Chemistry
Investigating Your World

www.acs.org/iyckit

International Year of Chemistry

The year 2011 has been designated by the United Nations as the International Year of Chemistry (IYC). Worldwide celebrations of chemistry in our day-to-day life have included a wide array of educational programs, hands-on activities for families, public lectures, and demonstrations. ACS offers a daily calendar of amazing chemistry at www.acs.org/iyc2011.

The purpose of the International Year of Chemistry is to:

- Help people understand how chemistry solves world problems.
- Inspire the next generation of chemists.
- Get people excited about the creative future of chemistry.
- Celebrate the 100th anniversary of Marie Curie's Nobel Prize in Chemistry.

Join us for the International Year of Chemistry 2011 as we honor the myriad of innovations and scientists who improve people's lives through the transforming power of chemistry.

About the American Chemical Society

The American Chemical Society (ACS) is the world's largest scientific society and one of the world's leading sources of authoritative scientific information. As a professional organization for chemists, ACS publishes numerous scientific journals and databases, convenes major research conferences, and provides educational, science policy, and career programs in chemistry.

ACS also produces resources for elementary, middle, and high school teachers. You can rely on ACS education resources to provide safe activities and accurate explanations that are just right for you and your students. Find out more at www.acs.org/education.

Acknowledgment of Support

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Chemistry
Investigating Your World

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Lesson 1
Production of a gas

Students combine different amounts of citric acid and baking soda as they try to make a column of foam rise to the top of a cylinder without spilling over.

Credits

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Overview

About this kit

This teacher's guide and accompanying kit have been given to you by the American Chemical Society, through a grant from the National Science Foundation and the National Institutes of Health, to help you teach your students basic chemistry concepts that support your science curriculum. Our hope is that by doing chemistry experiments within the context of an engaging story, and reading about examples of chemistry in their daily lives, your students will enjoy learning chemistry and will be eager to learn more.

The lessons in this kit are embedded within a story that takes place in four different areas of the world. At each stop, students meet a scientist and learn about his or her work and how it relates to the geography of the region. Students then do a related inquiry-based activity to learn about chemical reactions. Supplies for these activities and teacher demonstrations are included in the kit. There is enough material for up to 32 students working in eight groups of four.

After each of the four lessons, students answer a content question to collect a secret word. At the end of the unit, students use the words to fill in the blanks and reveal a quote about science. Decide as a class the correct quote and type it in at **www.acs.org/iyckit** to enter a drawing for a prize.

Learning objectives

- Students will be able to identify the four clues that a chemical change may have occurred.
- Students will recognize the terms *reactant*, *product*, *precipitate*, *exothermic*, and *endothermic* and know how they are used in the context of chemical reactions.
- Students will conclude that increasing the amount of reactants affects the amount of product.
- Students will be able to estimate the pH of a variety of acidic and basic solutions based on their color and the range of colors displayed on a pH color chart.
- Students will be able to explain that in chemical reactions, atoms in the reactants rearrange to form the products.
- Students will be able to use a thermometer to identify changes of temperature in different chemical reactions.

Safety

The activities in this guide have been reviewed by the ACS Committee on Chemical Safety and are considered safe when conducted as written. Find specific information about safe handling and disposal of chemicals on the first page of each lesson and in the MSDS included in the kit.

Students and teachers must wear properly fitting goggles as they prepare for, conduct, and clean up from the hands-on science activities in this unit.

About chemical and physical change

Your students may be required to learn the difference between chemical and physical change. During a chemical change, the atoms in the reactants rearrange and bond together in different ways to form new substances. In a physical change, substances may be altered in some way, but remain the same substance. New substances are not formed. Tearing paper is an example of a physical change, while burning paper is a chemical change.

The lessons in this guide focus on the four clues of chemical change—production of a gas, color change, formation of a precipitate, and temperature change. These are clues that a chemical change *may* have occurred. Sometimes similar clues are observed during physical changes, such as in the following examples.

- **Production of a gas**
  Open a soda bottle and observe bubbles of gas rising to the surface. Before the bottle was opened, carbon dioxide was dissolved in the water. The carbon dioxide collected together to form bubbles, but did not become a new substance. This is a physical change, not a chemical change.

- **Color change**
  Place a few drops of food coloring in water and stir. The water changes color as the pigment in the food coloring dissolves and spreads out in the water. The water and food coloring do not react to form a new substance.

- **Temperature change**
  Heat a pot of water on the stove. The temperature of the water increases, but the water does not become a new substance.

- **Production of a precipitate**
  Mix two liquids like corn syrup and melted chocolate. Then allow the mixture to cool and harden. Even though the mixture becomes solid, the chemical composition of the corn syrup and the chocolate has not changed.

Be sure to explain to students that clues of chemical change indicate that a chemical reaction *may* have occurred. To find out conclusively requires further investigation.

Elements of each lesson

The series of four lessons in this guide is part of an imaginary trip around the globe to meet scientists, learn general concepts about chemical reactions, and get a sense of the wide variety of ways that scientists use chemistry to solve world problems.

Meet the scientist

Students visit a scientist in Iceland, Fiji, Peru, and Antarctica. Each scientist briefly describes his or her work, which is related to the geography of the area. The scientist then asks the students and teacher to do a chemistry challenge. Each challenge features one of the four common clues that a chemical reaction may have occurred—production of a gas, color change, formation of a precipitate, and a change in temperature.

Solve a chemistry challenge

The teacher does a demonstration to introduce the clue of chemical change that is being explored. Then students conduct a chemistry challenge to sharpen their inquiry skills and develop a new understanding about chemical reactions. For example, when students combine different amounts of citric acid and baking soda to make just the right amount of foam reach the top of a small vial, they practice using the terms *reactants* and *products,* and they see the relationship between the two.

The big chemistry idea

A clear explanation of the key chemistry concepts highlighted in the hands-on activity is provided on the student activity sheet.

Get your secret word

At the end of each lesson, students answer a question about the activity. Then they use a chart to find the secret word. At the end of the four lessons, students use these words to fill in the blanks of a quote about science. Teachers may submit the completed quote to **www.acs.org/iyckit** to be entered into a drawing for a prize.

The chemical reaction in action!

Each activity is related to a product that uses the featured clue of chemical change. For example, airbags in automobiles inflate when a chemical reaction produces nitrogen gas.

The chemistry continues

Find more related hands-on activities at **www.acs.org/iyckit** to further explore the concepts introduced in each lesson.

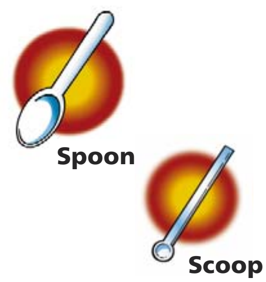
Materials list

Chemicals

- Citric acid (100 g)
- Sodium carbonate (100 g)
- Sodium bicarbonate (250 g)
- Calcium chloride, anhydrous (250 g)
- Universal indicator (8–30 mL dropper bottles)
- Sealed reaction bag with citric acid and baking soda
- Foot warmer

Equipment

- 32 portion cups
- 16 small clear plastic cups (3-oz size)
- 32 disposable droppers
- 16 small plastic spoons (about $\frac{1}{4}$ tsp)
- 16 small plastic scoops (about $\frac{1}{32}$ tsp)
- 8 clear plastic vials
- 8-spot plates each with 12 wells
- 8 small metric measuring cups (30 mL)
- 8 small student thermometers
- 1 box of flat toothpicks



Demonstration supplies

- Detergent solution (30 mL bottle)
- Bromthymol blue (30 mL dropper bottle)
- Small metric measuring cup (30 mL)
- Small plastic test tube with rubber stopper
- Dropper
- Balloon
- 2 small plastic spoons
- 2 small plastic scoops
- 2 straws

Specialty items for extension activities on www.acs.org/iyckit

- Small glow sticks
- PUR packet
- Goldenrod paper

Labels

- 8 citric acid
- 8 sodium carbonate
- 8 sodium bicarbonate
- 8 calcium chloride
- 16 citric acid solution
- 16 sodium carbonate solution
- 8 universal indicator pH color charts

Teacher-supplied items

- Water (tap water is fine)
- Vinegar
- 1 disposable water bottle (8 oz)
- 1 sandwich-sized zip-closing plastic bag
- 8 coffee filters
- 16 tall clear plastic cups
- Paper towels
- Waste container or bucket

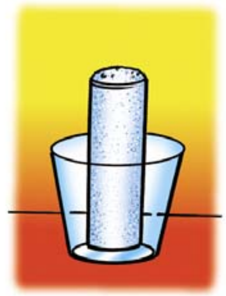
*Reuse the labeled portion cups from lesson to lesson. When reusing the small plastic cups, be sure to rinse and dry them thoroughly.

