lussac's Law can be used to calculate changes in pressure or temperature using the following proportion:

$P_1/T_1 = P_2/T_2$

Avogadro's Law: Equal volumes of gases at the same temperature and pressure contain the same number of molecules (n) regardless of their chemical nature and physical properties. This number (Avogadro's number) is 6.022×10^{23}.

$V/n = K$, *where* V *is volume,* n *is the number of molecules, and* K *is a constant.*

Finally, the **ideal gas law** is a combination of these laws that relates temperature, pressure, and volume.

$PV = nRT$, *where* P *is pressure,* V *is volume,* T *is temperature,* n *is the number of molecules, and* R *is the ideal gas constant.*

The equation is called "ideal" because it is based on a hypothetical ideal gas. However, this law serves as a useful approximation for most gases under most conditions.

LESSON 30: Balloon in a Bottle

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 371, but spend more time on the different states of matter and their properties. Name items in the classroom, and ask the students to say whether they are solids, liquids, or gases. In which state is the glass bottle? Solid! It has a definite shape and volume. In which state is the water? Liquid! It has a definite volume but no definite shape. Pour the water into different containers to illustrate how the shape changes but not the volume. In which state is the substance inside the balloon? Gas! It has no definite shape or volume. Discuss with the class how they know certain gases exist if they can't see them.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Place a balloon over a Pyrex® glass bottle or flask to observe the behavior of the balloon in response to changes in temperature.

OBJECTIVE

This lesson uses a balloon and a Pyrex® glass vessel to demonstrate the relationship between the temperature and volume of a gas. It also addresses the relationship between energy and temperature.

OBSERVATION & RESEARCH

Energy is defined as the capacity to do work or produce heat. Energy can take many different forms, including light, sound, electricity, chemical bonds, mechanical motion, and thermal energy. The **law of conservation of energy** (first law of thermodynamics) states that while energy can change from one form to another, it can neither be created nor destroyed. When matter changes, whether through a physical or chemical change, the amount of energy in the system is the same before and after the changes, but the energy may be in a different form or forms.

Temperature is a measure of the average kinetic energy (energy of motion) of particles in a substance. It is a measure of how fast the particles are moving around. The temperature of a substance is measured using a thermometer. Temperature, thermal energy, and heat are related, but they are not the same thing.

Thermal energy is the total energy of particles in a substance. The transfer of thermal energy from an object at a higher temperature to an object at a lower temperature is known as **heat**. Heat is commonly transferred (moved from one substance to another) in one of three ways—conduction, convection, or radiation.

Conduction is the transfer of energy by collisions between nearby atoms. Conduction is the most common means of heat transfer in solid matter. For example, on a hot summer day, if you grab the handle of a car door, the heat will move from the door handle to your hand. If you touch that hand to your face, you will notice that your hand will feel warmer than usual because of the energy transfer.

Convection is the transfer of energy by the bulk molecular motion within a liquid or gas. Convection occurs because of temperature differences within the fluid or between the fluid and its container. You may notice the results of convection in homes or buildings that are a few stories high. If there are not special temperature controls on each floor, the upper floors will often be warmer than the bottom floor because the hot air will rise and the cooler air will fall.

Radiation is the transfer of energy (as electromagnetic waves) through an empty space or clear material without heating the empty space or clear material. The most common form of radiation is solar radiation. In solar radiation, the rays from the sun heat up the earth.

In this experiment, when the Pyrex® glass vessel is heated, conduction causes the heat from the hot plate to transfer through the bottle and to the water and gas inside.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of measurements can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on energy changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on energy and heat can be found in the Energy section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 30: Balloon in a Bottle

DIFFERENTIATION IN THE CLASSROOM

The liquid inside begins to vaporize as it becomes warmer. In addition, the liquid and gases inside the vessel transfer the heat through convection, causing the hot air to rise. The heated gas also expands according to Charles' Law, causing the balloon to inflate. When the hot air is cooled, the volume of the gas decreases and tries to pull more air in

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the temperature of the gas, does the volume of the gas change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

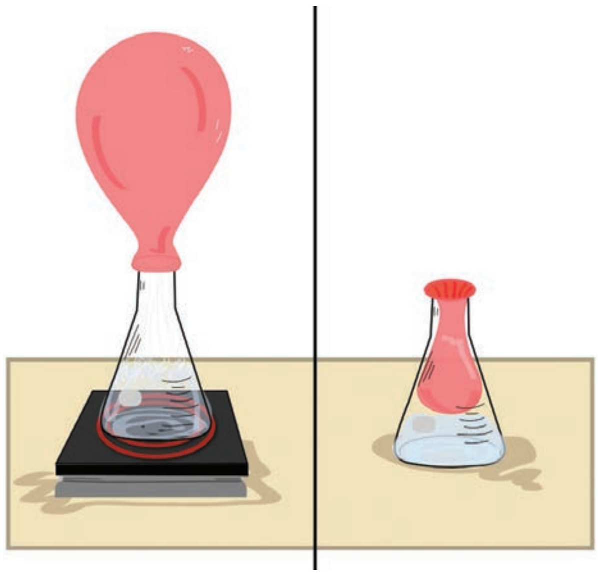
Part One

1. Fill the Pyrex® glass vessel with no more than a half cup of cold tap water.
2. Place a balloon over the opening of the vessel.
3. Place the vessel on a hot plate and heat it.
4. Watch as the balloon inflates. Note that the expansion of the balloon is mainly a result of the expansion of the air inside. However, some of the expansion results from the water vapor that is released from the heated water.
5. Remove the vessel from the heat, and allow it to cool for a few minutes.

Be careful while handling hot items. If a hot plate is not available, microwaving the water for a few minutes will also work.

Part Two

1. Fill the Pyrex® glass vessel with no more than a half cup of hot tap water, and place it on a hot plate. Heat the vessel until the water begins to boil.
2. Take the vessel off of the hot plate and allow the boiling water to sit for about 10 seconds.
3. Place a balloon over the opening of the vessel.
4. Let the solution cool, and observe the balloon as it is sucked into the vessel. (Freeze or refrigerate the vessel to speed up this process.)



DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What is inside the glass container? What occurs when the container is heated? What happens when the container is cooled? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

Fun Fact

Pyrex® is a brand name for a type of glassware made from borosilicate glass (primarily made of silica and boron oxide). Borosilicate glass is less dense and more resistant to thermal shock than regular glass.

LESSON 30: Balloon in a Bottle

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and identify different types of measurements, such as mass, volume, and temperature.
- Differentiate between the different states of matter.
- Describe the relationship between the temperature and volume of a gas and understand that this relationship is known as Charles' Law.
- Describe the relationships between temperature, pressure, volume, and amount of gas.
- Define energy and explain the law of conservation of energy (see ***Differentiation in the Classroom***).
- Compare and contrast the different types of heat transfer (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Before the lesson begins, tell the students you can inflate a balloon without blowing into it. Ask them if they know how this is possible.
- If it is not possible to use a Pyrex® glass vessel and a hot plate, the volume and temperature relationship can still be demonstrated using empty 2-liter plastic soda pop bottles. Run the bottle with the cap off under hot water for a minute or two. Immediately place the cap on, and place the bottle in a refrigerator, freezer, or ice bath for 10 minutes. Upon removing the bottle, it should look like someone squeezed it. The reduction of temperature has caused a reduction of volume within the bottle. Run the bottle under hot water again, with the cap still on, and the bottle should return to its original shape.
- Give the students balloons, and tell them to ask their parents if they can try an experiment at home. Instruct them to partially (not completely) blow up the balloon, tie it tight, and then put it in their freezer. They should then check the balloon 10 minutes later. The balloon should be smaller.

REAL-WORLD APPLICATIONS

- Charles' Law is used to explain the operation of a hot-air balloon. An object will float when it weighs less than the fluid it displaces. **Displacement** is the act of moving something out of its original position or of one substance taking the place of another. When a gas is heated, it expands. Since density is defined as the amount of matter per unit of volume, as the volume of the air increases, its density decreases. Therefore, hot air is less dense than cold air and will rise above the cold air. Once the air in a balloon gets hot enough, the combined weight of the balloon plus this hot air is less than the weight of an equal volume of cold air outside that it is displacing. As a result, the balloon starts to rise. The balloon will return to the ground when the gas in the balloon is allowed to cool.
- The air pressure in a car tire (not the actual rubber) is primarily responsible for supporting the weight of a car. People who live in areas where temperature changes significantly with the seasons should check the air pressure in their tires often. The changes in temperature will change the pressure within the tire.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

OBSERVE & RESEARCH

1. Write down the materials you observe. ____

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2. Predict how these materials may be used. ____

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3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter		
Mass		
Volume		
Solid		
Liquid		
Gas		
Energy		
Temperature		

LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

4. Consider what will happen when a balloon attached to the opening of a glass vessel is heated and then cooled and why.

▶ **Write your hypothesis.** ____

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PERFORM YOUR EXPERIMENT

Part One

1. Fill the Pyrex® glass vessel with no more than a half cup of cold tap water.
2. Place a balloon over the opening of the vessel.
3. Have your teacher place the vessel on a hot plate and heat it. Observe the balloon.
4. Once your teacher removes the vessel from the hot plate, allow it to cool for a few minutes.

Part Two

1. Fill the Pyrex® glass vessel with no more than a half cup of hot tap water. Have your teacher heat the vessel on a hot plate until the water begins to boil.
2. Have your teacher take the vessel off the hot plate, and allow the boiling water to sit for about 10 seconds.
3. Place a balloon over the opening of the vessel.
4. Let the solution cool and observe the balloon. You can also freeze or refrigerate the vessel to speed up the process.

ANALYZE & CONCLUDE

1. In Part One, what happens to the balloon when it is placed on top of the vessel filled with cold tap water, and the vessel is heated? ____

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2. In Part Two, what happens to the balloon when it is placed on top of the vessel filled with heated tap water and then allowed to cool? ____

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LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

3. What is Charles' Law, and how does it relate to this experiment? ______________________________

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4. What is Boyle's Law? ____

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5. What is Gay-Lussac's Law? ____

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6. What is the ideal gas law? ____

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7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________

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LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Law of conservation of energy		
Thermal energy		
Heat		
Conduction		
Convection		
Radiation		

2. What relationships are described by the gas laws? ______________________________

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3. How is the energy transferred in this experiment? Explain. ______________________________

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LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. A Pyrex® glass vessel, balloons, water, hot plate …

2. Predict how these materials may be used. A Pyrex® glass vessel may be used in the lab to heat a substance. Balloons may be used as decorations. Water may be used to drink or boil food. A hot plate may be used to heat a substance. These materials may be used to demonstrate the physical properties of water and air.

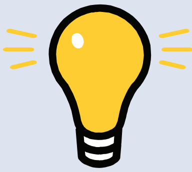
3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter	Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth.	
Mass	A measure of the amount of matter in a substance.	
Volume	A physical property that measures the amount of space a substance occupies.	
Solid	A state of matter characterized by a definite volume and definite shape.	
Liquid	A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first.	
Gas	A state of matter that has no definite volume or shape; a gas will take the shape of the container that holds it, filling the entire container.	
Energy	The ability to do work or produce heat.	
Temperature	A measure of the average kinetic energy of particles in a substance, generally identified by sensations of hot and cold.	

LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. Consider what will happen when a balloon attached to the opening of a glass vessel is heated and then cooled and why.



▶ **Write your hypothesis.** A balloon placed over the opening of a glass vessel containing cold water will inflate as the vessel is heated because of the relationship between the temperature and the volume of a gas. Likewise, when the heated vessel is cooled, the balloon will be pulled into the bottle because of the decrease in temperature and volume.

PERFORM YOUR EXPERIMENT

Part One

1. Fill the Pyrex® glass vessel with no more than a half cup of cold tap water.
2. Place a balloon over the opening of the vessel.
3. Have your teacher place the vessel on a hot plate and heat it. Observe the balloon.
4. Once your teacher removes the vessel from the hot plate, allow it to cool for a few minutes.

Part Two

1. Fill the Pyrex® glass vessel with no more than a half cup of hot tap water. Have your teacher heat the vessel on a hot plate until the water begins to boil.
2. Have your teacher take the vessel off the hot plate, and allow the boiling water to sit for about 10 seconds.
3. Place a balloon over the opening of the vessel.
4. Let the solution cool, and observe the balloon. You can also freeze or refrigerate the vessel to speed up the process.

ANALYZE & CONCLUDE

1. In Part One, what happens to the balloon when it is placed on top of the vessel filled with cold tap water, and the vessel is heated? The balloon increases in size when the vessel and the air inside is heated.

2. In Part Two, what happens to the balloon when it is placed on top of the vessel filled with heated tap water and then allowed to cool? The balloon is pulled inside the vessel.

LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

3. What is Charles' Law, and how does it relate to this experiment? Charles' Law states that the volume and temperature of a gas are directly proportional. As the temperature of a gas increases, the volume of the gas increases at a proportional rate. In this experiment, as the gas in the vessel is heated, the volume of the gas increases, causing the balloon to expand.

4. What is Boyle's Law? Boyle's Law states that at at constant temperature, the product of the pressure and the volume of an ideal gas is always constant.

5. What is Gay-Lussac's Law? Gay-Lussac's Law states that the pressure exerted on a container by a gas is directly proportional to the temperature of the gas.

6. What is the ideal gas law? The ideal gas law is a combination of the gas laws that relate temperature, pressure, and volume. It is represented by the equation $PV = nRT$.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as

LESSON 30 ACTIVITY SHEET: Balloon in a Bottle

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Law of conservation of energy	A scientific law stating that while energy can change form, it cannot be created or destroyed; also known as the first law of thermodynamics.	
Thermal energy	The total energy of particles in a substance.	
Heat	The flow of thermal energy from one substance to another because of differences in temperature.	
Conduction	The transfer of energy by collisions between nearby atoms.	
Convection	The transfer of energy by the bulk molecular motion within a liquid or gas.	
Radiation	The transfer of energy (as electromagnetic waves) through an empty space or clear material without heating the empty space or clear material.	

2. What relationships are described by the gas laws? The relationships described by the gas laws include those between pressure and volume, volume and temperature, pressure and temperature, and volume and the amount of moles.

3. How is the energy transferred in this experiment? Explain. Heat is transferred from the hot plate to the glass vessel and the water inside by conduction. The heat is then transferred between the water and air in the bottle through convection.

LESSON 31: Marshmallow Launcher

ESTIMATED TIME **Setup:** 10–15 minutes | **Procedure:** 15–20 minutes

• DESCRIPTION

Launch marshmallows from a plastic-spoon catapult to demonstrate the differences between potential and kinetic energy and explore the law of conservation of energy.

• OBJECTIVE

This lesson examines properties of matter and introduces kinetic and potential energy and energy transfer. Students create a catapult using a plastic spoon, and explore ways to make marshmallows travel the farthest through the air. The lesson can be extended to discuss other forms of energy.

• CONTENT TOPICS

Scientific inquiry; measurement; properties of matter; energy (potential, kinetic)

• MATERIALS

- ❑ Plastic spoons
- ❑ 1–2 bags of miniature marshmallows
- ❑ Permanent marker
- ❑ Tape measure or yardstick
- ❑ Masking tape
- ❑ Protractor (optional)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 385 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- PS3.C: Relationship Between Energy and Forces
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Matter is defined as anything that has mass and takes up space. It is everything around us! People characterize and classify matter by its properties. One of those properties is mass. Mass is a measure of the amount of matter in a substance. The mass of an object can be measured with a balance. Mass is used to determine a variety of other measurements, properties, and changes in matter, such as force, kinetic energy, and more.

Energy is defined as the ability to do work or generate heat. Work occurs when a force causes an object to be displaced—to move from its original position. A force is a push or pull on an object. Work is a measure of the change in energy. In order for work to be done, some object must supply the force, and it must possess some form of energy to supply that force. If someone picks up a box from the ground and puts it on a table, the person supplies the force that acts on the box. The person has chemical potential energy that is obtained from food, allowing him or her to do the work.

Energy can take many different forms, including mechanical energy, nuclear energy, thermal energy, and light. The law of conservation of energy (first law of thermodynamics) states that while energy can change from one form to another, it can neither be created nor destroyed. When matter changes, whether through a physical or chemical change, the amount of energy in the system is the same before and after the change, but the energy may be in a different form or forms.

Mechanical energy is a form of energy determined by the motion or position of a substance. The total mechanical energy of a substance is the sum of its kinetic and potential energy. **Kinetic energy** exists when an object is in motion; it is the energy of motion. The faster an object moves, the more kinetic energy it has. **Potential energy** is "stored" energy, typically a result of an object's location. Because of these components, mechanical energy naturally exists in every system in the universe.

When a rollercoaster starts at the top of a hill, it has zero kinetic energy because it is not moving. All of its energy is potential. Once the rollercoaster starts moving down the hill, the potential energy becomes kinetic energy. No energy has been created or destroyed during this process. It has simply changed form.

In the experiment, the plastic spoon catapult illustrates the change from potential to kinetic energy. A force (and therefore energy) is needed to bend the spoon backward. As a result, energy becomes "stored" in the spoon as elastic potential energy. The more the spoon is bent (compressed), the more elastic potential energy is stored. When the spoon is released, the potential energy in the spoon becomes kinetic energy, pushing the marshmallow forward. The marshmallow continues to move across the room after the spoon has stopped moving due to its inertia. **Inertia** is the resistance of an object to a change in its state of motion.

When there is more energy, more work can be done. Therefore, the distance the marshmallow travels depends on both force and the amount the spoon is compressed (the energy transferred from the person to the spoon).

FORMULAS & EQUATIONS

Force is a push or pull on an object, which is calculated using the mass and the acceleration of the object:

$$F = ma$$

Work occurs when a force is applied, causing an object to be displaced. Therefore, work can be described by the following relationship between force and distance:

$$W = Fd$$

Kinetic energy is the energy of motion. It is determined by the following equation:

$$KE = \frac{(\text{mass}) \times (\text{velocity})^2}{2} \quad \text{or} \quad KE = \frac{1}{2}mv^2$$

Potential energy is stored energy. If the mass of an object, the height at which it rests, and the force of gravity acting on the object are known, then its gravitational potential energy can be determined using the following equation:

$$PE = mgh$$

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of measurement can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on properties of matter and energy changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

HYPOTHESIS

▶ When a plastic spoon is used as a catapult, compressing the spoon more will supply it with more energy and cause a marshmallow placed in the spoon to move farther through the air when the spoon is released.

LESSON 31: Marshmallow Launcher

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 385, but spend more time on the concept of energy, specifically mechanical energy. Use an analog clock or watch (not digital) to begin the discussion. Explain that the arms of the clock have energy, allowing them to move around the face. They have the energy of motion—kinetic energy. Then, ask the students what happens if the arms stop moving. Is the energy lost? No! Explain potential energy.

Provide other examples to help the students grasp the concepts of kinetic and potential energy. Put a book on the edge of a desk, and ask the students what type of energy it has—potential. There is energy stored in the book. Then, push the book off the desk. Ask the students if the book has energy as it falls. Of course! Its potential energy has transformed into kinetic energy.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Launch marshmallows from a plastic-spoon catapult to explore different forms of energy and the transfer of energy.

OBJECTIVE

This lesson introduces different forms of energy and the transfer of energy. Students create a catapult using a plastic spoon and explore ways to make the marshmallow travel the farthest through the air.

OBSERVATION & RESEARCH

Energy is defined as the ability to do work or generate heat. **Work** occurs when a force causes an object to be displaced—to move from its original position. A **force** is a push or pull on an object. In order for work to be done, some object must possess energy to supply the force.

According to the **law of conservation of energy** (first law of thermodynamics), while energy can change from one form to another, it can neither be created nor destroyed. When matter changes, the amount of energy in the system is the same before and after the change, but it may be in a different form or forms.

In the experiment, the plastic spoon catapult experiences a number of energy transformations. The bent spoon has elastic potential energy. **Potential energy** is "stored" energy, typically a result of an object's location. On the other hand, **kinetic energy** exists when an object is in motion. The sum of an object's kinetic and potential energy is known as mechanical energy. **Mechanical energy** is a form of energy determined by the motion or position of a substance.