Iceland

Lesson 1
Production of a gas

TEACHER GUIDE

Lesson summary



Students meet volcanologist Victor Helguson, who is studying the gases released by volcanoes in Iceland. Students conduct a chemical reaction to produce one of the primary volcanic gases—carbon dioxide. Then, as their "chemistry challenge," students will use this chemical reaction to make a column of foam rise to the top of a vial without spilling over.

Key concepts

- Production of a gas is a clue that a chemical reaction may have occurred.
- The substances that combine in a chemical reaction are called *reactants.*
- The substances that are produced in a chemical reaction are called *products*.
- Changing the amount of reactants affects the amount of products produced in a chemical reaction.

Safety

Be sure you and the students wear properly fitting goggles. Read and follow all safety warnings on the labels of the citric acid and sodium bicarbonate containers. Have students wash their hands after the activity.

Proper disposal

At the end of the lesson, have students pour their used solutions in a waste container. Dispose of this waste down the drain or according to local regulations. The leftover citric acid and sodium bicarbonate powders can be disposed of with the classroom trash. Wipe up spills with paper towels and dispose of them with the classroom trash.

The chemistry continues

Find more related hands-on activities at **www.acs.org/iyckit** to further explore the concepts introduced in this lesson.

Introduction

1. Introduce students to the over-arching story that connects the lessons in this unit to the first scientist.
Distribute the student activity sheets, pages 17–23, and page 70. Be sure students understand the premise of the story and the idea that in chemical reactions, substances combine to make something new.

In this first lesson, students imagine that they are traveling to Iceland. While there they meet chemist and volcanologist Victor Helguson, who explains that volcanoes release gases dissolved in magma. He goes on to say that carbon dioxide gas is one of the main gases released. Nobody can control the amount of carbon dioxide gas released from volcanoes. But students can use chemistry to make carbon dioxide gas, and they can actually control the amount they produce.

Teacher demonstration

2. Do a demonstration to introduce students to the idea that during a chemical reaction something new is made.
Tell students that volcanoes release carbon dioxide that had been trapped in magma deep within the earth. As the magma gets closer to the surface, pressure is reduced and the gas is released. Tell students that gases can be produced in other ways, like with chemical reactions. As you watch this demonstration, look for signs that a chemical reaction is taking place.

You will need

- Goggles for you and the students
- Citric acid
- Sodium bicarbonate
- Water
- Plastic test tube
- Rubber stopper
- Graduated dropper
- 2 small plastic scoops

Procedure

1. Place one level scoop of citric acid in the test tube.
2. Use a graduated dropper to add 1 mL of water to the test tube.
3. Add 1 scoop of sodium bicarbonate and quickly place the rubber stopper in the test tube.
4. Hold the test tube straight up. Be sure to point it away from yourself or students.

Expected results
There will be bubbling, and the rubber stopper will pop out of the test tube.

Ask students

- **The citric acid and baking soda reacted and made new chemicals. How do you know that something new was made?**
  Bubbles form that weren't there before and something pushed the stopper out of the test tube.
- **What type of gas is formed in this reaction?**
  The gas that makes the bubbles is carbon dioxide.
- **Where do you think the carbon dioxide gas comes from?**
  It is made from atoms from the citric acid and baking soda.

Teacher demonstration

3. Do a demonstration to introduce students to their chemistry challenge.
Tell students that you will make an acid solution using citric acid and add it to baking soda. Tell them that you will also add a drop of detergent so that the bubbles formed during the reaction will last longer. This will create a foam that will give you a sense of how much carbon dioxide gas is produced. Tell students that you are using certain amounts citric acid and baking soda so that the foam doesn't rise too high in the vial.

Question to investigate
How can you make just the right amount of foam so that it rises all the way to the top of a vial without overflowing?

You will need

- Goggles
- Detergent solution
- Sodium bicarbonate
- Citric acid
- Water
- Small metric measuring cup
- 2 small plastic scoops
- 2 small clear plastic cups
- Clear plastic vial

Scoop

Preparation instructions
Make a detergent solution by adding 5 mL of liquid dish detergent to 30 mL of water. You will need only one drop of this solution for the demonstration. Divide the rest of the detergent solution equally into one portion cup for each group for the student activity. After the activity, rinse and dry these cups for use in a later activity.

Procedure

1. Measure about 5 mL of water and pour it into a small plastic cup.
2. Add 1 scoop of citric acid and swirl.
3. Add 1 drop of detergent solution and swirl.
4. Place 1 scoop of sodium bicarbonate in the plastic vial.
5. Pour the citric acid and detergent solution into the vial so that it mixes well with the baking soda.
6. Stand the vial up inside a small clear plastic cup as shown.

Expected results

A white foam will rise part way up the vial.

Student activity

4. Have students vary the amount of reactants to create a level of foam that rises to the top of the vial.

Remind students that the foam in your vial only rose about halfway up.

Ask students

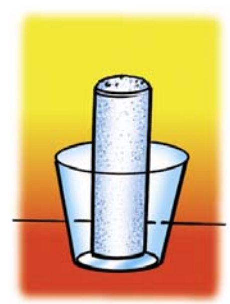
- **If you wanted to make more carbon dioxide gas, what would you do?**
  Add more citric acid or more baking soda or more of both.

Activity summary

Information on how to conduct this activity is included on the student activity sheet. Students will conduct three trials to test different quantities of citric acid and baking soda. Each group should decide how much of each reactant they will use for each trial and record this amount in the chart on their activity sheet.

Preparation instructions

- Use the pre-made stickers to label one portion cup *citric acid* and another portion cup *sodium bicarbonate* for each group. These cups will be reused for other lessons in this kit.
- Place about ½ tsp citric acid and ½ tsp sodium bicarbonate in their labeled cups.



Expected results

Two scoops of citric acid in 5 mL of water and one scoop of sodium bicarbonate should make an amount of foam that gets close to the top of the vial or goes slightly above. Results will vary.

Class discussion

5. Discuss student observations and introduce the terms r*eactants* and *products*.

Ask students

- **How did you make just the right amount of carbon dioxide gas?**
  Students will give their winning amounts of citric acid and baking soda. The answers may vary from group to group.

Tell students that *reactants* are the chemicals that combine together and rearrange to become different chemicals. The new and different chemicals are called *products*.

Ask students

- **Which chemicals are the reactants?**
  Citric acid and baking soda are the reactants. Detergent and water are not reactants because they remain the same.
- **What is the name of the product that formed the tiny bubbles in the foam?**
  Carbon dioxide gas is in the bubbles.

Explain to students that atoms from the citric acid and atoms from the baking soda rearrange during the chemical reaction and form carbon dioxide gas and other substances that were not there before.

6. Have students answer the question in order to get a word for the quote.
Have students read the "big chemistry idea" and answer the question in order to get a word for the quote. In the activity sheet, the scientist gives some congratulatory words and sends students to the next part of the chemistry adventure—meeting an oceanographer in Fiji!

Teacher demonstration

7. Do a demonstration with the enclosed reaction bag to show how a chemical reaction that produces a gas can be used to inflate a bag.
Tell students that producing a gas can be very useful and being able to control the amount produced is very important, as they will see in the next demonstration. Explain that the reaction bag contains baking soda and the small inner bag contains citric acid solution. Tell students that you are using this to model how an airbag in a car works. In an airbag, different chemicals are used and a different gas is produced, but the idea that chemicals combine to produce a gas is the same.

Ask students

- **How can I get this chemical reaction started?**
  Students should realize that you will have to somehow combine the citric acid and baking soda because reactants cannot react unless they touch each other.
- **What do you think will happen when I break the citric acid packet?**
  The chemicals will react and produce carbon dioxide gas.

Warn students that this reaction may cause a loud sound if the inner bag becomes so inflated that it pops.

You will need

- Reaction bag containing baking soda powder and citric acid pouch
- Sandwich-sized zip-closing plastic bag

Procedure

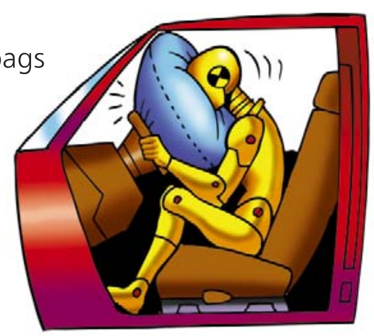
1. Place the reaction bag inside a sandwich-sized zip-closing plastic bag.
2. Remove as much air as possible and seal the outer bag.
3. Smack the liquid-filled pouch with your fist or step on it with the heel of your shoe until it breaks.
4. Shake the bag to help the reactants combine.

Expected results

The reaction bag will inflate to the point where the bag breaks. More carbon dioxide gas will be produced and will partially inflate the sandwich bag.

Application

Have students read page 23 of the student activity sheet. Explain that airbags in cars inflate when two chemicals are allowed to combine. One of the products is nitrogen gas, which inflates the airbag. Nitrogen is a great choice for an airbag because it is a gas that is naturally in air and is not flammable.



Lesson 1
Production of a gas

STUDENT ACTIVITY SHEET

Name: ___________________________

Chemistry: Investigating your world

Chemists work on every continent, and their work affects people everywhere. You may think you're just sitting in your classroom. But you're about to take a trip around the world. It is the International Year of Chemistry, after all. So for this activity, we're going global!

Here's the challenge: You are on a team that is racing around the world, meeting scientists and conducting chemistry challenges. When you arrive in each new place, you will meet a scientist. He or she will explain an experiment that you need to do. You'll also find out how the chemistry concepts in the experiment are used to improve people's lives.

At the end of each lesson, you will be asked a question about your chemistry challenge. When you answer the question, you will receive a secret word as a clue. Your final task is to use all four words to fill in the blanks in the following quote about science.

"All the _____________ is a _____________ to the ____________ _____________."

Dr. Martin H. Fischer
Chemist and physician

Are you ready to get started? Then, strap on your seat belt. You are headed first to … Iceland! While on the plane, read about chemical reactions. The information on the next page will get you up to speed and help you solve the challenges ahead.

Lesson 1
Production of a gas

STUDENT ACTIVITY SHEET

Name: ____________________________

Chemical reactions

As you travel around the world, you will see how different scientists use chemical reactions in their work. Read about chemical reactions here, and get ready to combine chemicals to make something new.

One of the amazing things about chemical reactions is that they create substances that were not there before! When two substances react with each other, atoms or groups of atoms from the substances come apart, rearrange, and then combine in different ways to form different substances.

Another great thing about chemical reactions is that they can be used to make lots of different materials that we need and use every day. Chemical reactions help make the materials that electronic equipment like computers and cell phones are made of. They help make different parts of cars, airplanes, and bicycles. Chemical reactions also help make many of the materials in buildings, sports equipment, medicine, clothing, and food.

Because chemical reactions make something new, you can usually tell when a reaction has happened. You will see something different from what was there to start with. Here are some clues that a chemical reaction may have taken place:

- A gas where there wasn't one before
- A new color
- A solid where there wasn't one before
- A change in temperature

Now that you know the clues of chemical change, keep an eye out for them. And get ready for some reaction action!

Lesson 1
Production of a gas

STUDENT ACTIVITY SHEET

Name: ___________________________

Meet the scientist

Country: Republic of Iceland
Scientist: Victor Helguson

Welcome to Iceland! My name is Victor Helguson, and I am a volcanologist. I study volcanoes. I try to predict when the next eruptions will happen. This is an important job in Iceland. We have about 130 volcanic mountains here. And that's in a country the size of Kentucky!

You may have heard about Eyjafjallajökull. When this volcano erupted in 2010, it spit out so much ash that airports across Europe had to shut down. There was just too much ash in the air for planes to safely fly. To better understand volcanoes, I study the magma inside them and the lava that comes out. I also collect gases that volcanoes emit. Certain changes in these gas emissions can be a sign that a volcano is set to blow.

Carbon dioxide (CO_2) is one of the main gases that seep out of active volcanoes. In the activity below, you will make your own CO_2.

Producing a gas can be very useful, especially if you can control the amount that you make. After the activity, you will see one way that using a chemical reaction to produce a gas can save lives!

Lesson 1
Production of a gas

S T U D E N T   A C T I V I T Y   S H E E T

Name: ___________________________

Your chemistry challenge
How can you make just the right amount of foam so that it rises all the way to the top of your vial without overflowing?

The rules
Keep the amount of water and detergent the same but try a different amount of citric acid or baking soda or both. A dome of foam at the top of the vial is OK, but the foam shouldn't drip down the vial.
GOOD LUCK!

You will need

- Goggles
- Citric acid
- Sodium bicarbonate
- Detergent solution
- Water
- Small metric measuring cup
- Dropper
- 2 small plastic scoops
- 2 small clear plastic cups
- Clear plastic vial

Scoop

Procedure
1. Decide on the number of scoops of citric acid and sodium bicarbonate you will combine, and write it in the chart.
2. Measure 5 milliliters (mL) of water and pour it into a small plastic cup.
3. Add the number of scoops of citric acid your group agreed on and swirl.
4. Add 1 drop of detergent solution and swirl.

5. Place the number of scoops of sodium bicarbonate your group agreed on in the plastic vial and stand it up in a cup as shown.
6. Pour the citric acid and detergent solution into the vial so that it mixes well with the baking soda.

Make foam rise to the top without overflowing

	Demonstration	First try	Second try	Third try
Water	5 mL	5 mL	5 mL	5 mL
Citric acid	1 scoop			
Detergent	1 drop	1 drop	1 drop	1 drop
Baking Soda	1 scoop			
How close did the foam get to the top of the cylinder?	Foam rises part way up			

The big chemistry idea

In the chemical reaction in this activity, the citric acid and the sodium bicarbonate are called *reactants*. The carbon dioxide gas and other substances that are produced by the reaction are called *products*. The citric acid and sodium bicarbonate are made of atoms. In the chemical reaction between these reactants, certain atoms come apart from one another and rearrange to form the gas and the other substances in the products. When more reacting substances are used, there are more atoms to create more products.

Get a word for the quote

Which of the following statements about chemical reactions is true? Circle the correct answer.

1. The atoms in the reactants rearrange to form the products.
2. The atoms in the products appear out of nowhere.
3. The atoms in the reactants are destroyed, and new atoms are created to make the products.

If you answered:	Your word for the quote is:
1	inquiring
2	asking
3	curious

Go to *Solve the science quote* on page 70 and write down your word in the chart next to the name of this lesson. You will fit it into the quote later.

Goodbye

Congratulations! Your mission here is complete. You will learn more about CO_2 at your next destination. Let me know if you come up with any interesting new ideas about volcanoes. And thanks for coming to Iceland!

<u>Next destination</u> **– Fiji!**

Lesson 1
Production of a gas

STUDENT ACTIVITY SHEET

Name: ___________________________

Chemical reaction in action!

Your mind may already be halfway to Fiji, but it's worth reflecting on what you just learned how to do. Chemical reactions that produce gases can make our lives better and safer. One example is the gas that inflates an air bag during a collision. Scientists have figured out a way to make this chemical reaction go super-fast to save lives in a car crash.