Potential energy is also found in atoms and molecules. The stored energy in the structures of atoms and molecules is transformed during a chemical reaction and is known as **chemical energy**. People obtain chemical energy from the food we eat. We store energy in the form of sugars that can be used to fuel reactions. Likewise, in cars, oxygen and thermal energy can be combined to release the chemical energy stored in gasoline.

During the experiment, a person uses stored chemical energy to bend (compress) the spoon. The person's chemical energy is transferred to the spoon and converted into elastic potential energy. The more the spoon is bent, the more elastic potential energy is stored. When the spoon is released, the potential energy in the spoon becomes kinetic energy, pushing the marshmallow forward. The marshmallow continues to move across the room after the spoon has stopped moving due to its inertia. **Inertia** is the resistance of an object to a change in its state of motion.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on types of measurement can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on energy changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on different forms of energy can be found in the Energy section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 31: Marshmallow Launcher

DIFFERENTIATION IN THE CLASSROOM

When there is a greater amount of energy, more work can be done. Therefore, the distance the marshmallow travels depends on both force and the amount of compression of the spoon (the energy transferred from the person to the spoon).

Along with chemical and mechanical energy, there are four other main forms of energy. **Thermal energy** is the total energy of particles in a substance. The transfer of thermal energy from an object at a higher temperature to an object at a lower temperature is known as **heat**. Chemical energy is often converted to thermal energy during chemical reactions. **Radiant energy** is the energy carried by electromagnetic waves, which includes X-rays, microwaves, ultraviolet radiation, and light. **Light** is used to describe the radiation in the electromagnetic spectrum that is visible to the human eye. Radiant energy (light) is converted into chemical energy by plants during the process of photosynthesis. **Electrical energy**, commonly called electricity, is energy resulting from the flow of charged particles, such as electrons or ions. Lightning is also a form of electrical energy. When lightning strikes, the electrical energy is transformed into thermal energy and radiant energy (light). **Nuclear energy** is the energy released when the nucleus of an atom is split or fused. The energy given off by nuclear reactions is extremely powerful.

NOTES

Fun Fact

The energy in the sun comes from nuclear fusion. The nuclear energy is converted into various other forms of energy, such as thermal energy and light.

Fun Fact

A compressed spring contains elastic potential energy.

LESSON 31: Marshmallow Launcher

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the amount the spoon is bent, does the distance traveled by the marshmallow change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

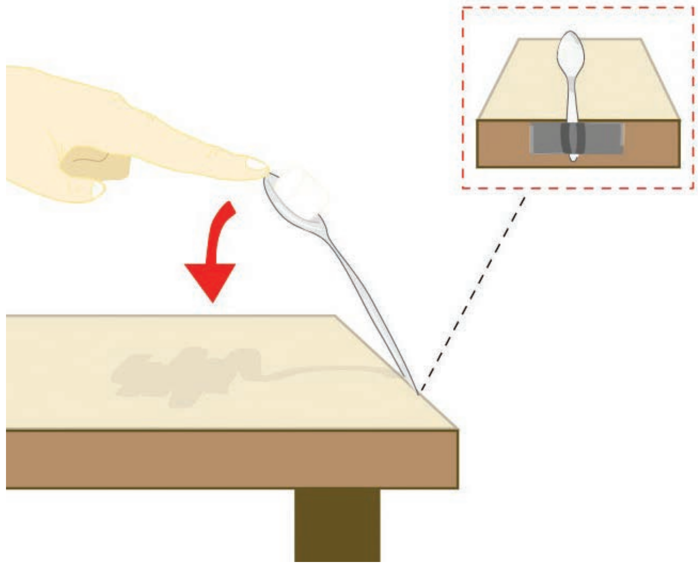
1. Set up the room so that you have at least 20 feet (6 meters) of open space from the front of the launching area to the landing area.
2. Instruct the students to construct their catapults by taping a plastic spoon firmly against the edge of a table or desk. The spoon should be perpendicular to the tabletop with the back of the spoon facing toward the table.
3. Have the students use a marker to mark their marshmallows with their initials for identification.
4. Tell the students to test the setup of their catapult and marshmallow. They should hold the marshmallow in the bowl of the spoon with their finger, and bend the spoon back carefully. (They may also want to use their other hand or thumb to help anchor the handle of the spoon against the table where it is taped.)
5. Measure the approximate amount the spoon is bent back from its original position.
6. Release the spoon to launch the marshmallow.
7. Have another student stand by the landing area to mark the place where the marshmallow originally landed. Then, have another student measure the distance from the edge of the desk (where the spoon is attached) to the place where the marshmallow landed.

Warn your students not to press the spoon back too far or the spoon may break.

Be cautious of broken plastic. Protective eyewear should be worn during this experiment.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens when the spoon is bent backward? Does the distance traveled by the marshmallow change when the spoon is bent back more or less? You can use the table in the activity sheet (or a similar one of your own) for students to record their data.



LESSON 31: Marshmallow Launcher

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the importance of measuring the correct quantities to obtain desired results.
- Understand the relationship between energy, work, and force.
- Define energy and explain the law of conservation of energy.
- Differentiate between kinetic and potential energy and provide examples.
- Explain the transformation of energy and give examples.
- Describe various forms of energy and give examples of those types of energy, including chemical, thermal, radiant, electrical, and nuclear (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Have a catapult contest. Provide each student with two to three marshmallows. Have them mark each of their marshmallows with their initials, launch them, and record the distance traveled. (If the spoon breaks, the distance will be recorded as zero.) Then, have each student calculate the average distance that his/her marshmallows traveled. Compare the results. The student (or students) with the largest average distance recorded wins! (Students can also work in teams with five to six marshmallows per team.)
- Ask students how they might change the mass or size of the marshmallow—purchase larger marshmallows to use in the experiment. Ask the class what will happen if they change the mass or size of the marshmallow. Discuss what might make the marshmallow travel farther. Then, test the students' hypotheses. Press a piece of a heavy rubber eraser or a marble deep into the middle of the marshmallow. Have students stand back (far from the landing area) for safety before launching the marshmallow.
- Challenge students to come up with their own catapult design to launch marshmallows. Then allow them to construct, test, and demonstrate their models in class.

REAL-WORLD APPLICATIONS

- The catapult is an ancient device used to throw or hurl a large object over a great distance. Catapults were used to attack castles and walled cities. Some catapults could throw stones weighing as much as 350 pounds for distances greater than 300 feet!
- Energy transfer occurs all around us. At a bowling alley, people use the chemical energy stored in their bodies to apply a force to the bowling ball, causing it to be displaced (work is done!). As the bowling ball travels down the lane, it has kinetic energy. When it hits the pins, the ball applies a force to the pins, causing them to move and hopefully fall over!

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter		
Mass		
Energy		
Work		
Mechanical energy		
Kinetic energy		
Potential energy		
Inertia		

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

4. Consider how bending a plastic spoon will affect the movement of a marshmallow resting in the spoon and why.

▶**Write your hypothesis.** ____

____

____

PERFORM YOUR EXPERIMENT

1. Construct a catapult by taping a plastic spoon firmly against the edge of a table or desk. The spoon should be perpendicular to the tabletop with the back of the spoon facing toward the table.
2. Use a marker to mark your marshmallows with your initials for identification.
3. Test the setup of the catapult. You should hold the marshmallow in the bowl of the spoon with a finger, and bend the spoon back carefully. (You may also want to use your other hand or thumb to help anchor the handle of the spoon against the table where it is taped.)
4. Measure the approximate amount the spoon is bent back from its original position.
5. Release the spoon to launch the marshmallow.
6. Have a classmate stand by the landing area. With tape, he or she should mark the place where the marshmallow originally landed. Then, you can measure the distance from the edge of the desk (where the spoon is attached) to the place where the marshmallow landed.
7. Record the results.

ANALYZE & CONCLUDE

1. Record the distance (in inches) that your marshmallow traveled in the table below. In the observations column, indicate whether any variables changed for each launch. For example, did you bend the spoon back more? Did you use a bigger marshmallow? Did it roll farther after the original landing?

Launch Number	Distance Traveled (in inches)	Observations
1		
2		
3		

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

2. How can you make the plastic spoon launch the marshmallow? ______________________________

____

____

3. What type of energy does the bent plastic spoon have? How does it get that energy? ______________

____

____

4. What type of energy does the marshmallow have when it is launched? Explain. ________________

____

____

5. What do you think will happen if you change the angle between the spoon and the tabletop? __________

____

____

6. What is the law of conservation of energy, and how does it relate to this experiment? ____________

____

____

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ______________

____

____

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Chemical energy		
Thermal energy		
Heat		
Radiant energy		
Light		
Electrical energy		
Nuclear energy		

2. How does the plastic spoon get the energy to launch the marshmallow? ______________________________

____

____

3. Most energy on the earth comes from the same source and is converted into other types of energy. What is the source? Give examples of how this energy is converted. ______________________________

____

____

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Plastic spoons, mini-marshmallows, permanent marker, yardstick, masking tape …

2. Predict how these materials may be used. Plastic spoons may be used to hold substances. Mini-marshmallows may be eaten as a snack. A permanent marker may be used to draw or write. A measuring tape or yardstick may be used to measure distance. These materials may be used to create a plastic-spoon catapult that launches mini-marshmallows and demonstrates potential and kinetic energy.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Matter	Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth.	
Mass	A measure of the amount of matter in a substance.	
Energy	The ability to do work or produce heat.	
Work	A measure of a change in energy that occurs when a force causes an object to be displaced.	
Mechanical energy	A form of energy determined by the motion or position of a substance; the total mechanical energy of a substance is the sum of its kinetic and potential energy.	
Kinetic energy	A form of energy associated with motion, calculated using the formula $KE = \frac{1}{2}mv^2$.	
Potential energy	The energy stored in a substance.	
Inertia	The resistance of an object to a change in its state of motion.	

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. Consider how bending a plastic spoon will affect the movement of a marshmallow resting in the spoon and why.

▶ **Write your hypothesis.** When a plastic spoon is used as a catapult, bending the spoon more will supply it with more energy and cause a marshmallow placed in the spoon to move farther through the air when the spoon is released.

PERFORM YOUR EXPERIMENT

1. Construct a catapult by taping a plastic spoon firmly against the edge of a table or desk. The spoon should be perpendicular to the tabletop with the back of the spoon facing toward the table.
2. Use a marker to mark your marshmallows with your initials for identification.
3. Test the setup of the catapult. You should hold the marshmallow in the bowl of the spoon with a finger, and bend the spoon back carefully. (You may also want to use your other hand or thumb to help anchor the handle of the spoon against the table where it is taped.)
4. Measure the approximate amount the spoon is bent back from its original position.
5. Release the spoon to launch the marshmallow.
6. Have a classmate stand by the landing area. With tape, he or she should mark the place where the marshmallow originally landed. Then, you can measure the distance from the edge of the desk (where the spoon is attached) to the place where the marshmallow landed.
7. Record the results.

ANALYZE & CONCLUDE

1. Record the distance (in inches) that your marshmallow traveled in the table below. In the observations column, indicate whether any variables changed for each launch. For example, did you bend the spoon back more? Did you use a bigger marshmallow? Did it roll farther after the original landing?

Launch Number	Distance Traveled (in inches)	Observations
1	Answers will vary	Answers will vary
2		
3		

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. How can you make the plastic spoon launch the marshmallow? To launch the marshmallow, hold the marshmallow in the bowl of the spoon, bend the plastic spoon back, and release it.

3. What type of energy does the bent plastic spoon have? How does it get that energy? The plastic spoon has potential energy (stored energy). As the spoon is bent backward, chemical potential energy from the person is transferred to the spoon and converted to elastic potential energy.

4. What type of energy does the marshmallow have when it is launched? Explain. The marshmallow has kinetic energy. Kinetic energy is the energy of motion, so when the spoon is released, the potential energy is converted to kinetic energy as the marshmallow flies through the air.

5. What do you think will happen if you change the angle between the spoon and the tabletop? The angle between the spoon and the tabletop will change the distance the marshmallow will travel. If the spoon is taped so it leans back more toward the table, the marshmallow may not travel as far.

6. What is the law of conservation of energy, and how does it relate to this experiment? The law of conservation of energy states that energy can neither be created nor destroyed. It changes forms. During the experiment, energy is never lost. It is simply converted from potential to kinetic energy.

7. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 31 ACTIVITY SHEET: Marshmallow Launcher

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Chemical energy	Energy stored in the structures of chemical substances that may be released or transformed during a chemical reaction.	
Thermal energy	The total energy of particles in a substance.	
Heat	The flow of thermal energy from one substance to another because of differences in temperature.	
Radiant energy	A form of energy carried by electromagnetic waves, which includes X-rays, microwaves, ultraviolet radiation, and light.	
Light	A specific group of electromagnetic waves that travel freely through space and can be detected by the human eye	
Electrical energy	A form of energy that results from the flow of charged particles, such as electrons or ions; also known as electricity.	
Nuclear energy	A form of energy released when the nucleus of an atom is split or fused.	

2. How does the plastic spoon get the energy to launch the marshmallow? The plastic spoon gets the energy to launch the marshmallow from elastic potential energy stored in the bent spoon.

3. Most energy on the earth comes from the same source and is converted into other types of energy. What is the source? Give examples of how this energy is converted. The source of most energy on the earth is radiant energy from the sun. It is converted into thermal energy when the sun's rays increase the temperature of an object. It is also converted into chemical energy through photosynthesis.

LESSON 32: T-Shirt Tie-Dye

ESTIMATED TIME **Setup:** 5 minutes | **Procedure:** 15–20 minutes

- ## DESCRIPTION

Use colored permanent markers to create fun, tie-dye designs on T-shirts.

- ## OBJECTIVE

This lesson demonstrates solubility and absorption through the process of tie-dyeing. Students use colored permanent markers and alcohol to create colorful designs on T-shirts. The lesson can be extended to explore polarity and diffusion.

- ## CONTENT TOPICS

Scientific inquiry; mixtures (solutions); separation processes (absorption, chromatography)

- ## MATERIALS

- ❑ White T-shirt
- ❑ Permanent colored markers
- ❑ Isopropyl rubbing alcohol (70%)
- ❑ Cups and/or jars (at least a three-inch diameter)
- ❑ Eye dropper or pipette
- ❑ Rubber bands

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 398 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Tie-dyeing has been around for decades and is a fun, colorful way to decorate plain T-shirts. Tie-dye is a form of art and expression, but it also involves a lot of chemistry. Dye is a natural or synthetic substance used to apply color to or stain other materials, such as fabrics and fibers. Permanent markers contain dyes that will be absorbed by fabrics, such as T-shirts. **Absorption** is a process by which matter takes in another substance. The absorbed substance is spread throughout the absorbing matter, such as when a kitchen sponge soaks up water.

Like most other things around us, dyes are mixtures. A **mixture** is made of two or more substances that are combined physically. A **solution** is a homogeneous mixture in which one or more substances (the solutes) are dissolved into another substance (the solvent). Solutions are made up of elements or compounds mixed together at the molecular level. For example, salt may be dissolved in water to form a saltwater solution. The salt is the solute, and the water is the solvent.

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. A substance that dissolves in another substance is **soluble**. For example, salt is soluble in water. If a substance does not dissolve, it is **insoluble**. For instance, butter is insoluble in water.

LESSON 32: T-Shirt Tie-Dye

Many markers are soluble in water, so they are called washable markers. If you tried to tie-dye a T-shirt with washable markers, the colorful design would be washed away if the shirt was put in the washing machine. Therefore, permanent markers are used in this experiment. The dye in permanent markers is insoluble in water. The colors can't be easily washed away. However, the dye in permanent markers is soluble in rubbing alcohol.

In the experiment, the dye in permanent markers will be absorbed by the T-shirt, but the colors will only spread so far through the material. When rubbing alcohol is added to the dye, the dye dissolves. The T-shirt will absorb the alcohol, which can travel farther through the shirt. Therefore, the dye that is dissolved in the alcohol can travel farther through the shirt, spreading the ink. When the alcohol dries, the dye remains as part of the T-shirt. The T-shirt can then be washed because the dye will not dissolve in water.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on the properties of solutions can be found in the Chemicals by Volume—Solutions section in CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on absorption can be found in the Laboratory Separations section in CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

FORMULAS & EQUATIONS

Markers are made up of dyes. Dye is a natural or synthetic substance used to apply color or to stain other materials, such as fabrics and fibers. Dyes are often mixtures of different colored particles. Although our eyes may only "see" one color, each of the separate colors keep their color properties within the mixture. Therefore, different colors can be separated out of some dyes. There is not one exact formula because different colors and types of markers contain a variety of different chemical compounds.

The substance used to dissolve the dye is isopropyl alcohol.

The chemical formula for isopropyl alcohol (isopropanol) is $\mathbf{C_3H_8O}$ or $\mathbf{(CH_3)_2CHOH}$.

At a normal room temperature, it is a clear, flammable liquid. Isopropyl alcohol is commonly called rubbing alcohol.

HYPOTHESIS

▶ Drawing designs on a T-shirt using permanent colored markers and then adding rubbing alcohol will dissolve the dye and allow the colors to spread through the fibers of the T-shirt.

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Perform the experiment as described on page 398, but spend more time on solutions and solubility. Mix salt in a cup of water to help the students visualize what a solution is and understand the parts of the solution. Then discuss other substances that are solutions, like lemonade and apple juice (flavoring and water or apples and water).

Then, add oil or a little butter to a cup of water. Try to mix the substance, so the students can observe what is happening. Then discuss solubility.

LESSON 32: T-Shirt Tie-Dye

DIFFERENTIATION IN THE CLASSROOM

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Use colored permanent markers to create fun, tie-dye designs on T-shirts.

OBJECTIVE

This lesson demonstrates various properties of liquids, specifically solutions. Students use colored permanent markers and alcohol to create colorful designs on T-shirts and explore solubility, polarity, diffusion, and chromatography.

OBSERVATION & RESEARCH

Tie-dyeing has been around for decades and is a fun, colorful way to decorate plain T-shirts. Permanent markers contain dyes that are absorbed by fabrics, such as T-shirts. Dyes are solutions. A **solution** is a homogeneous mixture in which one or more substances (the solutes) are dissolved into another substance (the solvent).

Solubility is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution. A substance that dissolves in another substance is **soluble**. If a substance does not dissolve, it is **insoluble**. Many markers are soluble in water, so they are called washable markers. However, the dye in permanent markers is insoluble in water. The colors can't be easily washed away. However, the dye is soluble in rubbing alcohol.

Solubility is also related to polarity. **Polar substances** are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side. Generally, polar solutes will only dissolve in polar solvents. Polar substances include acetic acid, salt, and sugar. **Nonpolar substances** are made up of particles that have an even distribution of electrons. The charges on the particles are neutralized. Nonpolar solutes generally only dissolve in nonpolar solvents. Nonpolar substances include oil and benzene. Isopropyl (rubbing) alcohol has both polar and nonpolar components, so it can dissolve both polar and nonpolar substances.

In the experiment, the dye in permanent markers will be absorbed by the T-shirt, but the colors will only spread so far through the material. When the rubbing alcohol is added to the dye, the dye dissolves. The T-shirt will absorb the alcohol, which can travel farther through the shirt because of diffusion and the process of chromatography. **Diffusion** is the movement of particles from an area of high concentration to an area of low concentration. Therefore, the alcohol spreads from an area of high concentration to an area of low concentration, spreading the ink.

Likewise, **chromatography** is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition. During chromatography, a mixture is moved over a stationary material, called the **stationary phase**. The mixture that flows over the material is called the **mobile phase**. The different parts that make up the mobile phase flow through the stationary phase at different rates. As a result, the components separate, generally leaving behind distinct bands of the different components.

In this experiment, as the dye and alcohol solution move through the T-shirt, the different color components of some of the colored markers may move through the paper at different rates. As a result, some colors may separate, leaving behind different bands of colors. When the alcohol dries, the dye remains as part of the T-shirt. The T-shirt can then be washed because the dye will not dissolve in water.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures and solutions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on solutions, solubility, and polar substances can be found in the Chemicals by Volume—Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on chromatography can be found in the Laboratory Separations section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action*.