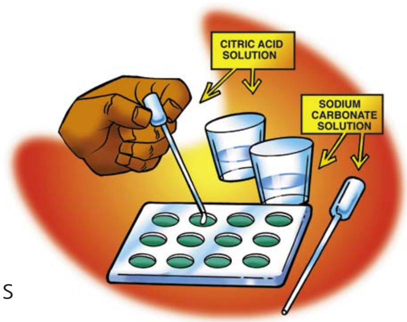
Traveling at high speeds, cars are seriously dangerous places to be during an accident. That's why many vehicles have seat belts and airbags. When two cars collide, passengers are often thrown forward and can become badly injured. Airbags are like large balloons. When they inflate, they prevent people from hitting the hard inside parts of the car. In order for airbags to work, however, they have to be fast. *Really* fast. That's where chemistry comes in.

Airbags are connected to a crash sensor, which has a built-in accelerometer that senses a sudden shift in the car's speed. When the crash sensor detects rapid deceleration, the airbag inflates with nitrogen gas at 200 MPH—faster than the blink of a human eye! In this case, nitrogen forms through a reaction between two chemicals called sodium azide and potassium nitrate. The entire process of airbag deployment takes just 1/25 of a second. After the airbag inflates, nitrogen gas eventually escapes through very small holes in the airbag material, allowing the passenger to safely exit the vehicle.

Fiji Islands

Lesson 2
Color change

TEACHER GUIDE



Lesson summary
Students meet marine chemist Sera Tuikabe, who is studying ocean acidification in the water surrounding the Republic of the Fiji Islands. Students combine different amounts of acids and bases to explore the range of color changes of universal indicator solution. Then as their chemistry challenge, students make as many different-colored solutions as they can.

Key concepts
- A change in color is a clue that a chemical reaction may have occurred.
- Universal indicator solution is green when it has a pH around 7.
- Acidic solutions have a pH less than 7.
- Basic solutions have a pH greater than 7.
- Adding a base to an acidic solution makes the solution less acidic.
- Adding an acid to a basic solution makes the solution less basic.
- Carbon dioxide gas reacts with water to form carbonic acid.

Safety


Be sure you and the students wear properly fitting goggles. Read and follow all safety warnings on the labels of the citric acid and sodium carbonate containers. Have students wash their hands after the activity. Bromthymol blue and universal indicators are both alcohol-based and flammable.

Proper disposal
At the end of the lesson, have students pour their used solutions in a waste container. Dispose of this waste down the drain or according to local regulations. The leftover citric acid and sodium carbonate powders can be disposed of with the classroom trash. Wipe up spills with paper towels and dispose of them with the classroom trash.

The chemistry continues
Find more related hands-on activities at **www.acs.org/iyckit** to further explore the concepts introduced in this lesson.

Introduction

1. Introduce students to a scientist, her work, and students' mission.
Distribute the student activity sheets, pages 32–37. In this lesson, students meet marine chemist Sera Tuikabe. She explains that carbon dioxide gas can dissolve in water and chemically change the water, making it more acidic. The harmful effects of acidic water on marine life are especially noticeable in corals, clams, starfish, and other creatures that have shells.

Teacher demonstration

2. Bubble carbon dioxide gas from two different chemical reactions through a color-changing indicator solution.
Tell students that you will produce carbon dioxide gas in two different ways. Then you will add the gas to a special solution called *bromthymol blue indicator* to see if the gas reacts with the solution. If a chemical reaction does occur, this blue solution will change color. A color change is a clue that a chemical reaction may have occurred.

You will need

- Goggles
- Bromthymol blue indicator
- Sodium bicarbonate
- Vinegar (bring this from home or use from school)
- Water
- Small metric measuring cup
- Small plastic spoon
- Plastic disposable water bottle, 8 ounces (collect from a student)
- Balloon
- 3 clear plastic cups
- 2 straws

Spoon

Preparation instructions

- Place 20 mL of water into two clean, unused, clear plastic cups.
- Add about 15–20 drops of bromthymol blue indicator to each cup and swirl so that the solutions are blue. Place a clean straw in each cup.
- Put about 30 mL of vinegar into the bottom of a small disposable plastic water bottle.
- With the help of an assistant, place about 2 small spoonfuls of sodium bicarbonate into a deflated balloon.

Procedure
1. Place the balloon over the top of the bottle.
2. Lift the balloon so that the baking soda drops into the vinegar and gently swirl the bottle.

Expected results
The balloon will stand up over the top of the bottle. The balloon will not fully inflate, but it will contain enough carbon dioxide gas for the next part of the demonstration.

Procedure
3. Twist the balloon so that you can remove it from the bottle without allowing the gas to escape.
4. Carefully remove the balloon and place the end of a straw into the opening while pinching the opening so that not too much gas escapes.
5. Place the other end of the straw into one of your cups of bromthymol blue indicator solution and gently squeeze the balloon to bubble the gas into the solution.

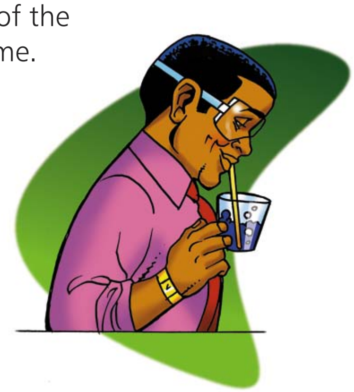
Expected results
The solution should change from blue to yellow.

Tell students that the carbon dioxide gas reacted with the water in the solution and formed an acid called *carbonic acid*. This acidic solution reacted with the indicator and caused the color to change.

Ask students

- **Next, I am going to gently blow my own breath into bromthymol blue indicator solution. Do you expect a color change? Why or why not?**
  Students may know that we exhale carbon dioxide gas. Because carbon dioxide produced from the vinegar and baking soda reaction changed the color of the indicator solution, carbon dioxide from another source should do the same.

Procedure
6. Place a straw in the cup of bromthymol blue indicator solution that you have not yet used.
7. Push the straw to the bottom of the cup and gently blow until the solution turns greenish-yellow.



Expected results
The indicator solution will turn a greenish yellow and may even turn completely yellow after about a minute of blowing through the solution.

Remind students that a change in color is a clue that a chemical reaction may have occurred. In a chemical reaction the reactants that we start with change to become different chemicals, or products. In this reaction, carbon dioxide gas reacts with water to make the product carbonic acid, which causes the color change. Tell students that oceanographer Sera Tuikabe uses the color changes from different indicators to help her measure the health of the water surrounding coral reefs.

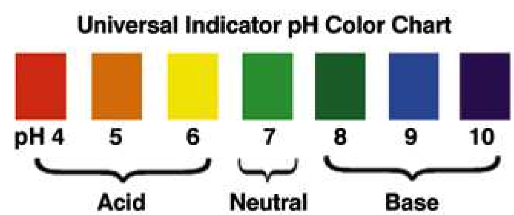
Teacher demonstration

3. Do a demonstration to introduce students to their chemistry challenge.
Tell students that in their chemistry challenge, they will use a type of indicator called *universal indicator*. This indicator solution starts out green, but changes color as it reacts with different substances. Its color changes can help you tell whether the solution is *acidic*, *neutral,* or *basic*. And if you are familiar with the range of color changes, you can not only tell whether a solution is acidic or not, you can tell how acidic it is.

You will need

- Goggles
- Universal indicator
- Citric acid
- Sodium carbonate
- Water
- Universal indicator pH color chart
- Small metric measuring cup
- 2 small plastic scoops
- 3 small clear plastic cups


Scoop



Note

Universal indicator pH color charts are included in this kit.
You may print additional charts in color from **www.acs.org/iyckit**.

Preparation instructions

- Add about 1 small scoop of citric acid to one clear plastic cup and 1 small scoop of sodium carbonate to another. Tell students that you have added a substance to each cup but do not tell them what is in each cup.
- In a clean, clear plastic cup, combine 60 mL water and 2.5 mL universal indicator solution.
- Line the three cups up as shown.

Procedure

1. While holding the cups up so that students can see, slowly add about ⅓ of the universal indicator to the cup with the citric acid.
2. Then slowly add about the same amount to the cup with the sodium carbonate. Try to leave about one third of the indicator solution in its cup.

Expected results

The citric acid turns the indicator from green to reddish. The sodium carbonate turns the indicator from green to purple.

Distribute one universal indicator pH color chart to each group.

Ask students

- **What do you know about the powders in each cup?**
  By looking at their pH color chart, students will know that the cup in which the solution turned reddish contained the acid and the solution that turned purple contained the base.

Procedure

3. Tell students to watch as you slowly pour the acidic (pink) universal indicator into the basic (purple) universal indicator solution.

Expected results

The basic solution changes color and goes toward neutral on the pH scale.

Tell students that acids and bases are like chemical opposites: If you add an acid to a basic solution, the solution becomes less basic. If you add a base to an acidic solution, the solution becomes less acidic.

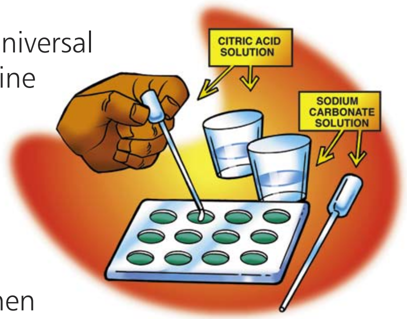
Student activity

4. Have students make at least 6 different colors by adding drops of acid and base to universal indicator solution.

Depending on students' experience using droppers, you may need to have students practice using them. Be sure to demonstrate the difference between "drops" and "squirts" and, if necessary, give students a chance to practice releasing single drops of water. In this activity, students will add a certain number of drops of each of the required solutions to each well.

Activity summary

Students will begin by preparing their acid and base solutions and adding universal indicator solution to 12 different wells on a spot plate. Then they will combine drops of citric acid and sodium carbonate (a base) in each well to make as many different colors as they can. This chemistry challenge is described in detail on the student activity sheet on page 35.



Preparation instructions

- Reuse the portion cup labeled *citric acid* from the previous activity. Then label one clean, unused, clear plastic cup and one dropper *citric acid solution* for each group.
- Label one portion cup sodium carbonate. Then label one clean, unused, clear plastic cup and one dropper *sodium carbonate solution* for each group.
- Place about ¼ teaspoon of citric acid and sodium carbonate in their labeled portion cups. Each group will make their own citric acid and sodium carbonate solutions in the clear plastic cups.

Expected results

The wells in the first row will be shades of green, blue, and purple. The wells in the second row will be shades of yellow, orange, and pink. And the wells in the third row will be varying shades of the colors in the first and second row.

5. Have students answer the question in order to get the word for the quote.

Have students read the "big chemistry idea" and answer the question in order to get the word for the quote. On the activity sheet, the scientist gives some congratulatory words and sends students to the next part of the chemistry adventure—meeting a wastewater treatment chemist in Peru.

Teacher demonstration

6. Do a demonstration to review the two clues of chemical change introduced in the first two lessons.

You will need

- Goggles
- Bromthymol blue indicator
- Sodium bicarbonate
- Citric acid
- Water
- Small metric measuring cup
- 2 small scoops
- 2 clear plastic cups

Scoop

Procedure

1. Place 10 mL of water in a clear plastic cup.
2. Add 1 scoop of sodium bicarbonate (baking soda) and swirl to dissolve.
3. Add 10 drops of bromthymol blue indicator to the baking soda solution.
4. Place 10 mL of water in a separate clear plastic cup.
5. Add 2 scoops of citric acid to the water and swirl to dissolve.

Ask students to predict

- What do you think will happen if you pour the citric acid solution into the sodium bicarbonate solution?

Procedure
6. Pour the citric acid solution into the sodium bicarbonate solution.

Expected results
The blue color will turn yellowish and there will be some bubbling.

Ask students

- **What two clues of chemical change did you observe?**
  A color change and production of a gas

Application

Give students the reading on page 37. Explain that people with diabetes can use a color-changing chemical reaction to help them keep track of the glucose levels in their bodies. A small strip of paper with different chemicals on it reacts with a person's urine; the darker the color, the more glucose in the urine. This amount of glucose is a reflection of the level of glucose in a person's blood.

Lesson 2
Color change

S T U D E N T A C T I V I T Y S H E E T

Name: ___________________________

Meet the scientist

Country: Republic of the Fiji Islands
Scientist: Sera Tuikabe

I hope you enjoyed the ocean views on your flight into Fiji! Ours is a country of more than 300 islands surrounded by the sea. I am a marine chemist. I study the quality of the water and how it affects living things.

Victor taught you that carbon dioxide comes out of volcanoes. CO_2 is a concern for me, too. Cars, factories, and other human activities release a lot of CO_2 into the air. Oceans absorb the gas. That makes the water more acidic, which lowers its pH. These changes spell trouble for corals, starfish, crabs, clams, and other sea creatures. In more acidic water, sea animals grow more slowly. It's also harder for them to build strong shells.

Coral reefs are very important to our country. Tourists come from all over the world to dive here, and we rely on reefs to provide us with food. Many kinds of fish live in and around them.

Fiji's coral reefs are in relatively good condition compared to others in the world. We want to keep it that way. In the next century, some experts predict that acidic water, warmer than normal temperatures, and other factors could destroy our coral reefs.

One part of my research is to test seawater for acidity by using chemical reactions that cause color changes. In this activity, you will learn how to interpret these color changes to measure the pH of a liquid.

Lesson 2
Color change

STUDENT ACTIVITY SHEET

Name: ___________________________

Your chemistry challenge

Make an acid and a base solution and then see how many different colors you can make by adding drops of both in a universal indicator solution. GOOD LUCK!

You will need

- Goggles
- Universal indicator solution
- Citric acid
- Sodium carbonate
- Water
- pH color chart
- Small metric measuring cup
- About 15 flat toothpicks
- 2 droppers
- 2 clear plastic cups
- Spot plate

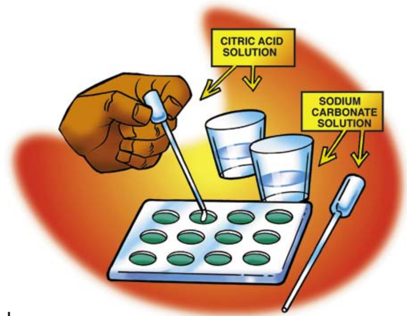
Procedure

Make a citric acid solution

1. Use your small measuring cup to place 25 mL of water in the cup labeled *citric acid.*
2. Use a flat toothpick to add one "toothpick scoop" of citric acid to the water in the citric acid cup. Gently swirl until the citric acid dissolves.

Make a sodium carbonate solution

3. Use your small measuring cup to place 25 mL of water in the cup labeled *sodium carbonate.*
4. Use a clean, flat toothpick to add one "toothpick scoop" of sodium carbonate to the water in the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.



Make as many different colors as you can

5. Use a clean dropper to add 10 drops of water to each well of the spot plate.
6. Add 2 drops of universal indicator to each of the wells.
7. Do not add anything to the first well. Then add a single drop of sodium carbonate to the second well. Stir with a toothpick and compare the color of the solution to the color chart. Record this color in the chart below.
8. Add 2 or more drops of sodium carbonate to the third and fourth wells in this row and stir with a toothpick to make other colors. Record the number of drops of sodium carbonate used to make each color.
9. Use drops of citric acid to see how many different colors you can make in the second row. Be sure to record the number of drops used to make each color.
10. In the third row, experiment with drops of both citric acid and sodium carbonate solutions to make as many different colors as you can. Be sure to record the number of drops of each solution used to make each color.
11. Use your pH color chart to estimate the pH of each of the different-colored solutions.