LESSON 32: T-Shirt Tie-Dye

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you change the type of liquid [solvent], does the dye behave differently?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Position one layer of the T-shirt over the mouth of the cup. Stretch the fabric over the opening and hold it in place with a rubber band.
2. Use the permanent colored markers to add small dots, lines, or designs to the part of the T-shirt that is stretched over the cup.
3. Use a dropper to place 5–10 drops of alcohol on the designs. Wait a few minutes for the alcohol to soak the colors.
4. Repeat steps 1–3 several times on different areas of the T-shirt.

Make sure the proper safety procedures are followed to protect students from the dyes and alcohol. Students should protect their clothing with a lab apron or lab coat, and wash their hands immediately after conducting the experiment.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens when the dye is initially added to the T-shirt? What happens when you add the alcohol? Have students answer the questions on the activity sheet (or similar ones of your own) to guide the process.

NOTES

LESSON 32: T-Shirt Tie-Dye

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Describe the process of absorption and how it relates to tie-dyeing.
- Define and provide examples of different types of mixtures.
- Define and identify solutions and the parts of a solution.
- Define soluble and insoluble substances and give examples.
- Differentiate between polar and nonpolar substances (see ***Differentiation in the Classroom***).
- Explain the processes of diffusion and chromatography (see ***Differentiation in the Classroom***).

Fun Fact

Shibori is a Japanese term for several methods of dyeing cloth. It includes a form of tie-dying that is used to create intricate designs on kimonos (traditional Japanese garments).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternative methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples, or have a discussion to generate other ideas as a class.

- Have the students bring in plain white T-shirts and create their own designs so they can take their shirts home. You can ask the students to closely examine their T-shirts after the experiment and look for color separations to explore chromatography.
- If you do not wish to do a T-shirt tie-dye experiment, you can simply use a paper towel to achieve the same results and teach the same lesson. Simply lay the paper towel on a surface that will not be ruined by the ink and make a design. Then, add the alcohol and observe. Likewise, smaller pieces of cloth can be used to create bandanas or wrist bands.

REAL-WORLD APPLICATIONS

- The leaves of most plants are green because they contain chlorophyll, and chlorophyll is green. However, not all leaves are the same shade of green. Leaves contain several different kinds of chlorophyll and some other pigments. The process of chromatography is used to separate the different pigments in plants and determine which pigments it contains.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Absorption		
Mixture		
Solution		
Solute		
Solvent		

4. Consider what will happen if you apply colored marker ink and rubbing alcohol to a white T-shirt and why.

▶**Write your hypothesis.** ______________________________

____

____

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

PERFORM YOUR EXPERIMENT

1. Position one layer of the T-shirt over the mouth of the cup. Stretch the fabric over the opening and hold it in place with a rubber band.
2. Use permanent colored markers to add small dots, lines, or designs to the part of the T-shirt stretched over the cup.
3. Use a dropper to place 5–10 drops of alcohol on the dots, lines, or designs.
4. Wait a few minutes for the alcohol to soak the colors and observe.
5. Repeat steps 1–4 several times on different areas of the T-shirt.

ANALYZE & CONCLUDE

1. What happens when you press the markers to the T-shirt? ____

____

____

2. What happens to the ink designs when you add drops of alcohol? ____

____

____

3. Do you think you will get a similar result if you place water on the ink designs? Why or why not? _____________

____

____

4. Why do you use permanent colored markers instead of washable markers? ________________________________

____

____

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps? ________________________

____

____

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance		
Nonpolar substance		
Diffusion		
Chromatography		
Stationary phase		
Mobile phase		

2. Do any of the color spots have different colored edges? Is so, what colors? Why do you think this happened?

____

____

____

3. Why do some of the colors separate into different colors? What is this separation process called? ________________

____

____

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. A white T-shirt, permanent colored markers, rubbing alcohol, cups, eye droppers, rubber bands, vinegar …

2. Predict how these materials may be used. A white T-shirt may be worn. Permanent colored markers may be used to draw or write. Rubbing alcohol may be used as a disinfectant. Cups may be used to hold a substance. These materials may be used to tie-dye T-shirts and demonstrate absorption and solubility.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Absorption	A process by which matter soaks up or takes in another substance.	
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Solute	A substance that is dissolved in a solution	
Solvent	A substance capable of dissolving another substance	

4. Consider what will happen if you apply colored marker ink and rubbing alcohol to a white T-shirt and why.

▶**Write your hypothesis.** Adding rubbing alcohol to permanent marker designs on a T-shirt will dissolve the dye and allow the colors to spread through the fibers in the T-shirt.

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

1. Position one layer of the T-shirt over the mouth of the cup. Stretch the fabric over the opening and hold it in place with a rubber band.
2. Use permanent colored markers to add small dots, lines, or designs to the part of the T-shirt stretched over the cup.
3. Use a dropper to place 5–10 drops of alcohol on the dots, lines, or designs.
4. Wait a few minutes for the alcohol to soak the colors and observe.
5. Repeat steps 1–4 several times on different areas of the T-shirt.

ANALYZE & CONCLUDE

1. What happens when you press the markers to the T-shirt? The colored markers stain the T-shirt, and you can make designs from the dye.

2. What happens to the ink designs when you add drops of alcohol? When you add drops of alcohol, the dye from the markers spreads farther through the fabric.

3. Do you think you will get a similar result if you place water on the ink designs? Why or why not? If you place only water on the designs, it will not have the same effect because the dye is not soluble in water. Therefore, only the water would spread through the T-shirt.

4. Why do you use permanent colored markers instead of washable markers? Washable markers are soluble in water. The dye would wash away in water. The dye in permanent markers is insoluble in water and can't be easily washed away.

5. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

   Answer 1: Valid because the data support my hypothesis.

   Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 32 ACTIVITY SHEET: T-Shirt Tie-Dye

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Polar substance	A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.	
Nonpolar substance	A substance made up of particles that have an even distribution of electrons; the charges on these particles are neutralized.	
Diffusion	The movement of particles from an area of high concentration to an area of low concentration.	
Chromatography	A group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.	
Stationary phase	A stationary material over which a mixture flows during a chromatography separation process.	
Mobile phase	The mixture that flows over the stationary material in a chromatography separation process.	

2. Do any of the color spots have different colored edges? If so, what colors? Why do you think this happened?

Yes, colors like green and purple have different colored edges because the rubbing alcohol will separate the dye into its constituent colors. Green may be split into yellow and blue. Purple may be split into blue and red.

3. Why do some of the colors separate into different colors? What is this separation process called? The different color components of some of the colored markers may move through the fabric at different rates. As a result, the colors separate, leaving behind different colors. This separation process is called chromatography.

LESSON 33: Elephant Toothpaste

ESTIMATED TIME **Setup:** 5–10 minutes | **Procedure:** 10–15 minutes

DESCRIPTION

Mix hydrogen peroxide with liquid dish soap and active yeast to initiate an "elephant size" chemical reaction.

OBJECTIVE

This lesson demonstrates a type of chemical reaction called decomposition and explores catalysts. Students observe as yeast, hydrogen peroxide, and soap initiate an astonishing chemical reaction. The lesson can be simplified to address physical and chemical changes.

CONTENT TOPICS

Scientific inquiry; elements and compounds; chemical reactions (decomposition); energy

Jump ahead to page 409 to view the Experimental Procedure.

MATERIALS

- ❑ Empty 16-oz plastic soda pop bottle
- ❑ Foil cake pan with 2-inch sides
- ❑ 20-volume hydrogen peroxide (6% solution)
- ❑ Liquid dish soap
- ❑ Active yeast
- ❑ Funnel
- ❑ Warm water
- ❑ Cup or bowl
- ❑ Food coloring (optional)

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O. Hydrogen peroxide is a similar compound made up of hydrogen and oxygen. However, hydrogen peroxide has two hydrogen atoms attached to two oxygen atoms (H_2O_2).

Matter often changes, and these changes can be either physical or chemical. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. A **chemical change** or **chemical reaction** occurs when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). As a result of a chemical reaction, new substances with new properties are formed.

LESSON 33: Elephant Toothpaste

The starting material or materials for a chemical reaction are referred to as the **reactants**. The substance or substances produced from a chemical reaction are called **products**. Sometimes a secondary product, a **byproduct,** can also be created at the same time as the desired product(s).

Not every chemical reaction occurs in the same way. There are different types of chemical reactions, including synthesis reactions, decomposition reactions, and displacement reactions. In this experiment, a decomposition reaction takes place. During a **decomposition reaction**, a compound breaks apart into two or more products. Most decomposition reactions need an outside source of energy in order to take place.

Hydrogen peroxide is not a very stable compound, so it slowly decomposes into water and oxygen gas under normal conditions. In this reaction, yeast is used as a catalyst. A **catalyst** is a substance that helps to change the rate of a reaction. During the reaction, the catalyst is not consumed. As a result, the yeast makes the reaction occur much faster; it causes the hydrogen peroxide to break down and release the oxygen gas much faster.

The soap is used to help us "see" the reaction. Bubbles of oxygen become trapped in the soap, creating foam. The reaction occurs so quickly, releasing so much gas and creating so much foam, that the foam begins to flow out of the bottle. The result of this reaction looks like toothpaste being squeezed out of a tube.

In addition, the bottle will feel warm to the touch because the reaction is exothermic. An **exothermic reaction** or process is one that gives off energy. In contrast, an **endothermic reaction** or process is one that requires or absorbs energy.

HYPOTHESIS

▶Adding yeast to hydrogen peroxide will cause the hydrogen peroxide to decompose quickly into water and oxygen gas, creating foam as the gas becomes trapped in liquid dish soap and pushes upward out of the bottle.

FORMULAS & EQUATIONS

Hydrogen peroxide is a relatively clear liquid substance. It is soluble in water and is often sold as a mixture of H_2O_2 in water. The hydrogen peroxide used in this experiment is actually a 6% solution of H_2O_2 in water.

The chemical formula for hydrogen peroxide is **H_2O_2.**

Hydrogen peroxide naturally decomposes into water and oxygen gas. The reaction is shown by the following equation:

$$2H_2O_2\ (aq) \rightarrow 2H_2O\ (l) + O_2\ (g)$$

The rate of the reaction can be increased by introducing a catalyst. In this experiment, the catalyst is yeast. Yeast is a microorganism that is part of the fungi family. Therefore, in the equation below, the catalyst is indicated above the arrow.

$$2H_2O_2\ (aq) \xrightarrow{\text{yeast}} 2H_2O\ (l) + O_2\ (g)$$

The hydrogen peroxide used in the experiment is actually a mixture of water and hydrogen peroxide.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, compounds, and physical and chemical changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

LESSON 33: Elephant Toothpaste

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

DESCRIPTION

Mix hydrogen peroxide with liquid dish soap and active yeast to initiate an "elephant size" chemical reaction.

OBJECTIVE

This lesson explores the differences between physical and chemical changes.

OBSERVATION & RESEARCH

Matter is often classified as either a pure substance or a mixture. All matter is made up of basic elements. **Elements** are pure substances that cannot be broken down further by normal chemical means. They are known as the building blocks of matter. A **compound** is a pure substance made up of two or more elements joined in a defined ratio. For example, water is a compound made up of the elements hydrogen and oxygen in a 2:1 ratio. Two hydrogen atoms and one oxygen atom join together, giving water the chemical formula H_2O. Likewise, hydrogen peroxide is a similar compound, made up of hydrogen and oxygen. However, hydrogen peroxide has two hydrogen atoms attached to two oxygen atoms (H_2O_2). Hydrogen peroxide is often mixed with water for household use. It is a mixture! A **mixture** is made of two or more substances that are combined physically.

Matter often changes, and these changes can be either physical or chemical. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. Examples of physical changes are breaking a stick or melting ice. The stick is still a stick, and the ice and water are both still H_2O after those changes. A **chemical change** or **chemical reaction** occurs when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). As a result of a chemical reaction, new substances with new properties are formed. An example of a chemical change is baking a cake. After the batter is heated, a new substance (the cake!) is formed.

Not every chemical reaction occurs in the same way. In this experiment, hydrogen peroxide breaks down into water and oxygen gas. This reaction occurs naturally, but yeast is used as a catalyst. A **catalyst** is a substance that helps to change the rate of a reaction. (During the reaction, the catalyst is not consumed.) As a result, the yeast makes the reaction occur much faster.

The soap is used to help us "see" the reaction. Bubbles of oxygen released by the reaction become trapped in the soap, creating a foam. The reaction occurs so quickly, releasing so much gas and creating so much foam, that the foam begins to flow out of the bottle. The result of this reaction looks like toothpaste being squeezed out of a tube.

HIGHER GRADE LEVELS/ADVANCED STUDENTS

Perform the experiment as described on page 409, but discuss the product of the reaction further. Oxygen gas is a product of the reaction and creates bubbles in the liquid dish soap. The gas becomes trapped in the liquid and creates a foam. A foam is a type of **colloid**. Discuss homogeneous mixtures, heterogeneous mixtures, and colloids.

Another option is to discuss other types of reactions. Give examples of **synthesis**, **displacement**, and **double displacement** reactions.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on elements, compounds, mixtures, and physical and chemical changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections.*

LESSON 33: Elephant Toothpaste

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If you do not add yeast, does the foam still form?) Review the information in the ***Scientific Inquiry*** section on pages 14 –16 to discuss variables.

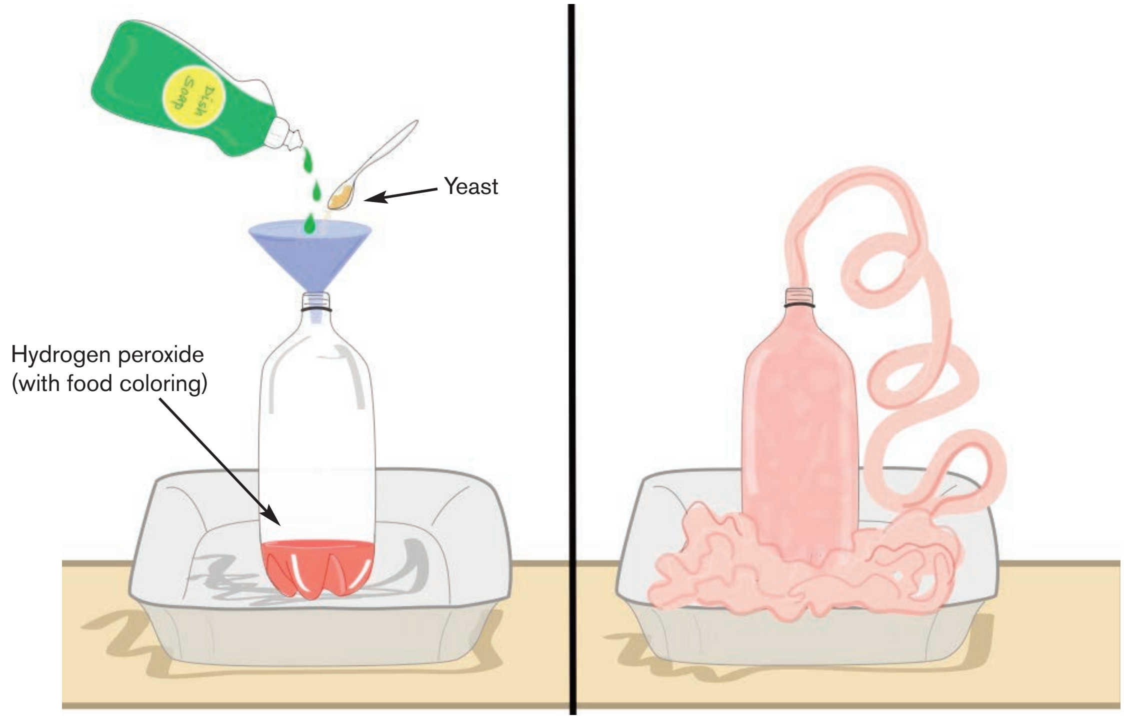
EXPERIMENTAL PROCEDURE

1. Place the empty soda pop bottle in the center of the cake pan. Put the funnel in the opening of the bottle.
2. Pour ½ cup of hydrogen peroxide through the funnel into the soda pop bottle.
3. Add about one tablespoon of liquid dish soap to the hydrogen peroxide in the bottle.
4. In a separate cup or bowl, mix one packet of yeast with warm water. (Follow the instructions on the packet of yeast when adding water.)
5. Pour the yeast mixture into the bottle, and then quickly remove the funnel.
6. Observe the reaction! (Along with observing with their eyes, students can also be allowed to touch the bottle to feel any changes taking place, and touch the foam that forms from the reaction.)

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. What happens when the soap is added to the hydrogen peroxide? What happens when the yeast is added? You can use the chart in the activity sheet (or a similar one of your own) for students to record their data.

NOTES



LESSON 33: Elephant Toothpaste

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Define and provide examples of elements and compounds.
- Differentiate between physical and chemical changes.
- Define and identify the parts of a chemical reaction.
- Explain the process of decomposition.
- Understand the role of a catalyst in a chemical reaction.
- Differentiate between exothermic and endothermic processes.
- Distiniquish among different types of mixtures (see ***Differentiation in the Classroom***).

Fun Fact

Hydrogen peroxide is used to whiten bones that will be put on display at museums.

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Introduce ways to expand on the lesson, or discuss them as a class. Use the following examples, or have a discussion to generate other ideas as a class.

Fun Fact

Yeast is a living organism!

- Add food coloring to make colorful foam. Add 3–4 drops of food coloring to the ½ cup of hydrogen peroxide before pouring it into the soda pop bottle. Have different students use different colors, and have them try mixing two colors together.

REAL-WORLD APPLICATIONS

- The rate at which hydrogen peroxide decomposes depends on temperature, the concentration of the hydrogen peroxide, and light. Hydrogen peroxide is often stored in refrigerated areas to slow the reaction. In addition, hydrogen peroxide solutions are often packaged in brown bottles; light causes the rate of the reaction to increase, so brown bottles are used to prevent light from getting into the bottle.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

OBSERVE & RESEARCH

1. Write down the materials you observe. ______________________________

____

____

2. Predict how these materials may be used. ______________________________

____

____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element		
Compound		
Physical change		
Chemical reaction		
Reactant		
Product		
Byproduct		
Decomposition		
Catalyst		

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

4. Consider what effects the addition of yeast might have on a mixture of hydrogen peroxide and liquid dish soap and why.

▶ **Write your hypothesis.** ______________________________

____

____

PERFORM YOUR EXPERIMENT

1. Place the empty soda pop bottle in the center of the cake pan. Put the funnel in the opening of the bottle.
2. Pour ½ cup of hydrogen peroxide through the funnel into the soda pop bottle.
3. Add about one tablespoon of liquid dish soap to the hydrogen peroxide in the bottle.
4. In a separate cup or bowl, mix one packet of yeast with warm water. (Follow the instructions on the packet of yeast when adding water.)
5. Pour the yeast mixture into the bottle, and then quickly remove the funnel.
6. Observe the reaction!

ANALYZE & CONCLUDE

1. List some of the physical properties of each substance in the chart below.

Liquid Dish Soap	Hydrogen Peroxide	Active Yeast

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

2. What is the purpose of adding liquid dish soap? ____

____

____

3. What purpose does the yeast have in the experiment? Explain. ______________________________________

____

____

4. Write the equation of the chemical reaction that occurs. What are the products of the reaction? ____________

____

____

5. Compare and contrast exothermic and endothermic reactions. ______________________________________

____

____

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? _______________________

____

____

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Colloid		
Synthesis		
Displacement		
Double displacement		

2. How do you know a chemical reaction occurred? ______________________________

____

____

3. What other chemical reactions release oxygen gas? ______________________________

____

____

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. An empty plastic soda pop bottle, hydrogen peroxide, liquid dish soap, food coloring, active yeast, funnel, cake pan ...

2. Predict how these materials may be used. An empty soda pop bottle may be used to hold a liquid. Hydrogen peroxide may be used as a disinfectant. Liquid dish soap may be used to clean. Yeast may be used to make bread and other baked goods rise. These materials may be used together to demonstrate a chemical reaction.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Element	A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom.	
Compound	A pure substance made up of two or more elements joined in a defined ratio.	
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances.	
Reactant	A starting material for a chemical reaction.	
Product	A substance formed as a result of a chemical reaction.	
Byproduct	A secondary product that is created from a chemical reaction at the same time as the primary, desired product(s).	
Decomposition	A chemical reaction in which a compound breaks apart into two or more products.	
Catalyst	A substance that helps to change the rate of a reaction but is not consumed or changed during the reaction.	

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

4. Consider what effects the addition of yeast might have on a mixture of hydrogen peroxide and liquid dish soap and why.

▶**Write your hypothesis.** Adding yeast to hydrogen peroxide will cause the hydrogen peroxide to decompose into water and oxygen gas very quickly. The oxygen gas will form bubbles in the soap and push upward out of the bottle.

PERFORM YOUR EXPERIMENT

1. Place the empty soda pop bottle in the center of the cake pan. Put the funnel in the opening of the bottle.
2. Pour ½ cup of hydrogen peroxide through the funnel into the soda pop bottle.
3. Add about one tablespoon of liquid dish soap to the hydrogen peroxide in the bottle.
4. In a separate cup or bowl, mix one packet of active yeast with warm water. (Follow the instructions on the packet of yeast when adding water.)
5. Pour the yeast mixture into the bottle, and then quickly remove the funnel.
6. Observe the reaction!

ANALYZE & CONCLUDE

1. List some of the physical properties of each substance in the chart below.

Liquid Dish Soap	Hydrogen Peroxide	Active Yeast
• Liquid • Slimey • ________ color • •	• Liquid • Slighty cloudy • Strong smell • •	• Dry • Powdery • White or yellowish • •

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

2. What is the purpose of adding liquid dish soap? The liquid dish soap allows bubbles of gas to form during the chemical reaction, and these bubbles create the expanding foam.

3. What purpose does the yeast have in the experiment? Explain. The yeast serves as a catalyst for decomposition of hydrogen peroxide. It speeds up the decomposition process to produce oxygen gas and water.

4. Write the equation of the chemical reaction that occurs. What are the products of the reaction? The products of this chemical reaction are water and oxygen gas. The chemical equation for the reaction is $2H_2O_2 \rightarrow 2H_2O + O_2$.

5. Compare and contrast exothermic and endothermic reactions. An exothermic reaction gives off heat, while an endothermic reaction requires or absorbs heat.

6. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 33 ACTIVITY SHEET: Elephant Toothpaste

ANSWER KEY: *Below are suggested answes. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Colloid	A mixture, between homogeneous and heterogeneous, in which very small particles are spread evenly throughout another substance.	
Synthesis	A chemical reaction in which two or more reactants combine to form a product.	
Displacement	A type of chemical reaction in which a reactant takes the place of some part of a compound to produce a new compound and release a separate product.	
Double displacement	A chemical reaction in which parts of two compound reactants replace each other to form two or more different compound products.	

2. How do you know a chemical reaction occurred? A chemical reaction occurred because new substances were formed that have different porperties than the original substances. Also, the heat given off during the experiment shows that an exothermic chemical reaction took place.

3. What other chemical reactions release oxygen gas? Photosynthesis is a chemical reaction that uses water, carbon dioxide, and light (energy) to produce glucose and oxygen gas.

RESOURCE GUIDE: Tips for Teaching Science, Technology, Engineering, and Math (STEM)

Even if you don't have a background in chemistry, you can still lead a chemistry experiment and other STEM activities in your class! Below are suggestions to help you prepare and present a STEM lesson to students!

PLAN IN ADVANCE

- **Read through the lesson and experimental procedure very carefully.** Thoroughly reading the material will enhance your comfort level with the background information, important terms, and experimental procedure. It will also prepare you to answer questions from students.

- **Note any questions you may have so that you can research them before you teach the lesson.** Many of your questions may be answered in the ***Observation & Research*** section of the lesson. Other questions may require you to do additional outside research.

- **Determine how you would like to conduct the experiment in class (groups, individually, etc.).** How you present the experiment, the quantity of materials needed, and the type of classroom discussions will vary depending on how you plan to conduct the experiment. You may also choose to use the experiments as demonstrations if you do not have enough class time allotted for hands-on experiments.

- **Obtain the necessary materials.** All of the materials used in the Activity Guide can be easily found at a grocery or all-purpose store (Walmart, Target, etc.). For a complete list of materials needed for each lesson in the Activity Guide, review the blue introductory box on the first page of each lesson. If you have difficulty finding certain materials, please contact us at comments@chemed.org.

- **Conduct a practice run of the experiment.** Having done the experiment beforehand, you will have a better idea of what to expect, how to instruct your students, and what hints or tips you can provide them throughout the process. Testing the experiment will also help you to resolve any potential issues, such as faulty materials, beforehand.

- **Become well versed in the concepts and specific topics that you want the students to learn.** Creating a list of key points and concepts that you want to convey to students will help you present the lesson in a fun, educational, and organized format. Remember, all of these lessons can be modified to address various concepts, so you can select which concepts best suit your classroom needs and tailor the lesson to your chosen curriculum.

- **Generate a list of related topics and potential questions that your students might ask.** Preparing a list can help you define the scope of the lesson plan and also ensure that you are covering the intended concepts. Students often ask questions about topics related to the experiment but not necessarily contained within the ***Observation & Research*** section. While additional background information and real-world examples are provided, researching potential questions and related topics will further develop background knowledge to help you to answer their questions and connect other interesting concepts to the lesson.

RESOURCE GUIDE: Tips for Teaching Science, Technology, Engineering, and Math (STEM)

SAFETY DISCUSSION

- **Obtain the necessary safety materials (goggles, aprons, etc.).** Your school may already have these materials. If not, ask your administration about how to obtain them. Review the ***Safety First*** section of this ***Resource Guide*** and the notes in the relevant lesson to determine the appropriate safety materials and procedures.

- **Before beginning the experiment with the class, be sure to go over the necessary safety precautions.** It is never too early to introduce students to safety practices. Even if certain information does not apply to your classroom, providing an overview and then discussing safety rules specific to your classroom is a great way to make them aware of the importance of safety when conducting experiments.

- **Discuss the importance of a safety plan.** Have students create a plan for the classroom, and then post it where everyone can see it. You may want to make this an assignment. Ask each student to research and write down 4–5 laboratory safety procedures. Then, compile a list together in class to develop your plan.

- **Model appropriate behavior by obeying the safety rules and procedures outlined in your classroom safety plan.** Your students are looking to you to set the standard for safety! Be their best safety example.

- **Check out the *Safety First* section on pages 421–423 in this guide for a more specific list of suggested classroom safety tips.** If you are not sure where to start or what safety procedures your students should understand, the ***Safety First*** section of this ***Resource Guide*** will help! Remember, you can't be too cautious with safety in the classroom. Even if certain information does not apply to your lesson, it is always good for students to learn about various safety procedures.

UTILIZE RESOURCES

- **Use the activity sheets following each lesson.** The activity sheets (and answer keys) will help to reinforce students' understanding of the concepts covered in the lesson and assess their learning.

- **The *Lesson Plan Vocabulary* and *Notable Chemists* sections of this *Resource Guide* are tools provided to assist in teaching scientific concepts.** They also reinforce the importance of inquiry and experimentation to discover new things.

- **Periodically review and reinforce the concepts covered.** Use the ***Review Games Suggestions & Content*** in this ***Resource Guide*** to devise a fun way to go over the material with students.

RESOURCE GUIDE: Safety First

The Chemical Educational Foundation® (CEF) hopes you and your students will enjoy the lessons in the *You Be The Chemist®* Activity Guide, but before the fun begins, remember … ***Safety First!*** For the chemistry experience to be truly enjoyed, safety should be an essential component of all science lesson plans. Students should learn the importance of classroom, laboratory, and general chemical safety at an early age. CEF encourages you to reinforce the importance of safety before every lesson.

Science activities are diverse, often require several steps, and can be more difficult to supervise than other instructional activities. As the teacher, you should perform each lesson first before assigning it to your students. A practice run will allow you to become more comfortable with teaching the lesson, enable you to better supervise and instruct your students, and help you recognize potential risks that could exist as students learn new skills and work with new materials.

Below are suggestions on how to better prepare your students for safety in the chemistry classroom and lab. While some of the tips may not apply to your grade level or lesson, it is never too early to teach your students about the importance of classroom and lab safety while conducting experiments!

To ensure everyday safety in your classroom, create and post a safety plan specific to your classroom environment, complete with evacuation procedures. To reinforce the safety rules, engage the students in a discussion or activity about safety. At the elementary level, something as simple as a poster contest (or assignment), in which the winning (or all) posters are displayed, is an easy and creative way to reinforce the rules. At the middle school level, group activities that involve safety scenarios or question-and-answer sessions will help reinforce the rules. Most important, educators should always model appropriate behavior by obeying safety rules and procedures in class.

In your safety discussion, be sure to stress that horseplay in the classroom or lab is dangerous and will not be tolerated. Emphasize the importance of understanding how to safely store, handle, and use chemicals before performing any lessons. Explain that this information can be found in many places, such as on the container's warning label. Product container labels include key warnings about storage, handling, and, if necessary, first aid and other emergency information. Another information source is the Material Safety Data Sheet (MSDS), which is available for most chemicals. The MSDS contains more detailed information about chemical characteristics, hazards, emergency information, storage and handling precautions, and disposal information.

You should also educate students about proper personal protection, such as wearing aprons, gloves, and safety goggles when performing any experiment.

The following pages list general classroom and lab safety tips for you to discuss with your students.

Be safe and have fun!

RESOURCE GUIDE: Safety First

- **Chemists Have No Taste**—As a general rule, chemists never use their sense of taste in the lab.
- **Ban All Food**—Food should not be stored or consumed in a lab setting. Even in harmless situations, eating food in a lab sets a poor safety example.
- **Smell It Properly**—Chemists never hold a chemical container under their nose to test for an odor. The proper method is called "wafting." Hold the open bottle at least 18 inches from your nose. Use your free hand to "fan" vapor over the bottle opening toward your nose and you can safely inhale only a slight amount of chemical vapor.
- **Protect the "Corner" of Your Eyes**—Eye protection should be provided and worn by teachers and students when performing lab experiments. Regular eyeglasses provide insufficient protection. Proper lab glasses protect both the front and sides of the eyes. It's those hazards, just out of normal view—to the sides of the eyes—that often do the most damage!
- **Eye Wash Times Three**—When working with chemicals, a chemist always makes provisions for an eye wash. If you do not have access to a professional eye wash station or wash bottle, keep on hand a supply (300–500 mL) of distilled water in a sterilized container.
- **Wear That Apron**—Most lab accidents are caused by spilled liquids. A nonabsorbent apron will direct liquid toward the floor, away from you. Do not use cloth aprons in the lab.
- **No Bag, No Sag**—Loose clothing can create a hazard in a lab setting. Sleeves and shirttails can interact with labware to create a spill.
- **Tie Back Hair**—Long hair in a chemistry lab can create a safety problem, especially around flames or caustic chemicals. Keep rubber ties, caps, or other hair accessories available for temporarily securing longer hair.
- **Turn Your Head to Talk**—Many heated lab vessels have been shattered by a tiny speck of saliva accidentally emitted as a chemist talks while working.
- **Love Your Labels**—Make sure that all chemicals and storage areas in your classroom or lab are clearly labeled. Chemicals should never be stored in an unlabeled container, even for a short period of time.
- **No ABCs with Chemical Storage**—While storing chemicals in alphabetical order may be convenient, it may not be safe to do so. Chemicals should be stored only by reactivity risk and compatibility.
- **A Partnership with MSDS**—A container of chemicals in your lab should always have a partner in your filing cabinet or computer file: a Material Safety Data Sheet (MSDS). Make certain all students and teachers have easy and immediate access to your MSDS file.
- **Stay Out of the Sun**—Direct sunlight will not only initiate the decomposition of many chemicals, it can also affect labware, stoppers, tubing, labels, etc.
- **Amber Bottles**—You may notice that some chemicals are stored in amber or dark-brown glass bottles. Amber glass is used to filter out ultraviolet (UV) light. Some chemicals will readily decompose in the presence of UV light. Keep chemicals in the same type of container in which they arrived from the manufacturer.
- **Neutralizers**—When planning to use hazardous chemicals, even in diluted form, a chemist will always prepare an appropriate neutralizing chemical beforehand and keep it handy.
- **Splash Guard**—Chemists must always prevent water from splashing out of the lab sink. When filling a beaker or other open-mouthed vessel in a lab sink, turn on the water first. Then bring the beaker mouth into the stream. This action prevents splashing.
- **Acid to Water**—A general chemical rule when diluting acids and other active chemicals: always add acid to water; NEVER add water to acid.

RESOURCE GUIDE: Safety First

- **Labware Not Glassware**—Do not substitute common glassware for labware. Household bottles and jars are usually made of common flint glass. They are unsuitable for heating chemicals over open flames or high-temperature heaters. Their ability to resist thermal shock is very limited. Most common glassware will shatter when heated. Most labware is made of borosilicate glass, which has a much greater resistance to thermal shock.

- **Stir Silently**—During manufacture, lab glassware is specially heated at the factory to create a completely smooth and nonporous surface. This surface provides no pores or pits in which chemicals can "hide." To avoid creating chemical hiding places, do not strike, scrape, or touch the interior surface of the vessel with a hard instrument when stirring the contents of the vessel. Otherwise, you may create microscopic nicks and scratches that will hold contaminating chemicals.

- **Watch Where You Point**—When opening chemical containers or heating lab vessels, always keep in mind the direction of the container's mouth. Point the opening away—away from you, away from others, and away from points of safety concern.

- **Preheating Procedure**—Although lab glassware is usually made of thermal, shock-resistant borosilicate glass, it is not immune to shattering from radical temperature changes. Do not thrust a room-temperature vessel into a burner flame. Instead, swirl the vessel as you slowly bring it into the heat source in several stages.

- **Tilt That Test Tube**—When heating a solution in a test tube, avoid holding the tube vertically in a flame. The hot liquid near the bottom of the tube can create a "geyser" effect and suddenly push liquid out of the tube. To avoid such action, chemists always tilt a test tube 30 degrees from vertical when heating.

- **Burner Flames**—A properly adjusted burner flame of natural gas or propane is pale and light blue in color. In a brightly lit room, the flames are often difficult to see. When not in direct use, either extinguish the flame or adjust the airflow to create a bright-yellow, easily visible flame.

- **Burner Temperature**—A typical Bunsen burner flame has a temperature of approximately 950 °C. If substituting a propane torch for a Bunsen burner, remember that the torch flame is about 1500 °C.

- **Boiling to Dryness**—When using lab glassware, avoid boiling liquids to the point at which the container is completely dry. A small amount of boiling liquid can create a "spot" of relatively cool glass. The tension between the cool spot and the surrounding hot glass could cause the vessel to crack or shatter.

- **Wire Gauze**—Place a piece of heavy gauge wire screen or wire gauze between a glass vessel and a burner flame or heat source. The screen conducts heat, creating a spread of heat over the entire under-surface of the vessel. This trick helps prevent breakage from thermal shock.

- **Wash Up**—Students should wash their hands with soap and water after completing an experiment. They should avoid touching their eyes and mouth until after they have washed their hands.

CHEMICAL DISPOSAL

It is unlikely that waste generated in introductory-level chemistry experiments will be harmful to the environment. However, discussing safe disposal teaches students about environmental health and safety.

Remember, disposal procedures vary. Before handling or moving a chemical for disposal, be sure to refer to the MSDS for disposal precautions. For more information, contact your school district's safety coordinator.

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RESOURCE GUIDE: Lesson Plan Vocabulary

A

Absorption: A process by which matter soaks up or takes in another substance

Accuracy: The closeness of a given measurement to the actual (true) value for that quantity of substance; to measure a quantity as close as possible to the true measurement (true value) of that quantity

Acid: A solution that contains an excess of hydrogen ions (H^+); acids have a higher concentration of hydrogen ions than pure water

Acid-base indicator: A substance that reveals the acidity or basicity of a solution through characteristic color changes; also simply known as an *indicator*

Adhesion: An attractive force that holds atoms or ions of different substances together

Aerobic respiration: The chemical process by which food molecules, such as glucose, combine with oxygen to release energy, carbon dioxide, and water

Air: A colorless and odorless gaseous mixture, composed mainly of nitrogen and oxygen

Air pressure: The cumulative force exerted on a surface by the weight of the air particles above that surface; also known as *atmospheric pressure*

Alloy: A uniform mixture made up of two or more metals or of a metal and a nonmetal

Amino acid: A type of substance that makes up proteins; amino acids are the building blocks of proteins

Amorphous solid: A solid made up of atoms or molecules that are locked into place but do not have a specific form or neat, repeating structure

Anemia: A condition in which the red blood cell count or the hemoglobin in red blood cells is abnormally low

Aqueous solution: A solution in which the solvent is water

Atom: The fundamental unit of an element; the smallest particle of an element that maintains the chemical properties of that element

Atomic number: The number of protons found in the nucleus of an atom; it is used to identify elements

Attraction: A force that draws particles together

Avogadro's Law: A scientific law stating that equal volumes of gases at the same temperature and pressure will contain the same number of molecules (n), regardless of their chemical nature and physical properties

B

Base: A solution that has an excess of hydroxide ions (OH^-); bases have a lower concentration of hydrogen ions than pure water

Boiling point: The temperature at which a liquid begins to form a gas

Boyle's Law: A scientific law stating that at a constant temperature, the product of the pressure and volume of an ideal gas is always constant

Buoyancy: An upward force that a fluid exerts on an object, enabling the object to float

Byproduct: A secondary product that is created from a chemical reaction at the same time as the primary, desired product(s)

C

Capillary: A tiny tube or vessel that is able to hold or transport liquids

Capillary action: The ability of a substance to be drawn (possibly upward) through a tiny tube or vessel by adhesive and cohesive forces; also known as *capillarity*

Carbohydrate: The most abundant group of organic compounds found in living organisms that are made up of sugars; carbohydrates are broken down during chemical processes to generate energy

RESOURCE GUIDE: Lesson Plan Vocabulary

Carbonation: The process of dissolving carbon dioxide gas in water or an aqueous solution under pressure

Catalyst: A substance that helps to change the rate of a reaction but is not consumed or changed during the reaction

Charles' Law: A scientific law stating that under constant pressure, the volume and temperature of a gas are directly proportional; therefore, the proportion of volume to temperature of a gas equals a constant

Chemical bond: A strong force of attraction that holds atoms together in a molecule

Chemical change: See *chemical reaction*

Chemical energy: Energy stored in the structures of chemical substances that may be released or transformed during a chemical reaction

Chemical property: A property of a substance that can be revealed by the way the substance interacts with other substances; describes an object's "potential" to undergo some chemical change or reaction due to its composition

Chemical reaction: A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a *chemical change*

Chemistry: A science that deals with the composition, structure, properties, and reactions of matter

Chromatography: A group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition

Cohesion: An attractive force that holds atoms or ions of a single body together; an attraction between particles of the same kind

Colloid: A mixture, between homogeneous and heterogeneous, in which very small particles are spread evenly throughout another substance

Compound: A pure substance made up of two or more elements joined in a defined ratio

Concentration: The amount of solute in a solution

Concentration gradient: The difference between the concentration of two fluids

Conclusion: A statement scientists make explaining whether a tested hypothesis was valid or invalid

Condensation: A physical change in which a substance changes states from a gas to a liquid

Conduction: The transfer of energy by collisions between nearby atoms

Control: Something that does not change throughout an experiment; a setup that is not changed

Controlled experiment: An experiment in which all conditions except one are held constant

Controlled variable: A thing that should not change during an experiment

Convection: The transfer of energy by the bulk molecular motion within a liquid or gas

Cosmic dust: Clouds of fine, solid particles that exist in outer space

Cross-linking: The formation of chemical bonds between complex molecules or molecular chains, such as polymers

Crude oil: A mixture made of hydrocarbon compounds that is used to produce various fuels, such as gasoline

Crystalline solid: A solid made up of atoms or molecules organized in specific, repeating patterns; these regular, repeating patterns form crystals

RESOURCE GUIDE: Lesson Plan Vocabulary

D

Data: Pieces of information that are collected and recorded before, during, or after an experiment

Decomposition: A chemical reaction in which a compound breaks apart into two or more products

Density: A physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are; the amount of matter per unit of volume ($d = m/v$)

Dependent variable: The variable that you observe when the independent variable is changed; also known as the *responding variable*

Deposition: A physical change in which a substance changes states from a gas to a solid

Desalination: The process of removing salt from a saltwater solution, such as sea water

Dew point: The temperature at which a gas begins to condense into a liquid

Diatomic molecule: Molecules consisting of two atoms bound together, such as diatomic oxygen gas (O_2)

Diffusion: The movement of particles from an area of high concentration to an area of low concentration

Displacement: The act of moving something out of its original position or of one substance taking the place of another; also a type of chemical reaction in which a reactant takes the place of some part of a compound to produce a new compound and release a separate product

Disposable: An object that is designed to be used once and then thrown away

Dissolve: To cause a substance to mix uniformly with a solvent, creating a solution

Distillation: A method of separating a liquid mixture based on the differences between the boiling points of the mixture's parts

Double displacement: A chemical reaction in which parts of two compound reactants replace each other to form two or more different compound products

Drag: The resistance of motion through a fluid; a mechanical force that opposes an aircraft's motion through the air

Ductility: The ability of a metal to be stretched into a thin wire or thread without breaking

Dye: A soluble substance used to stain or color fabrics and fibers, such as paper, cotton, etc.