Estimate the pH of your colorful solutions

Drops of sodium carbonate	Drops of citric acid	Color	Approximate pH
0	0	green	7
1	0		
	0		
	0		
0			
0			
0			
0			

Imagine that you add a drop of universal indicator solution to a small sample of water from a swimming pool and the solution turns orange. What could you add to the pool water to make the pH closer to neutral?

The big chemistry idea

Universal indicator is made of a combination of molecules called *pigments*, which give the indicator its green color. When an acid or base reacts with this indicator, the indicator changes to a new substance, which results in a color change. Acids and bases are like chemical opposites. You can make an acidic solution become more neutral by adding a base. You can make a basic solution become more neutral by adding an acid.

Get your secret word

What was the color of the most acidic solution you created?

1. Purple
2. Red
3. Green

If you answered:	Your word for the quote is:
1	state
2	world
3	city

Go to *Solve the science quote* on page 70 and write down your word in the chart next to the name of this lesson. You will fit it into the quote later.

Goodbye

You did it! Now that you know one way to measure pH in water, go talk to my friend Adriana. She studies water that is sent down drains and toilets, and she works to make it clean enough to use again.

Next destination **– Peru!**

Lesson 2
Color change

S T U D E N T   A C T I V I T Y   S H E E T

Name: ___________________________

Chemical reaction in action!

The world of medicine offers an example of using color changes in chemistry to help people. A small color-changing test strip called Clinistix can be used by people who have diabetes. People with diabetes need to keep close track of the amount of glucose (a type of sugar) in their blood stream.

For many years, people with diabetes had to draw their own blood to check glucose levels. Now they can do a quick and pain-free test by dipping the end of a Clinistix in a little bit of urine. The Clinistix changes color depending on the amount of glucose present. Because the amount of glucose in urine is related to the amount of glucose in blood, a person with diabetes can painlessly check his or her glucose level. Depending on the results from the Clinistix, a person will know if a change in diet or medication is needed to get his or her glucose level where it should be.

Each Clinistix testing strip contains two *enzymes*. An enzyme is a type of molecule that helps speed up chemical reactions. One of the enzymes causes a chemical reaction with glucose that produces a certain chemical. The second enzyme speeds up a reaction between this chemical and the pigment on the strip, causing the color change.

The intensity of the color produced is related to the amount of glucose present; the darker the color of the test strip, the more glucose is present in the sample.

Lima, Peru

Lesson 3
Forming a precipitate

T E A C H E R G U I D E

Lesson summary

Students meet chemist Adriana Garcia, who is a chemist at a wastewater treatment plant in Lima, Peru. She explains that one of the challenges with cleaning water is removing particles that are so small they do not settle or get caught in the filters. The best way to solve this problem is to use a chemical reaction that forms a precipitate, which is large enough to settle or get caught in the filters. Students combine two clear colorless solutions and get a white precipitate, which they filter. The products of this chemical reaction are chalk, salt, and water, which are recognizable and noticeably different from the reactants.

This lesson will take two class periods. You will begin with a demonstration, and then students will conduct a chemical reaction that forms a precipitate. The precipitate will need to filter slowly and then dry overnight. On the first day, while students wait for the products to dry, introduce the chemical equation for this reaction. Students will be able to recognize all of the products. On the second day, students compare the precipitate to the reactants to find that it is truly a different substance with different properties.

Key concepts

- Formation of a precipitate is a clue that a chemical reaction may have occurred.
- A precipitate is a solid that forms in the chemical reaction between liquids. It does not dissolve in the resulting solution.
- The products of a chemical reaction are different from the reactants, but are made of the same type and number of atoms.

Safety

Be sure you and the students wear properly fitting goggles. Read and follow all safety warnings on the labels of the calcium chloride and sodium bicarbonate containers. Bromthymol blue is alcohol-based and flammable. Have students wash their hands after the activity.

Proper disposal

At the end of the lesson, have students pour their used solutions in a waste container. Dispose of this waste down the drain or according to local regulations. The leftover calcium chloride, sodium bicarbonate, and the product calcium carbonate can be disposed of with the classroom trash. Wipe up spills with paper towels and dispose of them with the classroom trash.

The chemistry continues

Find more related hands-on activities at www.acs.org/iyckit to further explore the concepts introduced in this lesson.

Introduction

1. Introduce students to a scientist, her work, and students' mission.

Distribute the student activity sheets, pages 46–53. In this lesson, students meet water chemist Adriana Garcia, who works to reduce the use of water from mountaintop glaciers by reusing wastewater. Students use a chemical reaction to form a precipitate from substances that were dissolved in water. As their chemistry challenge, students compare the solubility of the precipitate to the reactants to prove that the precipitate is different from the reactants.

Teacher demonstration

2. Do a demonstration to introduce students to the term *precipitate*.

Hold up a cup of calcium chloride solution and sodium carbonate solution. Tell students that while both solutions are clear and colorless like ordinary water, both have different chemicals dissolved in them. A coffee filter cannot be used to remove these dissolved particles, because they are so small that they can slip right through little holes in the filter. Even the holes are too small for us to see. A chemical reaction between the two solutions can change these reactants into products that are large enough to get trapped in this filter.

You will need

- Goggles
- Sodium carbonate
- Calcium chloride
- Water
- Small metric measuring cup
- 2 small spoons
- 2 clear plastic cups

Spoon

Preparation instructions

- Place about 30 mL of water in each of two plastic cups.
- Add 1 spoon of calcium chloride to one of the cups. Swirl until the calcium chloride dissolves.
- Add 1 spoon of sodium carbonate to the other cup. Swirl until the sodium carbonate dissolves.

Procedure

1. Very slowly pour the calcium chloride solution into the sodium carbonate solution.

Expected results

White particles will form and sink to the bottom.

Tell students that you combined two liquids, and a solid was formed. Although they are small particles, they are solid, and will not dissolve no matter how much you stir. Tell students that the solid that forms from two liquids is called a *precipitate*. This solid is calcium carbonate, which is the main substance in chalk and sea shells.

Student activity

3. Have students make a precipitate and collect it with a coffee filter.

Tell students that they will use calcium chloride and sodium bicarbonate, not sodium carbonate, which you used in the demonstration. In this reaction, the precipitate is the same, calcium carbonate, but there is another noticeable product. Tell students to watch out for other clues of chemical change, which they learned about in the first two lessons.

Activity summary

Information on how to conduct this activity is included on the student activity sheet on page 48. First, students will make sodium bicarbonate and calcium chloride solutions. They will combine the solutions and then use a filter to collect the precipitate. The liquid will need to drip through overnight to give the precipitate a chance to dry.

Note

While students are making their sodium bicarbonate and calcium chloride solutions, they may notice that the solutions change temperature. As sodium bicarbonate dissolves in water, the solution gets colder. As calcium chloride dissolves in water, the solution gets warmer. This phenomenon is not the focus of this activity, but may be something students notice. If they do observe this, you can explain that although a temperature change is one of the four clues of chemical change, it can also occur during the physical change of dissolving.

Preparation instructions

- Use the pre-made stickers to label a set of portion cups *calcium chloride*. If you conducted lesson 1, reuse the portion cups labeled *sodium bicarbonate.*
- Place ½ teaspoon of calcium chloride and sodium bicarbonate in their labeled cups.

Expected results

The combined solutions will slowly bubble and will look much whiter than the clear-looking solutions you started with. The white color is actually caused by particles of the precipitate calcium carbonate. After filtering and drying, the precipitate is white and powdery. It is calcium carbonate, which is chalk.

Collect the cups and filters and store them out of the way until the next time the class meets. Once the liquid has flowed through the filter, you may choose to remove the coffee filters with the precipitate from the top of each cup and lay them flat on a paper towel. This will speed up the drying process.

If you'd like to separate the sodium chloride from the water that flowed through the filter, pour the liquid into a wide shallow dish, like a petri dish, and allow the water to evaporate for a few days. As the water evaporates, students will see salt crystals forming in the solution. Eventually, they will see the characteristic cubic shape of salt crystals (sodium chloride).