E

Electric charge: A basic property of some subatomic particles that can be classified as either positive or negative; a characteristic property of matter identified by an imbalance of electrons, whether an excess or deficiency of electrons

Electrical conductivity: A measure of the rate at which electricity can travel through a material

Electrical energy: A form of energy that results from the flow of charged particles, such as electrons or ions; also known as *electricity*

Electrically neutral: An atomic state in which the number of protons in an atom equals the number of electrons, thus, the positive and negative charges are balanced

Electricity: See *electrical energy*

Electromagnetic wave: A wave (continuous vibration through space) that carries energy through space by radiation

Electron: A subatomic particle that carries a negative charge and occupies the space outside the nucleus of an atom

Element: A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom

RESOURCE GUIDE: Lesson Plan Vocabulary

Emulsion: A colloid that consists of liquids spread throughout other liquids; the liquids in an emulsion do not completely mix and are often unstable

Endothermic change: A change that needs energy added to take place

Energy: The ability to do work or produce heat

Enzyme: A type of protein found in living cells that acts as a catalyst by increasing the rate of a chemical reaction within living organisms

Equilibrium: A state of balance between opposing forces or elements; a state of balance in which a chemical reaction and its reverse reaction occur at equal rates

Error: A concept associated with inaccuracy or a flaw in measurement

Evaporation: A vaporization process that occurs at the surface of a liquid

Exothermic change: A change that gives off energy, generally sensed as heat

Experiment: An operation carried out under controlled conditions in order to discover an unknown effect or phenomenon; to test or establish a hypothesis as valid or invalid

F

Filter paper: A porous paper that can be used to separate suspended solids from a liquid

Filtrate: A liquid collected, following a filtration process, that is free of solid particles

Filtration: A separation process that uses the different sizes of a mixture's parts to separate those parts

Fluid: Any substance made up of particles that flow or move freely, such as a liquid or gas

Force: A push or pull acting on an object, sometimes causing a change in position or motion

Freezing: A physical change in which a substance changes states from a liquid to a solid

Freezing point: The temperature at which a substance begins to change from a liquid to a solid

Frequency: The number of complete waves or pulses that pass a given point per second

Friction: The force that resists motion between two substances in contact

G

Gas: A state of matter that has no definite volume or shape

Gas laws: A set of laws that describe the relationships between volume, temperature, and pressure of gases

Gay-Lussac's Law: A scientific law stating that the pressure exerted on a container by a gas is directly proportional to the temperature of the gas

Gravity: The force of attraction between all masses in the universe; the force that tends to draw all substances in the earth's atmosphere toward the center of the earth

H

Heat: The flow of thermal energy from one substance to another because of differences in temperature

Hemoglobin: A protein found in red blood cells that contains iron and transports oxygen from the lungs to different parts of the body

Heterogeneous mixture: A type of mixture in which the makeup is not the same throughout; the substances are not evenly mixed

Homogeneous mixture: A type of mixture that is considered to be the same throughout; the substances are evenly mixed

RESOURCE GUIDE: Lesson Plan Vocabulary

Hydrocarbon: A compound made of only the elements hydrogen (H) and carbon (C)

Hypothesis: A possible explanation of an observation that can answer a scientific question

I

Ideal gas law: A combination of gas laws that relates temperature, pressure, and volume through the formula, PV = nRT, where P is pressure, V is volume, T is temperature, n is the number of moles, and R is the ideal gas constant

Immiscible: The inability to mix evenly; the inability of two or more substances to form a homogeneous mixture when combined

Independent variable: The variable you are going to change in an experiment

Index of refraction: The ratio of the speed of light in a vacuum to the speed of light in a substance

Indicator: See *acid-base indicator*

Inertia: The resistance of an object to a change in its state of motion

Insoluble: The inability of a substance to be dissolved into another substance

Insulation: Any material that resists the flow or transfer of heat, sound, or electric current; also known as an *insulator*

Ion: An atom or group of atoms that has lost or gained one or more of its outer electrons; an ion will have either a positive or a negative charge

K

Kinetic energy: A form of energy associated with motion, calculated using the formula $KE = {}^{1}/_{2}mv^2$

L

Law of conservation of energy: A scientific law stating that while energy can change form, it cannot be created or destroyed; also known as the *first law of thermodynamics*

Light: A specific group of electromagnetic waves that travels freely through space and can be detected by the human eye; also known as *visible light*

Lipid: A type of organic compound that is insoluble in water and helps with insulation and the regulation of body functions; lipids are also used to store energy in the body

Liquid: A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first

Litmus paper: An acid-base indicator that changes color in the presence of acids and bases; blue litmus paper turns red in the presence of an acid, and red litmus paper turns blue in the presence of a base

Luster: The ability of a metal to reflect light; this property gives metals a shiny appearance

M

Magnet: An object that creates a strong magnetic field and is able to attract iron

Magnetic field: An area of magnetic force around certain substances (metals) that causes them to move in certain ways even if they do not touch

Magnetism: A force of attraction or repulsion between materials that produce a magnetic field

Malleability: The ability of a metal to be flattened, shaped, or formed without breaking when pressure is applied

Mass: A measure of the amount of matter in a substance

Matter: Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth

RESOURCE GUIDE: Lesson Plan Vocabulary

Measure: To mark or fix in multiples of a specific unit based on a comparison to some sort of standard

Measurement: A technique in which properties of a substance are determined by comparing it to some sort of standard

Mechanical energy: A form of energy determined by the motion or position of a substance; the total mechanical energy of a substance is the sum of its kinetic and potential energy

Melting: A physical change in which a substance changes states from a solid to a liquid

Melting point: The temperature at which a substance begins to change from a solid to a liquid

Metalloids: See *semi-metals*

Metals: A set of elements that are usually solid at a normal room temperature and are found primarily on the left side of the periodic table; most metals have similar characteristics, such as good thermal and electrical conductivity, luster, malleability, and ductility

Miscible: The ability to mix evenly; the ability to mix in all proportions to form a homogeneous solution

Mixture: A physical combination of two or more substances that can be physically separated

Mobile phase: The mixture that flows over the stationary material in a chromatography separation process

Molecule: The simplest structural unit of an element or compound that is made up of atoms held together by chemical bonds and maintains the chemical properties of the element or compound

Monomer: A single molecule capable of combining with other similar molecules to form a polymer

N

Neutral: A particle that carries no electric charge; a solution that contains a concentration of hydrogen ions that is equal to pure water

Neutron: A subatomic particle that carries no electric charge and is found in the nucleus of an atom

Newton's First Law of Motion: The first part of Sir Isaac Newton's theory of motion stating that an object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction, unless acted upon by an unbalanced force

Newton's Second Law of Motion: The second part of Sir Isaac Newton's theory of motion stating that the relationship between an object's mass (m), its acceleration (a), and the applied force (F) is described by the formula $F = ma$

Newton's Third Law of Motion: The third part of Sir Isaac Newton's theory of motion stating that for every action, there exists an equal and opposite reaction

Newtonian fluid: A fluid that has a constant viscosity at a constant temperature, regardless of any applied force or rate of flow

Nonmetals: A set of elements that are generally gases or solids at a normal room temperature and are found primarily on the right side of the periodic table

Non-Newtonian fluid: A fluid that does not have a constant viscosity; the viscosity of a non-Newtonian fluid varies based on the force applied or how fast an object is moving through the liquid

Nonpolar substance: A substance made up of particles that have an even distribution of electrons; the charges on these particles are neutralized

Nonvolatile solute: A solute that has little tendency to escape from a solution

Nuclear energy: A form of energy released when the nucleus of an atom is split or fused

RESOURCE GUIDE: Lesson Plan Vocabulary

Nucleation site: An area where droplets of liquid can condense from a vapor, bubbles of gas can form in a boiling liquid, or new crystals can grow in a solution

Nucleus: The center of an atom containing protons and neutrons

O

Osmosis: The diffusion of water across a semi-permeable membrane (a membrane that allows some ions or molecules to pass through but not others)

Outer space: A region beyond the limit of the earth's atmosphere or any other celestial body (planet, star, asteroid, etc.)

Oxidation: The loss of at least one electron when two or more substances interact, which may or may not involve oxygen

P

Paraffin wax: A white, pliable solid that can be obtained from crude oil

Periodic table of elements: An arrangement of the chemical elements by atomic number so that elements having similar properties fall in the same column

Permanent magnet: A type of magnetic substance that keeps a certain level of magnetism for a long time

pH: A measure of the concentration of hydrogen ions in a solution; used to characterize acids and bases

pH scale: A scale that is used to measure the acidity of (concentration of hydrogen ions in) a solution; the pH scale generally ranges from 0 to 14

Photosynthesis: The process by which some living organisms, primarily green plants, convert light energy, carbon dioxide, and water into oxygen gas and sugars that store chemical energy

Physical change: A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance

Physical property: A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance

Polar substance: A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side

Polarity: The state of having a positive or a negative charge

Poles: The ends of a magnet, each having an opposite charge, one positive and one negative; these poles are called the north pole (N) and the south pole (S)

Polymer: A large molecule formed by combining many smaller molecules (monomers) in a regular pattern

Potential energy: The energy stored in a substance

Power: The rate at which energy is converted or work is performed

Precipitate: A solid formed from a solution following a chemical reaction, specifically a precipitation process

Precipitation: A separation process that separates a particular component from a solution by reacting the solution with another substance to form a solid

Precision: The degree to which repeated measurements under unchanged conditions show the same results

Pressure: The amount of force exerted on an area

Product: A substance formed as a result of a chemical reaction

Protein: A type of complex organic compound made up of amino acids and involved in various cell functions; proteins help the body to grow and repair damage

RESOURCE GUIDE: Lesson Plan Vocabulary

Proton: A subatomic particle that carries a positive charge and is found in the nucleus of an atom

Pyrex® glass: A heat-resistant glass used to make scientific and cooking equipment

R

Radiant energy: A form of energy carried by electromagnetic waves, which includes X-rays, microwaves, ultraviolet radiation, and light

Radiation: The transfer of energy (as electromagnetic waves) through an empty space or clear material without heating the empty space or clear material

Random error: A type of error or flaw in measurement that is not controllable and is due to chance

Reactant: A starting material for a chemical reaction

Refraction: The bending of light as it passes from one medium to another

Respiration: A set of reactions that take place inside cells to convert the energy stored in food into another type of chemical energy that can be used by the body

Rocket: A device propelled by the ejection of matter (usually a gas) and often expelled as a result of the combustion of some internal material

Rocketry: A branch of engineering science that studies the design and operation of rockets

Rust: The reddish-brown brittle substance formed by the oxidation of iron; also known as *iron (III) oxide*

S

Saturation: The point at which no more of a solute can be dissolved into a solvent or solution

Semi-metals: A set of elements that have some properties of both metals and nonmetals and are found along a zigzag dividing line between metals and nonmetals on the periodic table; also known as *metalloids*

Separation process: A process that divides a mixture into two or more distinct substances

Shear stress: A pressure or force in the structure of a substance that arises when its layers are shifted horizontally in relation to each other

Sieving: A separation process by which solids of different sizes are separated from a mixture by passing the mixture through a screen

Sol: A colloid made up of fine solid particles suspended in a liquid or another solid

Solid: A state of matter characterized by a definite volume and a definite shape

Solubility: A measure of the amount of solute that can be dissolved in a solvent

Soluble: The ability of a substance to dissolve in another substance

Solute: A substance that is dissolved in a solution

Solution: A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent)

Solvent: A substance capable of dissolving another substance

Static electricity: The buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material

Stationary phase: A stationary material over which a mixture flows during a chromatography separation process

Sublimation: A physical change in which a substance changes states from a solid to a gas

Suction: A force that attracts a substance to a region of lower pressure when there is a difference in pressure

RESOURCE GUIDE: Lesson Plan Vocabulary

Surface tension: A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface "film"

Surfactant: Any substance with the ability to reduce the surface tension of a liquid; also known as a *surface active agent*

Synthesis: A chemical reaction in which two or more reactants combine to form a product

Systematic error: A type of error or flaw in measurement that is controllable and has a known cause, such as instrument error, method error, or human error

T

Temperature: A measure of the average kinetic energy of particles in a substance, generally identified by sensations of hot and cold

Temporary magnet: A type of magnet that acts like a permanent magnet when it is within a strong magnetic field but loses its magnetism when the magnetic field is removed

Thermal conductivity: The measure of the rate at which thermal energy can travel through a material

Thermal energy: The total energy of particles in a substance

Thrust: The mechanical force that pushes a rocket or an aircraft through the air

Transparent: A substance that allows light to pass through it easily so that objects beyond or behind the substance can be seen clearly

Triatomic molecule: A molecule consisting of three atoms bound together, such as ozone (O_3)

Triglyceride: A type of organic compound that is part of the lipid family and is made up of a glycerol (a type of alcohol) and three fatty acids

V

Vacuum: A volume of space that has essentially no matter; also known as a *partial vacuum*

Vapor: A common term used to describe a substance in its gaseous state, such as water vapor

Vaporization: A physical change in which a substance changes states from a liquid to a gas

Viscosity: The measure of a fluid's thickness or resistance to flow

Volatility: The tendency of a substance to vaporize (change into a gaseous state)

Volume: A physical property that measures the amount of space a substance occupies

W

Watercolor paint: A pigment dissolved in water that is used to create colorful designs on fibrous materials, such as paper

Wavelength: The distance between one wave crest (top of the wave) and the next, or between one wave trough (bottom of the wave) and the next

Weight: A measure of the pull of gravity between an object and the earth or the planets, sun, etc.

Work: The measure of a change in energy that occurs when a force causes an object to be displaced

X

Xylem: A complex plant tissue made up of networks of vessels (or small hollow tubes) that transport water and dissolved minerals through the plant; provides structural support to the plant

RESOURCE GUIDE:
Review Game Suggestions & Content

The following questions are provided as a means of reviewing and reinforcing the concepts that your students have learned in the lessons provided. This content is supplied to benefit you and your class in a number of ways—be creative and have fun!

Suggestions for review game setups:

- Divide your class into groups, and use the content on the following pages to create a fun question-and-answer competition.
- Choose a few lessons or major content topics to create a Jeopardy-style game.
- Use the material taken from the Fun Facts as bonus questions on tests!

LESSON 1: GOOFY PUTTY

1. A(n) __________ is made of two or more substances that are combined physically.
a. mixture

2. A uniform mixture in which one or more substances are dissolved in another substance is a(n) _________.
a. solution

3. Color, shape, boiling point, melting point, and density are examples of _________ properties of matter.
a. physical

4. Acidity, toxicity, and flammability are examples of _________ properties of matter.
a. chemical

5. Any change in a substance's form that does not change its chemical makeup is a(n) _____________.
a. physical change

6. During a(n) _____________, the structure or composition of the materials in a substance is changed or rearranged.
a. chemical reaction (or chemical change)

7. A(n) __________ is the smallest structural unit of an element or compound that keeps the chemical properties of that element or compound.
a. molecule

8. Long, chain-like molecules that are formed by connecting many repeating units are called __________.
a. polymers

9. A(n) ________ is a single molecule capable of combining with other similar molecules.
a. monomer

10. Hydrous sodium borate is also known as ________.
a. borax

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 2: "AGELESS" APPLES

1. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) ______.
   a. acid

2. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) _________.
   a. base

3. The _________ measures the concentration of hydrogen ions in acids and bases.
   a. pH scale

4. The lower the concentration of H^+, the ________ the pH will be.
   a. higher

5. A substance with a pH higher than 7 is considered to be ______.
   a. basic (or a base)

6. Pure water is a(n) ________ substance with a pH of 7.
   a. neutral

7. __________ are complex organic compounds that are involved in almost all cell functions.
   a. Proteins

8. A(n) ___________ is a substance that helps change the rate of reaction.
   a. catalyst

9. Proteins that act as catalysts by increasing the rate of chemical reactions are called ___________.
   a. enzymes

10. __________ are the building blocks of proteins.
    a. Amino acids

LESSON 3: RUSTING WOOL

1. A(n) ________ is a uniform mixture made up of two or more metals or a metal and a nonmetal.
   a. alloy

2. Two atoms of oxygen bound together forming a molecule of O_2 is referred to as a(n) __________ molecule.
   a. diatomic

3. The triatomic form of oxygen is commonly called _________.
   a. ozone

4. ___________ often occurs when oxygen molecules interact with other substances.
   a. Oxidation

5. Iron oxide, a brittle reddish-brown substance that forms on iron, is most commonly called ________.
   a. rust

6. Rust is formed through a(n) _____________ between oxygen, water, and iron.
   a. chemical reaction (or chemical change)

7. A(n) _____________ is any change in a substance's form that does not change its chemical makeup.
   a. physical change

8. When the atoms of a substance are rearranged and the bonds between the atoms are broken or formed, a substance has undergone a(n) _____________.
   a. chemical reaction (or chemical change)

9. ____________ occurs when one substance takes the place of another.
   a. Displacement

10. The set of reactions that take place inside the cells of living things to convert energy from nutrients into a type of stored energy that can be used by the body is called ___________.
    a. respiration

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 4: BUOYANT BUTTER

1. __________ is a measure of the amount of matter in a substance.
   a. Mass

2. The amount of space an object occupies is the object's __________.
   a. volume

3. __________ is the physical property of matter that describes how closely packed together the atoms or molecules of a substance are.
   a. Density

4. __________ occurs when one substance takes the place of another.
   a. Displacement

5. Measurements are ________ if they are close to the true measurement of an object or substance.
   a. accurate

6. Measurements are _________ if you take the same measurement and get the same result over and over.
   a. precise

7. The density of a solid is measured in what units?
   a. g/cm^3 or kg/m^3

8. The formula for calculating density is _________.
   a. $d = m/v$

9. In terms of density, a stick of butter is _______ than water.
   a. less dense

10. Which is denser: freshwater or salt water?
    a. Salt water

LESSON 5: LUMPY LIQUIDS

1. _________ are made of two or more substances that are combined physically.
   a. Mixtures

2. A uniform mixture in which one or more substances are dissolved into another substance is a(n) _________.
   a. solution

3. A(n) _____________ divides a mixture of substances into two or more distinct products.
   a. separation process

4. __________ is a separation process in which a solid is formed in a solution following a chemical reaction.
   a. Precipitation

5. The solid that forms from a solution after a chemical reaction is called a(n) __________.
   a. precipitate

6. The process by which a mixture is separated based on the sizes of the parts that make up the mixture is called _________.
   a. filtration

7. The liquid that flows through the paper during a filtration separation process is called the _________.
   a. filtrate

8. A physical property that describes the ability of a chemical substance to dissolve in a solvent to create a uniform solution is called __________.
   a. solubility

9. If a substance does not dissolve in another substance, it is __________.
   a. insoluble

10. A(n) _____________ is any solution in which the solvent is water.
    a. aqueous solution

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 6: RUBBER EGGS

1. Pure substances that cannot be broken down further by normal chemical means are ________.
   a. elements

2. A(n) ________ is a pure substance made up of two or more elements joined in a defined ratio.
   a. compound

3. A(n) ________ is made of two or more substances that are combined physically.
   a. mixture

4. A change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed, is a(n) ____________.
   a. chemical reaction (or chemical change)

5. The bubbles that form during the experiment contain ___________ gas, which is produced from the chemical reaction between the vinegar and the eggshell.
   a. carbon dioxide

6. A(n) _______ is an atom or molecule that has lost or gained one or more of its outer electrons.
   a. ion

7. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) _________.
   a. acid

8. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) _______.
   a. base

9. A solution containing an H^+ concentration equal to pure water is _______.
   a. neutral

10. Substances that change colors at different levels of acidity are ________, which are used to determine whether a solution is an acid or a base.
    a. indicators

LESSON 7: MILK RAINBOW

1. _______ have a definite volume and definite shape.
   a. Solids

2. ______ have a definite volume but no definite shape.
   a. Liquids

3. ______ have no definite volume and no definite shape.
   a. Gases

4. A property of liquids that describes the attraction of liquid particles at the surface is called __________.
   a. surface tension

5. A(n) ___________ is a substance that has the ability to reduce the surface tension of a liquid.
   a. surfactant

6. A(n) ________ is a mixture in which very small particles are spread evenly throughout another substance.
   a. colloid

7. A mixture that is considered to be the same throughout is called a(n) ___________.
   a. homogeneous mixture

8. A mixture in which the makeup is not the same throughout is called a(n) ___________.
   a. heterogeneous mixture

9. A(n) __________ is a mixture that consists of liquids spread throughout other liquids.
   a. emulsion

10. ________ is an emulsion of fats and proteins spread throughout water.
    a. Milk

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LESSON 8: THE MOVING MOLECULE STOMP

1. A substance undergoes a(n) ________ change when only its form, not its chemical makeup, is changed.
   a. physical

2. Particles in a(n) ________ are generally locked into place giving the substance a definite shape and volume.
   a. solid

3. ____________ are made up of atoms or molecules that have a specific, repeating arrangement.
   a. Crystalline solids

4. Solids made up of atoms or molecules that are locked into place but do not have a specific, repeating structure are known as _____________.
   a. amorphous solids

5. Particles in a(n) ________ move around freely, allowing it to flow, but still experience attractive forces.
   a. liquid

6. Particles in a(n) ________ are spaced far apart and move around freely and rapidly in random directions.
   a. gas

7. A physical change from a solid to a liquid is called ________.
   a. melting

8. A physical change from a liquid to a solid is called ________.
   a. freezing

9. A physical change from a liquid to a gas is called ________.
   a. vaporization

10. A physical change from a gas to a liquid is called ________.
   a. condensation

LESSON 9: EGG-DYE SOLUTIONS

1. A(n)______ is an atom or molecule that has lost or gained one or more of its outer electrons.
   a. ion

2. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) _______.
   a. acid

3. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) ________.
   a. base

4. A solution containing an H^+ concentration equal to pure water is ________.
   a. neutral

5. The concentration of hydrogen ions in acids and bases is measured on the ________.
   a. pH scale

6. Substances that change colors at different levels of acidity are _________, which are used to determine whether a solution is an acid or a base.
   a. indicators

7. A(n) ___________ occurs when two or more substances interact, producing a change in the structure of the substance(s).
   a. chemical reaction (or chemical change)

8. A(n) ________ is the starting material for a chemical reaction.
   a. reactant

9. The substance or substances produced from a chemical reaction are called ________.
   a. products

10. A secondary product created at the same time as a desired product during a chemical reaction is called a(n) _________.
   a. byproduct

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LESSON 10: IRON IN CEREAL

1. _______ is the metal element needed to transport oxygen throughout the body.
a. Iron

2. ________ is the protein molecule in red blood cells that picks up oxygen in the lungs and transports it to different parts of the body.
a. Hemoglobin

3. Iron deficiencies, such as _________, occur when the body has an insufficient amount of healthy red blood cells.
a. anemia

4. A force of attraction or repulsion between materials that produce a magnetic field is called _________.
a. magnetism

5. _________ are pure substance that cannot be broken down further by normal chemical means.
a. Elements

6. A(n) _______ is a pure substance made up of two or more elements joined in a defined ratio.
a. compound

7. A(n) _______ is made of two or more substances that are combined physically.
a. mixture

8. In this lesson, a(n) ________ is used to separate iron particles from the cereal mixture.
a. magnet

9. Iron, cobalt, and nickel are the only elements known to produce a(n) _________.
a. magnetic field

10. A(n) ______________ divides a mixture of substances into two or more distinct products.
a. separation process

LESSON 11: DIAPER POLYMERS

1. A(n) ________ is the smallest particle of an element or compound that retains the chemical properties of that element or compound.
a. molecule

2. Long, chain-like molecules that are formed by connecting many repeating units are called _________.
a. polymers

3. A(n) ________ is a single molecule capable of combining with other similar molecules.
a. monomer

4. ________ is the movement of particles from an area of high concentration to an area of low concentration.
a. Diffusion

5. The diffusion of water across a semi-permeable membrane is called ________.
a. osmosis

6. A(n) _______ is any substance made up of particles that flow or move freely.
a. fluid

7. Both _______ and _______ are considered fluids.
a. liquids, gases

8. Sodium chloride is commonly known as ________.
a. table salt

9. ___________ is the bonding of separate polymer chains in a network that makes the polymer stronger.
a. Cross-linking

10. ___________ is added to the polymer in the experiment to draw the water back out of the polymer.
a. Table salt

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LESSON 12: THE GREAT ESCAPE

1. _________ are pure substances that cannot be broken down further by normal chemical means.
   a. Elements
2. A(n) _________ is a pure substance made up of two or more elements joined in a defined ratio.
   a. compound
3. A(n) _________ is made of two or more substances that are combined physically.
   a. mixture
4. A uniform mixture in which one or more substances are dissolved in another substance is a(n) ________.
   a. solution
5. _________ is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution.
   a. Solubility
6. For solid solutes, as temperature increases, solubility __________.
   a. increases
7. For gas solutes, as temperature increases, solubility __________.
   a. decreases
8. __________ is defined as the capacity to do work or produce heat.
   a. Energy
9. The law of _______________ states that while energy can change from one form to another, it can neither be created nor destroyed.
   a. conservation of energy
10. _________ is a measure of the average kinetic energy of particles in a substance.
    a. Temperature

LESSON 13: DISAPPEARING GLASS

1. _________ is a measure of the ability to do work or produce heat.
   a. Energy
2. Light, microwaves, and X-rays are all types of ______________.
   a. electromagnetic waves
3. _________ is a property of light that describes the bending of light as it passes from one medium to another.
   a. Refraction
4. The ____________ refers to the angle that is formed between the light and the surface of the object.
   a. index of refraction
5. ________ is the distance between one wave crest (top of the wave) and the next, or between one wave trough (bottom of the wave) and the next.
   a. Wavelength
6. _________ is the number of complete waves or pulses that pass a given point per second.
   a. Frequency
7. _________ is the measure of the amount of matter in a substance.
   a. Mass
8. __________ is the measure of the amount of space an object occupies.
   a. Volume
9. ________ have a definite volume and a definite shape.
   a. Solids
10. ________ have a definite volume but no definite shape.
    a. Liquids

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LESSON 14: WACKY WAXY WATERCOLORS

1. __________ is a white, pliable solid obtained from crude oil.
   a. Paraffin wax

2. A(n) _________ is made of two or more substances that are combined physically.
   a. mixture

3. A uniform mixture in which one or more substances are dissolved in another substance is a(n) _________.
   a. solution

4. A substance that has the ability to dissolve in another substance is__________.
   a. soluble

5. A substance that does not dissolve in another substance is __________.
   a. insoluble

6. A(n) ________ is a compound made of only the elements hydrogen and carbon.
   a. hydrocarbon

7. __________ are made up of atoms or molecules that have a specific, repeating structure.
   a. Crystalline solids

8. __________ are made up of atoms or molecules that are locked into place but do not have a specific, structured pattern.
   a. Amorphous solids

9. __________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
   a. Polar substances

10. __________ are made up of particles that have an uneven distribution of electrons.
    a. Nonpolar substances

LESSON 15: FLOATING PAPER CLIPS

1. ___________ are a state of matter that have a definite volume but no definite shape.
   a. Liquids

2. ___________ is a property of liquids that describes the attraction of liquid particles at the surface.
   a. Surface tension

3. The upward force that a fluid exerts on an object that enables the object to float is called _________.
   a. buoyancy

4. A(n) _______ is any substance made up of particles that move freely, such as liquids and gases, and that easily changes shape when force is applied.
   a. fluid

5. _________ is the act of moving something out of its original position or of one substance taking the place of another.
   a. Displacement

6. The measure of the pull of gravity between an object and the earth is ________.
   a. weight

7. A(n) __________ is a substance that has the ability to reduce the surface tension of a liquid.
   a. surfactant

8. Anything that has mass and takes up space is called _________.
   a. matter

9. _________ is a measure of the amount of matter in a substance.
   a. Mass

10. _________ is a measure of the amount of space an object occupies.
    a. Volume

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LESSON 16: FOUNTAIN OF SODA POP

1. A(n) ________ is a uniform mixture in which one or more substances are dissolved in another substance.
a. solution

2. __________ is a physical property that describes the ability of a chemical substance to dissolve in a solvent and create a uniform solution.
a. Solubility

3. A substance that has the ability to dissolve in another substance is __________.
a. soluble

4. A substance that does not dissolve in another substance is ________.
a. insoluble

5. As pressure increases, the solubility of gases in a liquid ___________.
a. increases

6. ___________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
a. Polar substances

7. ___________ are the tiny nooks and crannies where bubbles form during the reaction between the Mentos® mints and the soda pop.
a. Nucleation sites

8. The reaction between the Mentos® mints and the soda pop creates __________ gas.
a. carbon dioxide

9. Soda pop is an example of a(n) _________ in which carbon dioxide gas is dissolved in the water and sugar.
a. solution

10. In a soda pop solution, carbon dioxide gas is a(n) _________.
a. solute

LESSON 17: BALLOON ROCKETS

1. ________ is the amount of push or pull on an object.
a. Force

2. The mechanical force that pushes a rocket or aircraft through the air is known as _______.
a. thrust

3. Newton's __________________ states that the relationship between an object's mass (m), its acceleration (a) and the applied force (F) is F = ma.
a. Second Law of Motion

4. Newton's ________________ states that for every action there is an equal and opposite reaction.
a. Third Law of Motion

5. _________ is the amount of force exerted on an area.
a. Pressure

6. When the gas is released from the balloon, the rocket is propelled forward by a force called ________.
a. thrust

7. ________ is a mechanical force that opposes a rocket or aircraft's motion through the air.
a. Drag

8. ________ is the rate at which energy is converted or work is performed.
a. Power

9. Drag is generated by the difference in velocity between a solid object and a(n) ________.
a. fluid

10. In this experiment, the gas particles in the balloon create _________ on the inside of the balloon.
a. pressure

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LESSON 18: PUFFED RICE FLEAS

1. _________ are pure substances that cannot be broken down further by normal chemical means.
   a. Elements

2. A(n) ________ is the fundamental unit of an element; it is the smallest particle of an element that retains the elements chemical properties.
   a. atom

3. Atoms are made up of smaller parts called ________, ________, and _______.
   a. protons, neutrons, electrons

4. The nucleus of an atom consists of _______ and ________.
   a. protons, neutrons

5. ________ occupy the space outside of the nucleus within an atom.
   a. Electrons

6. _________ is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material.
   a. Static electricity

7. _________ is a general term that includes a variety of occurrences that result from the flow of electric charges.
   a. Electricity

8. Protons have a(n) _______ electric charge.
   a. positive

9. Neutrons have a(n) _______ electric charge.
   a. neutral

10. Electrons have a(n) _______ electric charge.
    a. negative

LESSON 19: LIQUID RAINBOW

1. _________ is a measure of the amount of matter in a substance.
   a. Mass

2. _________ is the amount of space an object occupies.
   a. Volume

3. _________ is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are.
   a. Density

4. A(n) ________ is a uniform mixture in which one or more substances are dissolved in another substance.
   a. solution

5. As more salt is dissolved in water, the density of the solution _________.
   a. increases

6. ____________ is a physical property that describes the ability of a chemical substance to dissolve in a solvent to create a uniform solution.
   a. Solubility

7. A substance that has the ability to dissolve in another substance is __________.
   a. soluble

8. A substance that does not dissolve in another substance is ________.
   a. insoluble

9. Salt is ________ in water.
   a. soluble

10. Butter is _______ in water.
    a. insoluble

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LESSON 20: HOLD THE SALT

1. ________ are made of two or more substances that are combined physically.
a. Mixtures

2. A(n) _________ is a uniform mixture in which one or more substances are dissolved in another substance.
a. solution

3. A(n) __________ is a means of separating a mixture of substances into two or more distinct products.
a. separation process

4. _________ is a method of separating a liquid mixture based on the differences between the boiling points of the mixture's parts.
a. Distillation

5. _________ is a physical change from a liquid to a gas.
a. Vaporization

6. ________ is a physical change from a gas to a liquid.
a. Condensation

7. ________ is a physical change from a solid to a liquid.
a. Melting

8. ________ is a physical change from a solid directly to a gas.
a. Sublimation

9. ________ is a physical change from a gas directly to a solid.
a. Deposition

10. A(n) ___________ is any change in a substance's form that does not change its chemical makeup.
a. physical change

LESSON 21: SEWER LEECHES

1. A(n) ________ is a uniform mixture in which one or more substances are dissolved into another substance.
a. solution

2. _________ is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution.
a. Solubility

3. _________ is the physical property of matter that describes how closely packed together the atoms or molecules of a substance are.
a. Density

4. ________ occurs when one substance takes the place of another.
a. Displacement

5. The upward force that a fluid exerts on an object that enables the object to float is called __________.
a. buoyancy

6. A substance that dissolves in another substance is__________.
a. soluble (or a solute)

7. A substance that does not dissolve in another substance is __________.
a. insoluble

8. ________ is the process of dissolving carbon dioxide gas in water.
a. Carbonation

9. ________ refers to the distribution of electrons in an atom.
a. Polarity

10. ___________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
a. Polar substances

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LESSON 22: MYSTERIOUS MIXTURES

1. A(n) ________ is made of two or more substances that are combined physically.
   a. mixture

2. A mixture that is considered to be the same throughout is called a(n) _______________.
   a. homogeneous mixture

3. A uniform mixture in which one or more substances are dissolved in another substance is a(n) _________.
   a. solution

4. A mixture in which the makeup is not the same throughout is called a(n) _______________.
   a. heterogeneous mixture

5. A(n) ______________ divides a mixture of substances into two or more distinct products.
   a. separation process

6. ________ is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.
   a. Chromatography

7. During chromatography, a mixture is moved over a certain material called the _______________.
   a. stationary phase

8. The mixture that flows over the material during a chromatography separation process is called the _______________.
   a. mobile phase

9. In this experiment, the coffee filters are used as the _______________.
   a. stationary phase

10. In this experiment, the colored water is used as the _______________.
    a. mobile phase

LESSON 23: EXPLODING BAGS

1. _____________ are properties of matter identified by using our senses or taking measurements.
   a. Physical properties

2. ____________ are properties of matter identified by observing how a chemical reacts with other substances.
   a. Chemical properties

3. A(n) ____________ is any change in a substance's form that does not change its chemical makeup.
   a. physical change

4. A(n) ____________ is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed.
   a. chemical reaction (or chemical change)

5. The substance or substances that start a chemical reaction are called ___________.
   a. reactants

6. The new substance or substances produced as a result of a chemical reaction are called ________.
   a. products

7. A(n) _______ is an atom or molecule that has lost or gained one or more of its outer electrons.
   a. ion

8. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) _______.
   a. acid

9. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) ___________.
   a. base

10. A solution containing an H^+ concentration equal to pure water is ___________.
    a. neutral

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LESSON 24: GRASPING FOR AIR

1. _______ is anything that has mass and takes up space.
   a. Matter

2. _______ is a state of matter with a definite shape and a definite volume.
   a. Solid

3. _______ is a state of matter with a definite volume but no definite shape.
   a. Liquid

4. _______ is a state of matter with no definite volume and no definite shape.
   a. Gas

5. _______ is the amount of force exerted on an area.
   a. Pressure

6. The force exerted on a surface by the weight of the air above that surface is called ___________.
   a. air pressure (or atmospheric pressure)

7. The act of moving something out of its original position or of one substance taking the place of another is known as _______.
   a. displacement

8. _______ is the amount of space an object occupies.
   a. Volume

9. A(n) _______ is a volume of space that has essentially no matter.
   a. vacuum

10. A(n) _______ is a force that attracts a substance or object to a region of lower pressure when there is a difference in pressure.
    a. suction

LESSON 25: CAPILLARY CARNATIONS

1. _______ have a definite volume and definite shape.
   a. Solids

2. _______ have a definite volume but no definite shape.
   a. Liquids

3. _______ have no definite volume and no definite shape.
   a. Gases

4. ___________ is the movement of liquids upward through a narrow tube, cylinder, or permeable substance because of cohesive and adhesive forces interacting between the liquid and the surface.
   a. Capillary action (or capillarity)

5. ___________ is the attractive force that exists between like particles in a certain liquid.
   a. Cohesion

6. ___________ is a property of liquids that describes the attraction of liquid particles at the surface.
   a. Surface tension

7. ___________ is the force of attraction between unlike particles.
   a. Adhesion

8. ___________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
   a. Polar substances

9. ___________ is a complex plant tissue made up of networks of vessels that transport water and dissolved minerals through the plant and also provides structural support to the plant.
   a. Xylem

10. ___________ causes water droplets to form into a sphere rather than spreading out flat.
    a. Surface tension

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LESSON 26: MELTING ICE WITH SALT

1. Pure substances that cannot be broken down further by normal chemical means are _________.
a. elements

2. A(n) _________ is a pure substance made up of two or more elements in a defined ratio.
a. compound

3. Sodium chloride is commonly known as _______.
a. table salt

4. A(n) _________ is any change in a substance's form that does not change its chemical makeup.
a. physical change

5. _________ is a physical change from a liquid to a solid.
a. Freezing

6. The temperature at which a liquid begins to form a solid is known as the _________.
a. freezing point

7. _________ is a physical change from a solid to a liquid.
a. Melting

8. The ________ is the temperature at which a substance begins changing states from a solid to a liquid.
a. melting point

9. _________ describes the tendency of a substance to vaporize.
a. Volatility

10. A(n) _________ is a solute that has little tendency to escape from a solution.
a. nonvolatile solute

LESSON 27: SEPARATING SALT & PEPPER

1. _________ are made of two or more substances that are combined physically.
a. Mixtures

2. A(n) ____________ separates a mixture of substances into two or more distinct products.
a. separation process

3. ____________ are properties of matter identified by using our senses or taking measurements.
a. Physical properties

4. ____________ are properties of matter identified by observing how a chemical reacts with other substances.
a. Chemical properties

5. _________ is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material.
a. Static electricity

6. Pure substances that cannot be broken down further by normal chemical means are _________.
a. elements

7. A(n) _________ is a pure substance made up of two or more elements in a defined ratio.
a. compound

8. _________ are the fundamental units of an element.
a. Atoms

9. The nucleus of an atom is comprised of _________ and _________.
a. protons, neutrons

10. Electrons are found outside of the nucleus and have a(n) _________ charge.
a. negative

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LESSON 28: ANTIGRAVITY WATER

1. Anything that has mass and takes up space is called ________.
a. matter

2. ________ have a definite volume and definite shape.
a. Solids

3. ________ have a definite volume but no definite shape.
a. Liquids

4. ________ have no definite volume and no definite shape.
a. Gases

5. ________ is the attractive force that exists between like particles in a certain liquid.
a. Cohesion

6. ________ is a property of liquids that describes the attraction of liquid particles at the surface.
a. Surface tension

7. ________ is the force of attraction between unlike particles.
a. Adhesion

8. ________ occurs when one substance takes the place of another.
a. Displacement

9. ________ is the amount of force exerted on an area.
a. Pressure

10. The force exerted on a surface by the weight of the air above that surface is called ________.
a. air pressure (or atmospheric pressure)

LESSON 29: SOLID OR LIQUID?