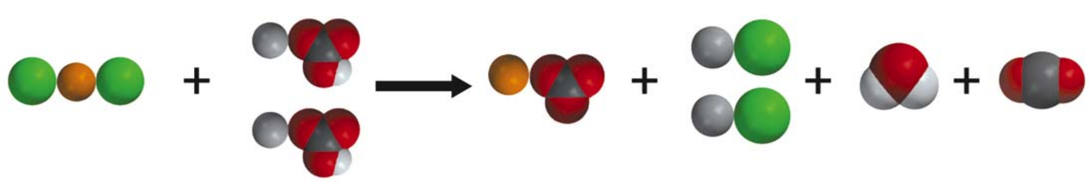
Class discussion

4. Discuss student observations and introduce the chemical equation for the reaction.

Ask students

- **Which two clues of chemical change did you observe?**
  Bubbling and a precipitate. Students may include a color change, because the liquid that was once clear and colorless turned white.
- **Could you get the precipitate to dissolve?**
  No. Even if you stir, the precipitate will not dissolve.

Have students look at the following chemical equation on their activity sheets.



$$CaCl_2 + 2NaHCO_3 \rightarrow CaCO_3 + 2NaCl + H_2O + CO_2$$

calcium chloride | **sodium bicarbonate** | **calcium carbonate** | **sodium chloride** | **water** | **carbon dioxide**

Ask students

- **Which are the reactants, and which are the products?**
  The reactants are calcium chloride and sodium bicarbonate. The products are calcium carbonate, sodium chloride, water, and carbon dioxide.

- **How many of each type of atoms is on the reactant side? The product side?**

Types of atoms	Number of each type of atom in the... reactants	products
calcium atom	1	1
chlorine atoms	2	2
sodium atoms	2	2
hydrogen atoms	2	2
carbon atoms	2	2
oxygen atoms	6	6

- **What do you think was in the bubbles?**
  Carbon dioxide gas was in the bubbles.

- **What is the precipitate? How do you know?**
  The precipitate is calcium carbonate, which is chalk and is also in eggshells, seashells, and coral. Looking at the chemical equation, the products are calcium carbonate, sodium chloride, water, and carbon dioxide. Carbon dioxide leaves the reaction as a gas and sodium chloride dissolves in the water, so the precipitate must be calcium carbonate.
- **What is the liquid left behind after you filtered the precipitate?**
  The liquid is saltwater. Students may not realize this, but there may also be some unreacted sodium carbonate or calcium chloride still in solution.

Class discussion

5. The next time the class meets, have students investigate whether the precipitate is really different from either of the reactants.
Distribute the paper towels or coffee filters with the dried precipitate to student groups.

Ask students

- **The precipitate looks similar to baking powder and calcium chloride. Could the precipitate be the same as one of the reactants?**
  The precipitate is calcium carbonate, which is different from the reactants.

Tell students that the precipitate is supposed to be different from the reactants, but that you would like them to do an activity to prove whether or not this is true. Remind students that the baking soda and calcium chloride both dissolved in water. Tell students that they will find out whether or not the precipitate dissolves in water. If it dissolves, we'd need to do another test to find out if it is the same as one of the reactants. But if it doesn't dissolve, we know that it must be different.

Activity summary

Have students follow the procedure on the student activity sheet on page 50. This activity provides evidence that the precipitate calcium carbonate really is a different substance from either of the reactants. Both sodium carbonate and calcium chloride dissolve in water. However, students will discover that the precipitate, calcium carbonate, does not dissolve in water. These white powders may appear similar, but they have different chemical properties and are therefore different.

6. Have students answer the question in order to get a word for the quote.

Have students read the "big chemistry idea" and answer the question in order to get the word for the quote. On the activity sheet, the scientist gives some congratulatory words and sends students to the next part of the chemistry adventure—meeting an industrial chemist in Antarctica.

Teacher demonstration

7. Do a demonstration to review the three clues of chemical change introduced in the first three lessons.

You will need

- Goggles
- Bromthymol blue indicator
- Sodium bicarbonate
- Calcium chloride
- Water
- Small metric measuring cup
- 2 small spoons
- 2 clear plastic cups


Spoon

Procedure

1. Place 10 mL of water in a clear plastic cup.
2. Add 1 spoon of sodium bicarbonate and swirl to dissolve.
3. Add 10 drops of bromthymol blue indicator to the sodium bicarbonate solution.
4. Place 10 mL of water in a separate clear plastic cup.
5. Add 1 spoon of calcium chloride and swirl to dissolve.
6. Pour the calcium chloride solution into the sodium bicarbonate solution.

Expected results

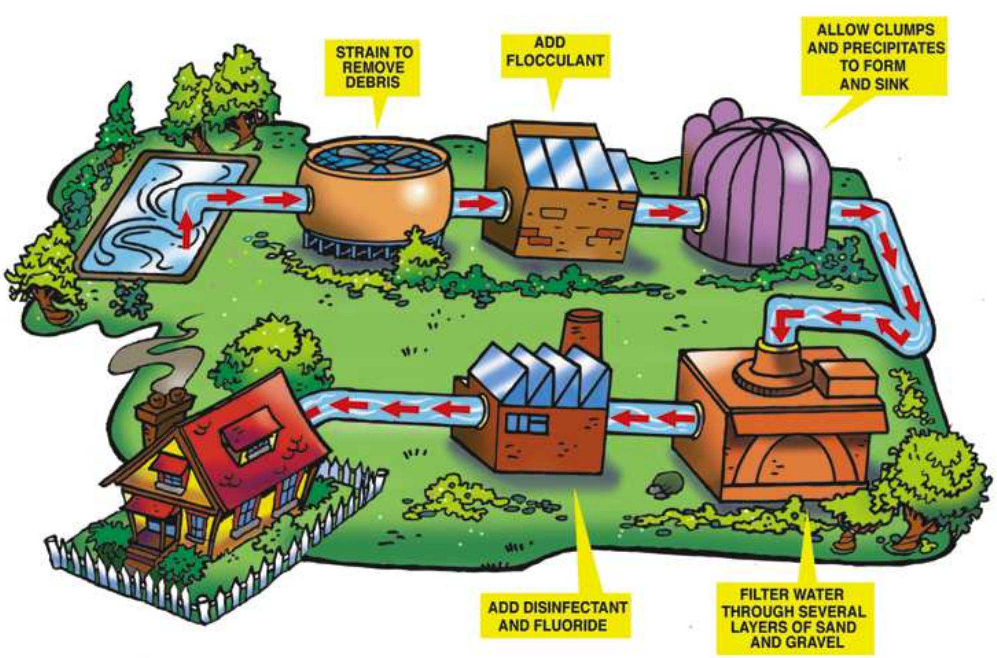
There will be bubbling, a color change, and a precipitate.

Ask students

- **Which three clues of chemical change did you observe?**
  A color change, bubbling, and the formation of a precipitate.
- **Did a chemical reaction occur? How do you know?**
  The chemicals you started with have changed, so the products are different.

Application

Give students the reading on page 52. Explain that the United States and other countries use filtering, along with chemical reactions that produce a precipitate, to make drinking water safe. The reading will describe the general process.



Lesson 3
Forming a precipitate

STUDENT ACTIVITY SHEET

Name: ___________________________

Meet the scientist

Country: Republic of Peru
Scientist: Adriana Garcia

I am so glad you have come to visit me in Peru! Sera told you about the problems of ocean acidification. My main interest is another kind of water problem—cleaning wastewater.

I live and work in a region that includes the city of Lima and the surrounding area. This metropolitan region extends from mountain valleys all the way to the coast. Even though it's very humid here, it almost never rains. So we need to be very careful about how we use water. We get most of our water from glacier ice high in the Andes Mountains. This supply of clean water isn't going to last forever—not with one-third of Peru's population living here!

My work involves trying to preserve this resource by reducing our use of glacier water. If we reuse water that is poured down drains and flushed down toilets, we would use less water from the glaciers. If we clean this water well, we can even use it to water plants in parks and maybe even on farms.