1. ________ have a definite volume and definite shape.
a. Solids

2. ________ have a definite volume but no definite shape.
a. Liquids

3. ________ have no definite volume and no definite shape.
a. Gases

4. A(n) ________ is any substance made up of particles that flow or move freely.
a. fluid

5. Both ________ and ________ are considered fluids.
a. liquids, gases

6. ________ is a measure of a fluid's resistance to flow.
a. Viscosity

7. A(n) ___________ fluid has a viscosity that remains constant, regardless of any applied force or rate of flow.
a. Newtonian

8. A(n) ___________ fluid is one that has a viscosity that varies based on the force applied or how fast an object is moving through the fluid.
a. non-Newtonian

9. ___________ is a pressure or force in the structure of a substance that arises when its layers are shifted horizontally in relation to each other.
a. Shear stress

10. Peanut butter, gravy, and ________ are examples of a unique type of matter known as non-Newtonian fluids because they exhibit different physical properties based on the amount of force applied.
a. ketchup

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LESSON 30: BALLOON IN A BOTTLE

1. Anything that has mass and takes up space is called ________.
   a. matter

2. ________ is the measure of the amount of matter in a substance.
   a. Mass

3. ________ is the measure of the amount of space an object occupies.
   a. Volume

4. ________ have a definite volume and definite shape.
   a. Solids

5. ________ have a definite volume but no definite shape.
   a. Liquids

6. ________ have no definite volume and no definite shape.
   a. Gases

7. ________ is a measure of the ability to do work or produce heat.
   a. Energy

8. ________ is a measure of the average kinetic energy of particles in a substance.
   a. Temperature

9. ___________ states that the volume and temperature of a gas are directly proportional.
   a. Charles' Law

10. The law of ______________ states that while energy can change from one form to another, it can neither be created nor destroyed.
    a. conservation of energy

LESSON 31: MARSHMALLOW LAUNCHERS

1. Anything that has mass and takes up space is called ________.
   a. matter

2. ________ is the measure of the amount of matter in a substance.
   a. Mass

3. ________ is the measure of the ability to do work or produce heat.
   a. Energy

4. ________ occurs when a force causes an object to be moved from its original position.
   a. Work

5. The law of ______________ states that while energy can change from one form to another, it can neither be created nor destroyed.
   a. conservation of energy

6. A form of energy determined by the motion or position of a substance is called ________.
   a. mechanical energy

7. A form of energy that exists when an object is in motion is called ________.
   a. kinetic energy

8. ________energy is stored energy.
   a. Potential

9. ________ is the resistance of an object to a change in its state of motion.
   a. Inertia

10. ________ is the amount of push or pull on an object.
    a. Force

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LESSON 32: T-SHIRT TIE-DYE

1. ________ is a process by which matter takes in another substance.
   a. Absorption

2. A(n) ________ is made up of two or more substances that are combined physically.
   a. mixture

3. A uniform mixture in which one or more substances are dissolved in another substance is a(n) ________.
   a. solution

4. ________ is a physical property that describes the ability of a chemical substance to dissolve in a solvent to create a uniform solution.
   a. Solubility

5. A substance that has the ability to dissolve in another substance is ________.
   a. soluble

6. A substance that does not dissolve in another substance is ________.
   a. insoluble

7. ________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
   a. Polar substances

8. ________ are made up of particles that have an uneven distribution of electrons.
   a. Nonpolar substances

9. ________ is the movement of particles from an area of high concentration to an area of low concentration.
   a. Diffusion

10. ________ is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.
    a. Chromatography

LESSON 33: ELEPHANT TOOTHPASTE

1. Pure substances that cannot be broken down further by normal chemical means are called ________.
   a. elements

2. A(n) ________ is a pure substance made up of two or more elements in a defined ratio.
   a. compound

3. A(n) ___________ is any change in a substance's form that does not change its chemical makeup.
   a. physical change

4. When the atoms of a substance are rearranged, and the bonds between the atoms are broken or formed, a substance has undergone a(n) ____________.
   a. chemical reaction (or chemical change)

5. A(n) ________ is the starting material for a chemical reaction.
   a. reactant

6. The substance or substances produced from a chemical reaction are called _______.
   a. products

7. A secondary product that is created at the same time as a desired product during a chemical reaction is called a(n) ________.
   a. byproduct

8. During a(n) ___________, a compound breaks apart into two or more products.
   a. decomposition reaction

9. A(n) ____________ is a reaction that gives off energy.
   a. exothermic reaction

10. A(n) ____________ is a reaction that requires or absorbs energy.
    a. endothermic reaction

RESOURCE GUIDE:
Sample Review Game Board

MATTER	MIXTURES & SEPARATIONS	PHYSICAL PROPERTIES & CHANGES	CHEMICAL REACTIONS	ACIDS & BASES	POLYMERS
A state of matter that has a definite volume but no definite shape is called a(n) __________.	A(n) ________ is a uniform liquid mixture composed of two or more substances.	A physical property that measures the amount of matter in an object is called __________.	A starting material for a chemical reaction is called a(n) _______.	Acids and bases are characterized on the __________ scale.	Any molecule that can combine with other molecules to form a polymer is called a(n) _________.
All matter is composed of ______, which are made up of protons, neutrons, and electrons.	A process that transforms a mixture of substances into two or more distinct products is called a(n) ________.	_________ is a physical change in which a substance changes states from a liquid to a gas.	A substance formed as a result of a chemical reaction is called a(n) _________.	Solutions that contain a higher concentration of hydrogen ions than pure water are known as _________.	Atoms of the element ________ make up the most common polymers.
The center of an atom is called the ________.	Several factors can affect solubility, including _________, pressure, and the nature of the solute or solvent.	________ is a physical property that describes how closely packed together the atoms of an element or molecules of a compound are.	When two or more substances interact to form new substances, a(n) _________ takes place.	A substance that reveals the acidity of a solution through characteristic color changes is called a(n) _________.	A large molecule formed by combining many smaller molecules in a regular, repeating pattern is called a(n) ________.
A(n) _________ is a state of matter characterized by a definite volume and a definite shape	In a solution, one substance, called the _________, is dissolved into another substance.	Condensation is a physical change in which a substance changes states from a(n) _______ to a(n) ________.	The loss of at least one electron when two or more substances interact is called ________.	Which is *not* an acid: vinegar, lemon juice, milk of magnesia, or orange juice? _________	A polymer with the capability to absorb large amounts of water is called a(n) ________________.
An atom is considered to be neutral when it has an equal number of protons and ________.	A porous paper that can be used to separate solids from liquids is called ______ paper.	A physical change from a solid state to a liquid state is called ____________.	The reddish-brown brittle substance formed by the oxidation of iron is known commonly as _________.	________ can be used to neutralize acids.	The formation of chemical bonds between molecular chains of a polymer is known as _________.

RESOURCE GUIDE:
Sample Review Game Board **ANSWER KEY**

MATTER	MIXTURES & SEPARATIONS	PHYSICAL PROPERTIES & CHANGES	CHEMICAL REACTIONS	ACIDS & BASES	POLYMERS
Liquid	Solution	Mass	Reactant	pH	Monomer
Atoms	Separation process	Vaporization	Product	Acids	Carbon
Nucleus	Temperature	Density	Chemical reaction (or chemical change)	Acid-base indicator	Polymer
Solid	Solute	Gas, liquid	Oxidation	Milk of magnesia	Super-absorbent polymer
Electrons	Filter	Melting	Rust	Bases	Cross-linking

RESOURCE GUIDE: Notable Chemists

AMEDEO AVOGADRO 1776–1856

Amedeo Avogadro was born on August 9, 1776, in Turin, Italy. He received his formal education in law, so he pursued his interest in physics and mathematics in his spare time.

In 1811, while teaching natural sciences at a high school in Vercelli, he published a memoir declaring a hypothesis now known as Avogadro's Law. His hypothesis stated that equal volumes of gases, at the same temperature and pressure, contain the same number of molecules. Avogadro's Law implies that relative molecular masses can be calculated from the masses of gas samples.

One of Avogadro's most important contributions to science was his resolution that particles could be composed of molecules and that molecules could be composed of even simpler units (atoms). The number of molecules in a mole (one gram molecular weight) was named "Avogadro's number" in honor of his theories of molarity and molecular weights. Avogadro's number has been determined to be about 6.02×10^{23}. This number is commonly used when working with chemical equations, allowing chemists to determine specific amounts of substances that are produced from a reaction.

NIELS BOHR 1885–1962

Niels Bohr was born in Copenhagen, Denmark, in 1885. He earned his doctorate in physics in 1911 from Copenhagen University.

In the spring of 1912, Bohr began working in Ernest Rutherford's laboratory in Manchester, England. Based on Rutherford's atomic theories, Bohr published his model of atomic structure in 1913, which introduced the concept of electrons traveling in orbits around the nucleus. He also proposed that the chemical properties of an element were determined by the number of electrons in the outer orbits.

In 1920, he was appointed head of the Institute for Theoretical Physics at Copenhagen University, a position he held for the remainder of his life. In 1922, he received the Nobel Prize in Physics for his work on the structure of atoms.

ROBERT BOYLE 1627–1691

Robert Boyle was born in Lismore, Ireland, in 1627. In 1635, Boyle's father, a wealthy Englishman, sent him away to school, where he initially did very well. After a few years, Boyle stopped progressing, so his father brought him home in 1638 to be privately tutored. When he was 12 years old, Boyle was sent on a grand tour of Europe to learn the great ideas of the time.

In 1646, he moved to Stalbridge, a manor house in the English countryside that his father had left him when he died. During his visits to London, Boyle attended what he called the "Invisible College," which consisted of a group of scientists who would hold regular meetings. This group would eventually become known as the Royal Society of London.

As a member of the original Royal Society of London, Boyle believed in acquiring knowledge by experimental investigation. His most famous discovery is known as Boyle's Law, which states that if temperature remains constant, the volume of a given mass of gas is inversely proportional to the absolute pressure. His other discoveries included showing that sound does not travel in a vacuum and that flames require air.

RESOURCE GUIDE: Notable Chemists

ROBERT BUNSEN 1811–1899

Robert Wilhelm Bunsen was born on March 31, 1811, in Göttingen, Germany. Bunsen began his study of chemistry at the University of Göttingen, where he received his doctorate when he was only 19 years old. From 1830 to 1833, he traveled throughout Germany and to Paris and Vienna, meeting fellow scientists and creating a valuable network of contacts. When Bunsen returned to Germany, he became a lecturer at Göttingen and began experimental studies with arsenious acid. His experiments produced the best known antidote against arsenic poisoning to date.

In 1838, Bunsen accepted a position at the University of Marburg. There he conducted studies of cacodyl compounds, which are products made from arsenic and are known to be poisonous, highly flammable, and extremely nauseating when inhaled. Bunsen's risky experiments helped advance his career and the studies of many other scientists, but his success was not without sacrifice. Bunsen nearly killed himself from arsenic poisoning and lost sight in one eye because of an explosion of an arsenic compound.

In 1852, Bunsen took a position at Heidelberg, where he experimented with nitric acid to produce pure metals, such as chromium, magnesium, and sodium by electrolysis. At this time, he also began collaborating with Sir Henry Enfield Roscoe on the formation of hydrogen chloride from hydrogen and chlorine.

In 1855, Bunsen perfected a special gas burner (invented by Michael Faraday) that is now known as the Bunsen burner. He used this burner to study emission spectroscopy of heated elements with Gustav Robert Kirchhoff. Through these studies, they discovered the elements cesium and rubidium.

JOCELYN BELL BURNELL 1943-PRESENT

Jocelyn Bell Burnell was born on July 15, 1943, in Belfast, Northern Ireland. She graduated from the University of Glasgow in 1965 with a Bachelor of Science in physics, and she completed her Ph.D. from New Hall, part of the University of Cambridge, in 1969.

While studying at Cambridge, she assisted in the construction of an 81.5 megahertz radio telescope that was used to track quasars—sources of electromagnetic energy, such as radio waves and visible light. As a postgraduate student, she discovered the first radio pulsars with her thesis supervisor Antony Hewish. A pulsar is a highly magnetized, rotating neutron star that emits a beam of electromagnetic radiation.

After finishing her Ph.D., Bell Burnell worked in England at the University of Southampton and University College London and at the Royal Observatory in Edinburgh, Scotland. She was appointed professor of physics at the Open University in 1991. Before retiring, she was Dean of Science at the University of Bath, and she was the President of the Royal Astronomical Society between 2002 and 2004. She is currently a visiting professor of astrophysics at the University of Oxford and a Fellow at Mansfield College. Her two-year term as president of the Institute of Physics ended in October 2010.

RESOURCE GUIDE: Notable Chemists

WALLACE CAROTHERS 1896–1937

Wallace Hume Carothers was born in Burlington, Iowa, in 1896. After high school, Carothers attended Capital City Commercial College in Des Moines, Iowa, studying accounting and secretarial administration. He then went on to a four-year college in Missouri to complete a bachelor's degree in chemistry. In 1924, he earned his doctorate from the University of Illinois. After graduating, he began teaching at Harvard but was soon recruited by the DuPont Company.

In April 1930, one of Carothers' assistants at DuPont, Arnold M. Collins, isolated a new liquid compound that spontaneously polymerized to produce a rubber-like solid. The new polymer was named neoprene and became the first commercially successful specialty rubber.

In early 1934, Carothers and his team used amines rather than glycols to produce polyamides instead of polyesters. Polyamides are synthetic fibers that behave like natural silk and are more stable than polyesters, which are structurally similar to natural fats and oils. Carothers' group soon discovered a new polyamide fiber called nylon. Nylon, however, was not commercialized as an alternative to silk stockings until after Carothers' death. Nylon went into production in 1939, and a display of the new nylon stockings was a sensational hit at the World's Fair in New York that same year.

EMMA PERRY CARR 1880–1972

Emma Perry Carr was born in 1880 in Holmesville, Ohio. After high school, she attended Mount Holyoke College. Although she did not graduate from Mount Holyoke, she would be involved with the school for the rest of her life.

Carr transferred first to The Ohio State University and then to the University of Chicago, where she earned her bachelor's degree in 1905. She began teaching as an instructor at Mount Holyoke but soon returned to the University of Chicago to earn her Ph.D. in 1910. Once equipped with her doctorate, she joined the faculty of Mount Holyoke, determined to strengthen the chemistry program. Carr taught freshman general chemistry but believing that students should conduct research to obtain hands-on experience with how chemistry works, she started a research program at Mount Holyoke.

Carr initiated research on ultraviolet spectroscopy, a method for studying materials by looking at how they respond to ultraviolet radiation. In 1919, she spent a year working in a lab at Queen's University in Belfast, Ireland, to learn more about the technique. Her research led to a better understanding of the nature of double bonds between carbon atoms in molecules. Carr retired in 1946 but continued to be engaged in science and education until her death in 1972.

RESOURCE GUIDE: Notable Chemists

MARIE CURIE 1867–1934

Marie Curie was born in Warsaw, Poland, in 1867. She left Poland at the age of 24 to attend classes at the Sorbonne in Paris. In 1893, Curie received her master's degree in physics and then received a second master's degree in math the following year.

In 1903, Curie became the first woman in France to receive a doctorate degree. She and her husband, Pierre, worked together, winning a Nobel Prize in 1903 for their work with radiation. Pierre passed away in 1906, and the Sorbonne offered Curie her late husband's position as professor.

Her acceptance made her the first female teacher at the Sorbonne. Curie won her second Nobel Prize in 1911 for her work with radium and radiation.

During World War I, Curie drove around battlefields with her invention, the X-ray machine, to evaluate the wounds of soldiers. As a result, she was named the director of the Red Cross Radiology Service. Unfortunately, Curie was not properly protected and was frequently exposed to dangerous levels of radiation. After the war, Curie founded the Radium Institute in Paris, which became a world center for the study of radioactivity. She continued to work until the end of her life.

JOHN DALTON 1766–1844

John Dalton was born in 1766 in Eaglesfield, England. He moved to the city of Manchester in 1793 after teaching for ten years at a Quaker boarding school near his home. He joined the Manchester Literary and Philosophical Society, and was provided with the facilities to conduct scientific studies. His early research dealt with color blindness, which was then sometimes referred to as "Daltonism."

Dalton's interest in meteorology prompted him to keep a meteorological diary in which he recorded over 200,000 observations. These observations first led him to his view of atomism. He proposed the Atomic Theory, stating that all matter was composed of small indivisible particles called atoms; atoms of a given element are identical but different from atoms of any other element, and atoms of one element can combine to form compounds with other elements.

Dalton also revealed that air is not a vast chemical solvent, but is, instead, a mechanical system, wherein the pressure exerted by each gas in a mixture is independent of the pressure exerted by the other gases. Thus, the total pressure is the sum of the pressures of each gas, a conclusion known today as Dalton's law of partial pressures.

HUMPHRY DAVY 1778–1829

Sir Humphry Davy was born in Penzance, England, in 1778. He was apprenticed to a surgeon but explored a wide range of other subjects, including chemistry. In 1798, he took a position at Thomas Beddoes' Pneumatic Institution in Bristol, investigating the use of newly discovered gases in the cure and prevention of disease. At the Institution, Davy discovered the anesthetic effect of nitric oxide (laughing gas).

In 1800, Davy began research on electricity and realized that the production of electricity was dependent upon a chemical reaction. He used electrolysis to discover new metals, including potassium, sodium, magnesium, and calcium.

Two years later, Davy became a professor of chemistry at the Royal Institution and continued to conduct research. His research and inventions led to improved safety and conditions in many industries, including agriculture and mining. Davy became a fellow of the Royal Society of London in 1803 and served as president from 1820 to 1827. In 1812, he was knighted by King George III.

MICHAEL FARADAY 1791–1867

Michael Faraday was born on September 22, 1791, in London, England. He received a basic education and was apprenticed to a local bookbinder when he was 14 years old. During his years as an apprentice, he educated himself by reading books on a wide range of scientific topics.

Faraday attended a series of lectures by chemist Humphry Davy at the Royal Institution in 1812. Following the lectures, Faraday wrote to Davy requesting a job as his assistant. In 1813, Davy appointed him to the job of chemical assistant at the Royal Institution. In 1814, Faraday accompanied Davy on an 18-month tour of Europe, during which he had opportunities to meet prominent scientists. Following his travels, Faraday worked with Davy conducting experiments at the Royal Institution. In 1821, he published his research on electromagnetic rotation, establishing the principle behind the electric motor. A decade later, he discovered electromagnetic induction, which led to the development of the electric transformer and generator. These inventions enabled electricity to become a mainstream technology.

RESOURCE GUIDE: Notable Chemists

JOSEPH LOUIS GAY-LUSSAC 1778–1850

Joseph Louis Gay-Lussac was born on December 7, 1778, in Saint-Léonard-de-Noblat, France, and grew up during the French Revolution. He was selected to attend the École Polytechnique, an institution founded during the French Revolution and designed to educate scientific and technical leaders, especially for the military. Gay-Lussac began his professional career as a professor of physics and chemistry at the École Polytechnique.

Gay-Lussac shared Antoine-Laurent Lavoisier's interest in the quantitative study of the properties of gases. Throughout 1804, Gay-Lussac ascended close to 23,000 feet (7,000 meters) above sea level in hydrogen-filled balloons to investigate the composition of the atmosphere. During these experiments, he gathered magnetic measurements at various altitudes, collected samples of air, and took pressure, temperature, and humidity measurements.

In 1808, Gay-Lussac discovered that gases at constant temperature and pressure combine in simple numerical proportions by volume. The resulting product or products—if gases—also bear a simple proportion by volume to the volumes of the reactants.

With his fellow professor, Louis-Jacques Thénard, Gay-Lussac decomposed boric acid by using fused potassium, thus discovering the element boron. The two also took part in contemporary debates that modified Lavoisier's definition of acids and furthered his program of analyzing organic compounds for their oxygen and hydrogen content.

DOROTHY HODGKIN 1910–1994

Dorothy Crowfoot Hodgkin, a British biochemist and crystallographer, was born on May 12, 1910, in Cairo, Egypt. She obtained degrees from Oxford and Cambridge Universities.

In 1964, Hodgkin won the Nobel Prize in Chemistry for determining the structures of biologically important molecules. She used X-rays to find the structural layouts of atoms and the overall molecular shape of over 100 molecules, including penicillin, vitamin B-12, vitamin D, and insulin. Hodgkin confirmed the molecular structure of vitamin B-12 with the help of one of the first computers. Through this understanding, scientists were able to determine how the body uses B-12 to build red blood cells and prevent some types of anemia. Likewise, her discovery of the molecular layout of penicillin helped scientists to develop other antibiotics. In 1969, with over 30 years of studying molecules, Hodgkin unlocked the key to the three-dimensional structure of insulin, helping scientists control the disease diabetes.

Hodgkin's improvements using X-ray crystallography established this technique as an important analytical tool. For her work, Hodgkin received many awards and honors, including the Order of Merit, one of the highest civilian honors awarded in Great Britain. She was only the second woman, after Florence Nightingale, to receive this award.

RESOURCE GUIDE: Notable Chemists

PERCY JULIAN 1899–1975

Percy Lavon Julian was born on April 11, 1899, in Montgomery, Alabama. During his childhood, it was rare for African Americans to pursue an education beyond eighth grade, but his father encouraged him to strive for a higher education.

Julian graduated first in his class from DePauw University in 1920. He worked as a chemistry instructor at Fisk University in Tennessee until 1923, when he attended Harvard University for his master's degree. In 1929, Julian continued his graduate work at the University of Vienna, Austria, receiving his Ph.D. in 1931.

In 1935, while teaching organic chemistry at DePauw, Julian and Josef Pikl completed the total synthesis of physostigmine, a drug used to treat glaucoma. Julian was offered the position of director of research in the Soya Products Division at Glidden in Chicago as a result of his work on physostigmine. In this position, Julian designed and supervised the construction of the world's first facility for the production of industrial-grade, isolated soy protein. He later began work on synthesizing progesterone and testosterone to produce these hormones on a large scale and reduce the cost of treating hormonal deficiencies.

Julian left Glidden after 18 years to found his own company, Julian Laboratories, Inc., in Franklin Park, Illinois. He sold the company in 1961, and three years later, he founded Julian Associates and the Julian Research Institute, which he managed for the rest of his life.

AUGUST KEKULÉ 1829–1896

Friedrich August Kekulé was born on September 7, 1829, in Darmstadt, Germany. He entered the University of Giessen in 1847 to study architecture, but after hearing lectures by Justus von Liebig, he decided to explore chemistry. In 1858, he was appointed professor of chemistry at the University of Ghent. In 1865, he was called to the University of Bonn to fill a similar position, which he held for the rest of his career.

Kekulé's studies and ideas led to the development of the theory of chemical structure, specifically regarding the structure of carbon compounds. He believed that carbon atoms combine to form chains of any length and complexity. In 1865, Kekulé published a paper revealing the structure of benzene as a six-member ring of carbon atoms with alternating single and double bonds.

Kekulé attributed his structural theory to visions of atoms and molecules, the first appearing to him while traveling on a bus in London and the second while dozing in front of a fire.

RESOURCE GUIDE: Notable Chemists

STEPHANIE KWOLEK 1923–PRESENT

Stephanie Kwolek was born in New Kensington, Pennsylvania, on July 31, 1923. After graduating from Margaret Morrison Carnegie College of Carnegie-Mellon University, she applied for a position as a chemist with the DuPont Company. Her research on polymers at DuPont inspired her to drop her plans for medical school and pursue a career in chemistry.

Kwolek specialized in the creation of long molecule chains at low temperatures that resulted in extremely strong and rigid petroleum-based synthetic fibers. In the 1960s, she discovered an entirely new branch of synthetics and liquid crystalline polymers. Her most important research resulted in the discovery of Kevlar®, a synthetic fiber five times stronger than steel but with half the density of fiberglass. Kevlar® was first marketed in 1971 and is best known as the material that is used to make bullet-resistant vests.

For her work, Kwolek received or was the co-recipient of 17 U.S. patents. She worked as a Research Associate in DuPont's Pioneering Lab until her retirement but continued to consult part-time for DuPont afterward.

ANTOINE-LAURENT LAVOISIER 1743–1794

Known as the "Father of Modern Chemistry," Antoine-Laurent Lavoisier was born on August 26, 1743 in Paris, France. In 1754, Lavoisier enrolled at the Collège Mazarin, which was well known for its science and math departments. At Mazarin, he was a model student, received many awards, and conducted many of his first serious experiments. In addition to his scientific studies, Lavoisier studied law, earning a bachelor's degree and a license to practice law in 1764. Although initially, he worked as a tax collector, Lavoisier realized his true calling was science, so he resumed his studies in mineralogy and chemistry.

In 1771, Lavoisier married Marie-Anne Pierrette Paulze, who expertly illustrated and recorded his experiments. Lavoisier conducted hundreds of experiments, all of which challenged the ideas of the time. He showed that oxygen was responsible for combustion and proved that water consisted of hydrogen and oxygen. He also proposed new chemical terms, including the word "element," which formed a basis for later chemists.

In 1793, the French Revolution had been raging for almost five years, and on December 24, soldiers broke into Lavoisier's laboratory to arrest him for being a former tax collector. On May 7, 1794, Lavoisier was tried before the Revolutionary Tribunal and executed by guillotine.

RESOURCE GUIDE: Notable Chemists

CARL VON LINDE 1842–1934

Carl von Linde was born on June 11, 1842, in Berndorf, Germay. He received his early education in science and engineering at the Federal Polytechnic in Switzerland. After working for locomotive manufacturers in Berlin and Munich, he joined the faculty at the Polytechnic in Munich.

From 1873 to 1877, his research led to the invention of the first reliable compressed ammonia refrigerator. He founded a successful company to promote his invention, but after a decade, he ceased his business activities to focus on research.

In 1895, he succeeded in liquefying air by first compressing it and then letting it expand rapidly to cool. Then, he slowly warmed the liquid air to obtain oxygen and nitrogen. Von Linde was soon extracting oxygen in large quantities and supplying it to hospitals and industries.

DMITRI MENDELEEV 1834–1907

Dmitri Mendeleev was born on February 8, 1834, in Siberia, Russia. He graduated with a master's degree from the Pedagogical Institute in St. Petersburg. Mendeleev was awarded a fellowship to study at the University of Heidelberg, Germany, and after completing studies there, he returned to St. Petersburg, where he successfully defended his doctoral dissertation and became a professor of chemistry at the University of St. Petersburg.

In 1869, Mendeleev published a periodic table, which arranged the 63 known elements based on relative atomic mass (atomic weight). He arranged the elements in ascending order of atomic weight and grouped them according to similar properties. He also left space on his periodic table, predicting the existence and properties of elements that had not yet been discovered.

Mendeleev was known to quarrel with political and academic authorities. Following his resignation from the University of St. Petersburg, the Russian government appointed him director of the Bureau of Weights and Measures in 1893. He held the position for the rest of his life.

ISAAC NEWTON 1643–1727

Sir Isaac Newton was born prematurely on January 4, 1643, in Woolsthorpe, England. He attended grammar school and received a standard education, although he did not excel in school. He was fascinated with mechanics and began inventing his own machines. Newton began studying at the University of Cambridge in June of 1661. At Cambridge, he was exposed to many philosophical ideas, prompting him to question the environment around him.

In his early twenties, Newton developed a new mathematical method that is now known as calculus. He then moved to the science of mechanics. Newton used the concepts of gravity and centrifugal force to explain why the earth's rotation does not cause people to fly off into space. He also developed the law of universal gravitation.

In 1668, Newton's development of the reflecting telescope brought him into the spotlight among the scientific community. His telescope was only six inches long and one inch in diameter, yet it magnified over 30 times! Newton also experimented with colors, proving that white light was made up of a mixture of colors.

In 1703, Newton was elected president of the Royal Society of London; less than two years after his election, Queen Anne knighted Newton in Cambridge. Newton remained president of the Royal Society until his death.

RESOURCE GUIDE: Notable Chemists

ALFRED NOBEL 1833–1896

Alfred Nobel was born in Stockholm, Sweden, on October 21, 1833. His family moved to St. Petersburg, Russia, in 1842, where he was educated by private teachers. His primary interests were in English literature, poetry, chemistry, and physics. Nobel's father wanted his son to join his business as an engineer, so he sent Nobel abroad for further training in chemical engineering. During this time, Nobel visited Sweden, Germany, France, and the United States.

While in Paris, Nobel met the Italian chemist Ascanio Sobrero, who had invented nitroglycerin. Nobel became very interested in nitroglycerin and how it could be used safely in construction work. Nobel experimented with different additives to make nitroglycerin safer to handle. He discovered that adding diatomaceous earth turned the liquid into a paste that could be shaped into rods for insertion into drilling holes. In 1867, he patented this material, which he called "dynamite." He also invented a detonator (blasting cap) that could be ignited by lighting a fuse. He obtained 355 patents in his lifetime.

In his will, Nobel designated his fortune to be used for prizes in physics, chemistry, physiology or medicine, literature, and peace, all of which reflected his passions in life. The executors of his will established the Nobel Foundation to handle his fortune and coordinate the Nobel Prize awards.

LOUIS PASTEUR 1822–1895

Louis Pasteur was born on December 27, 1822, in Dole, France. He focused his education on physics and chemistry and earned a doctorate degree from École Normale in Paris in 1847.

In 1849, Pasteur was appointed lecturer of chemistry at Strasbourg University, and in 1854, he was made professor of chemistry and dean of the new Faculty of Sciences at Lille. While there, he studied the process of fermentation, concluding that the presence of microorganisms caused liquids to sour. He discovered that it was possible to prevent souring by heating the liquids to a certain temperature and pressure before boiling, a process now known as pasteurization.

In 1864, Pasteur developed his "germ theory," arguing that germs attacked the body from the outside and made people sick. He persisted with his theory and concluded that doctors should disinfect their hands and instruments before touching a patient to avoid spreading germs. Through his experiments, Pasteur also realized that people could be protected against disease by infecting them with a small amount of the weakened virus. He went on to invent the vaccines for rabies, anthrax, and diphtheria.

Pasteur's research on rabies resulted in the founding of a special institute in Paris for the treatment of the disease. This became known as the Institut Pasteur, and it was directed by Pasteur himself until his death.

RESOURCE GUIDE: Notable Chemists

LINUS PAULING 1901–1994

Linus Pauling was born in 1901, in Portland, Oregon, and worked as a laborer while earning his bachelor of science degree at Oregon State University at Corvallis. He went on to earn a Ph.D. in chemistry at the California Institute of Technology.

In the 1920s, Pauling revolutionized chemistry by incorporating the study of quantum physics. He used the new theory of wave mechanics to explain the chemical bonds in molecules. Pauling's resonance theory was critical in the creation of many of the drugs, dyes, plastics, and synthetic fibers commonly used today.

After the 1945 atomic bomb detonation, Pauling began to study the effects of radiation. Pauling educated the public about radiation hazards and campaigned for peace, disarmament, and the end of nuclear testing. These activities were considered to be treasonous during the first years of the Cold War and resulted in his passport being revoked by the U.S. State Department. When Pauling won the Nobel Prize in Chemistry in 1954 and could not leave the U.S. to accept it, pressure from around the world forced the government to lift this restriction.

Pauling continued his peace activism, and in 1957, he drafted a petition calling for an end to the atmospheric testing of nuclear weapons. This campaign led to a Nobel Peace Prize for Pauling in 1962 and to the first Nuclear Test Ban Treaty.

WILLIAM PERKIN 1838–1907

William Henry Perkin was born on March 12, 1838, in London, England. In 1853, Perkin entered the Royal College of Chemistry in London at only 15 years old. While on Easter break in 1856, Perkin conducted experiments in a simple laboratory in his London apartment. Through his experiments, he discovered that aniline could be transformed into a crude mixture that resulted in a bright-purple color when mixed with alcohol. Perkin soon realized that his solution could be used to color fabric, therefore becoming the first synthetic dye.

Perkin quickly patented his new dye, which he called mauveine, and began to consider ways to commercialize his product. With the help of his father and brother, Perkin set up a factory near the Grand Union Canal outside of London. His company received an unexpected boost when the Empress Eugenie of France decided the new color flattered her. Perkin's success demonstrated that chemistry could be financially and academically profitable!

Perkin continued research in organic chemistry for the rest of his life. He discovered and marketed other synthetic dyes, including Britannia Violet and Perkin's Green. In 1874, Perkin sold his factory and retired a very wealthy man.

ELEUTHÈRE IRÉNÉE DU PONT 1771–1834

Eleuthère Irénée du Pont was born in Paris, France, in 1771. Chemist Antoine Lavoisier hired du Pont to work in the Essonne Gunpowder factory. At this factory, du Pont learned how to manufacture gunpowder.

During the French Revolution, the du Ponts, like many others, found themselves under attack. In 1799, they left for the United States. Once in the U.S., du Pont recognized a business opportunity stemming from the poor quality of the gunpowder that was generally available. In 1802, he set up a powder works on the banks of the Brandywine River in Delaware. Initially, du Pont had difficulty getting things started and accumulated considerable debt. However, du Pont persevered, becoming the founder of the successful DuPont Company.

The DuPont Company became a major American business enterprise. When du Pont died in 1834, the company was producing over one million pounds of gunpowder per year.

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JOSEPH PRIESTLEY 1733–1804

Joseph Priestley was born in Fieldhead, England, in 1733. He was educated to be a minister and spent most of his life working as a preacher or a teacher. In 1794, he emigrated to the United States.

Priestley's first scientific work, *The History of Electricity* (1767), was encouraged by Benjamin Franklin, whom he had met in London. In preparing the publication, Priestley began to perform experiments, at first merely to reproduce research reported in the literature but later to answer questions of his own. In the 1770s, he began his most famous scientific research on the nature and properties of gases. At that time, he was living next to a brewery, which provided him with an ample supply of carbon dioxide.

His first chemical publication was a description of how to carbonate water, an imitation of some naturally occurring bubbly mineral waters. Priestley began examining all the "airs" that might be released from different substances. Many following Aristotle's teachings still believed there was only one "air." By clever design of apparatus and careful manipulation, Priestley isolated and characterized eight gases, including oxygen, a record not equaled before or since. In addition, he contributed to the understanding of photosynthesis and respiration.

ERNEST RUTHERFORD 1871–1937

Lord Ernest Rutherford was born on August 30, 1871, in Nelson, New Zealand. Rutherford received his early education in government school and entered Nelson Collegiate School when he was 16. In 1889, he attended the University of New Zealand, Wellington, studying mathematics and physical science. In 1894, he entered Trinity College, in Cambridge, England as a research student and became J.J. Thomson's first graduate student at the Cavendish Laboratory.

Rutherford began experimenting with the transmission of radio waves but soon turned to the new field of radioactivity. In 1898, he reported the existence of alpha and beta rays in uranium radiation and indicated some of their properties. He also demonstrated that radioactivity was the spontaneous disintegration of atoms. In 1907, Rutherford became chair of physics at the University of Manchester, and in 1908, he received the Nobel Prize in Chemistry for his work with radioactivity.

At Manchester, Rutherford postulated the concept of the nucleus and developed the basis for the atomic model. He was also the first scientist to successfully transmute one element, nitrogen, into another, oxygen. In 1914, Rutherford was knighted, and in 1931, he was deemed First Baron Rutherford of Nelson, New Zealand, and Cambridge.

RESOURCE GUIDE: Notable Chemists

WILLIAM THOMSON (LORD KELVIN) 1824–1907

William Thomson (Lord Kelvin) was born on June 26, 1824, in Belfast, Ireland. At 10 years old, Thomson attended the University of Glasgow in Scotland, which provided facilities for elementary school students. In 1845, Thomson received his B.A. degree from the University of Cambridge in England and a year later, he became the chair of natural philosophy at the University of Glasgow in Scotland.

In 1848, Thomson introduced a new scale of absolute temperature measured in units that are now called Kelvins. Absolute zero on the Kelvin scale, the temperature at which atoms stop moving, equals negative 273 degrees Celsius.

Thomson's scientific work covered a variety of subjects, and he was well known for unifying different theories. His collaboration with James Joule played a major role in developing the second law of thermodynamics. They also observed what is now called the Joule-Thomson effect—that the temperature of a gas decreases when it expands in a vacuum.

Thomson also played a major role in laying the first transatlantic telegraph cable, risking his life several times during this process. In 1866, he was knighted by Queen Victoria for his work, and he was raised to the peerage of Baron Kelvin of Largs in 1892. He was a fellow of the Royal Society and served as president between 1890 and 1895.

EVANGELISTA TORRICELLI 1608–1647

Evangelista Torricelli was born in Faenza, Italy, on October 15, 1608. In 1624, he entered a Jesuit College to study mathematics and philosophy. In 1626, he traveled to Rome to study Galileo's laws of motion. He succeeded Galileo as grand-ducal mathematician and professor of mathematics at the University of Pisa. At the university, Torricelli solved some of the great mathematical problems of that time.

In 1634, while working to solve a problem facing pumpmakers, Torricelli made an important discovery. He used mercury, which has a density that is 14 times that of water, to raise water in a pump to the desired height. During his experiments, he realized that the column of mercury fluctuated with the atmospheric pressure, thus inventing the first barometer and demonstrating that a vacuum exists.

Torricelli also designed and built a number of telescopes and simple microscopes. Several large lenses, engraved with his name, are still preserved at the Museum of Science in Florence.

RESOURCE GUIDE: Notable Chemists

FRIEDRICH WÖHLER 1800–1882

Friedrich Wöhler was born on July 31, 1800, in Eschersheim, Germany. He began his education at the Gymnasium in Frankfurt, and in 1820, he entered the University of Marburg planning to become a physician. After receiving his medical degree in 1823, he began his study of chemistry with Europe's leading chemist Jöns Jacob Berzelius in Stockholm. Wöhler worked with Berzelius for a year, adopting his techniques and learning the chemistry of new elements.

Wöhler returned to Germany in 1825 to teach chemistry at the municipal technical school in Berlin. During his years at the school, Wöhler made two of his most notable discoveries. In 1828, he synthesized urea (an organic compound) from a completely inorganic substance. His discovery opposed the traditional belief that only living things could produce organic compounds and revealed that all matter, living or not, is governed by the same chemical laws. During this time, Wöhler also developed a method for preparing metallic aluminum on a small scale.

In the following years, Wöhler often collaborated with Justus von Liebig, advancing the study of organic chemistry. Together, they discovered organic radicals—groups of atoms in a molecule that tend to stay together during chemical reactions. They also investigated the family of plant bases called alkaloids, which include caffeine, nicotine, and morphine.

Celebrate Chemistry All Year!

There are many notable days on the calendar that can easily be related to chemistry. Celebrate with your students by conducting a science experiment!

NATIONAL STATIC ELECTRICITY DAY	JANUARY 9
NATIONAL INVENTORS' DAY	FEBRUARY 11
NATIONAL POISON PREVENTION WEEK	3RD WEEK IN MARCH
WORLD HEALTH DAY	APRIL 7
NATIONAL TEACHER APPRECIATION DAY	APRIL 7
EARTH DAY (U.S.)	APRIL 22
NATIONAL ENERGY EDUCATION DAY	APRIL 23
SPACE DAY	1ST FRIDAY IN MAY
NATIONAL TEACHER DAY	TUESDAY OF THE 1ST FULL WEEK IN MAY
TEACHER APPRECIATION WEEK	2ND WEEK IN MAY
WEIGHTS AND MEASURES DAY	MAY 20
NATIONAL SAFETY MONTH	JUNE
WORLD ENVIRONMENT DAY	JUNE 5
PETROLEUM DAY	AUGUST 27
NATIONAL CHILD HEALTH DAY	1ST MONDAY IN OCTOBER
FIRE PREVENTION DAY	OCTOBER 9
NATIONAL METRIC WEEK	2ND WEEK IN OCTOBER
NATIONAL MOLE DAY	OCTOBER 23
NATIONAL CHEMISTRY WEEK	3RD WEEK IN OCTOBER
NATIONAL HEALTH EDUCATION WEEK	3RD WEEK IN OCTOBER
MAKE A DIFFERENCE DAY	4TH SATURDAY IN OCTOBER
AMERICA RECYCLES DAY	NOVEMBER 15
AMERICAN EDUCATION WEEK	2nd WEEK IN NOVEMBER
UNIVERSAL CHILDREN'S DAY	NOVEMBER 20
NOBEL PRIZE DAY	DECEMBER 10

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