How do we “clean” dirty water? Basically, we use filters and chemistry. Filters catch waste particles and allow the rest of the water to flow through. But some waste is so small that it can slip right through the filters. With help from chemistry, we make these tiny particles bigger. Then our filters can catch them!

In your activity, you will use a chemical reaction and a filter to remove some very small dissolved particles.

Lesson 3
Forming a precipitate

S T U D E N T   A C T I V I T Y   S H E E T

Name: ____________________________

Your chemistry challenge
Remove chemicals that are dissolved in water. GOOD LUCK!

You will need
- Goggles
- Calcium chloride
- Sodium bicarbonate
- Water
- 2 small spoons
- Coffee filter or paper towel
- Small metric measuring cup
- 2 small plastic cups
- Tall plastic cup

Spoon

Procedure

Make solutions

1. Make a sodium bicarbonate solution by placing 1 spoon of sodium bicarbonate into a clean plastic cup.
2. Add 10 mL of water and swirl until as much sodium bicarbonate dissolves as possible.
3. Make a calcium chloride solution by placing 1 spoon of calcium chloride into a clean plastic cup.
4. Add 10 mL of water and swirl until as much calcium chloride dissolves as possible.

Do the chemical reaction

5. Pour one solution into the other.
6. Swirl to see if you can get the white substance to dissolve. This is the precipitate.

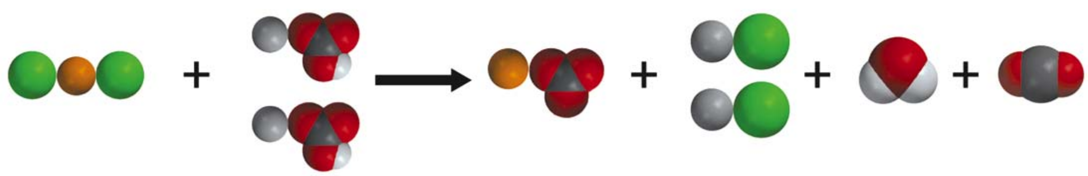
Filter the precipitate

7. Use a coffee filter and a tall plastic cup to make a filter as shown.
8. Pour the contents of the cup into the coffee filter and let the liquid drip though. Let it sit overnight and observe the next day.

The big chemistry idea

You combined two liquids, and a solid formed. They may be small particles. But they are solid and do not dissolve in the solution. This solid that forms during a chemical reaction between two liquids is called a *precipitate*. This solid is calcium carbonate, which is the main substance in chalk and sea shells.

Refer to this chemical equation to answer the following questions.



$CaCl_2$ calcium chloride + $2NaHCO_3$ sodium bicarbonate → $CaCO_3$ calcium carbonate + $2NaCl$ sodium chloride + H_2O water + CO_2 carbon dioxide

How many of each type of atom is on either side of the chemical equation?

Types of atoms	Number of each type of atom in the... reactants	products
calcium atoms		
chlorine atoms		
sodium atoms		
hydrogen atoms		
carbon atoms		
oxygen atoms		

What do you think was in the bubbles?

What is the precipitate?

What will be left in the liquid after you filter the precipitate?

Question to investigate

Is the precipitate different from the reactants?

You will need

- Goggles
- Precipitate, calcium carbonate
- Water
- Small metric measuring cup
- Small clear plastic cup
- Small spoon

Spoon

Procedure

1. Place one spoonful of the precipitate into a clean plastic cup.
2. Add 10 mL of water and swirl until as much of the precipitate dissolves as possible.

Does the precipitate dissolve in water?

How do you know that the precipitate is different from the reactants?

Get a word for the quote

What was the color of the precipitate that you made?
Circle the correct answer.

1. Blue
2. Black
3. White

If you answered:	Your word for the quote is:
1	Classroom
2	Research station
3	Laboratory

Go to *Solve the science quote* on page 70 and write down your word in the chart next to the name of this lesson. You will fit it into the quote later.

Goodbye

Way to go! You've done such a good job making and investigating a precipitate, I think you're ready for your final challenge. This time you'll get to "chill with chemistry."

Next destination **– Antarctica!**

Lesson 3
Forming a precipitate

STUDENT ACTIVITY SHEET

Name: ___________________________

Chemical reaction in action!

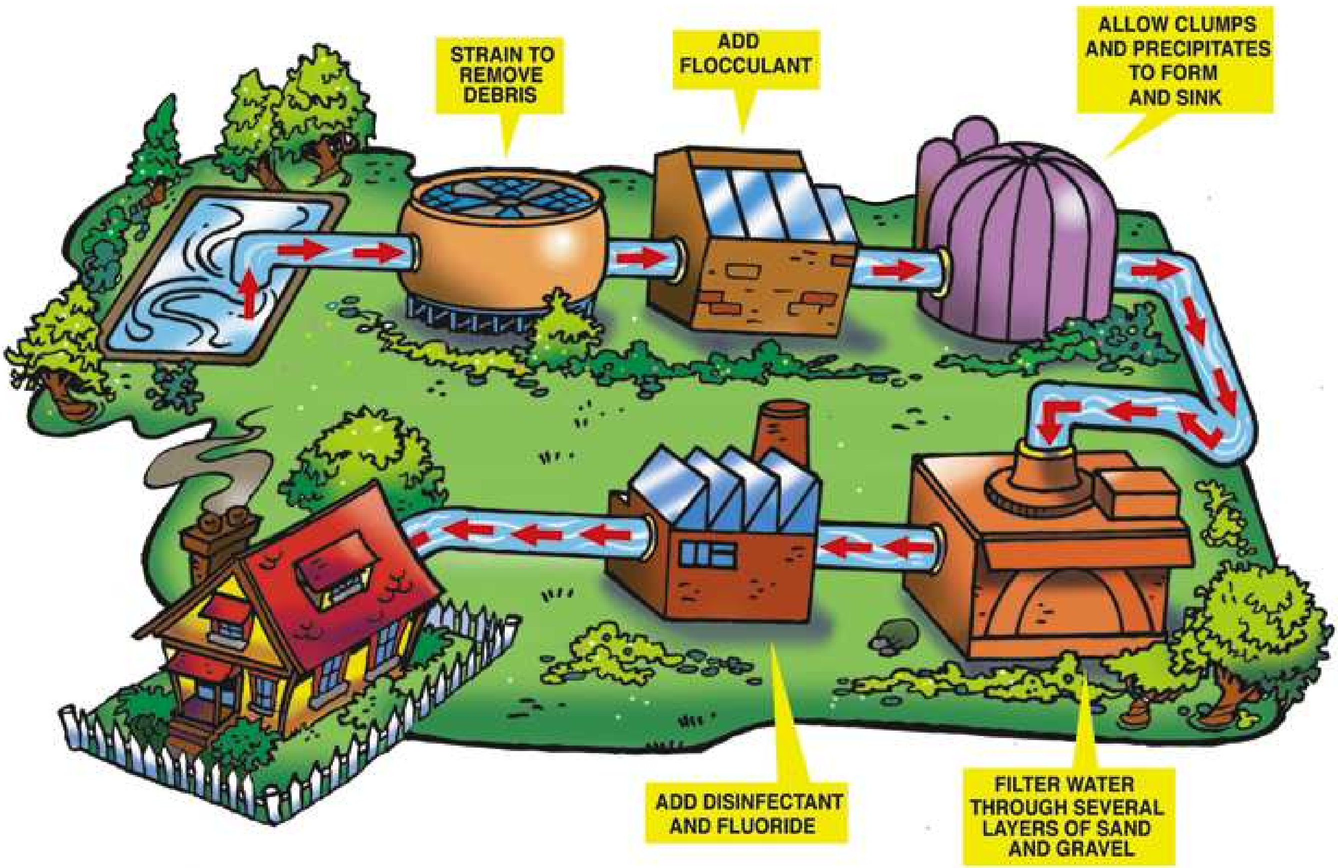
It's a long trip to the South Pole. As you gaze out the window, reflect on what you learned from Adriana. She works on treating the wastewater that *leaves* people's homes. But what about the water that *comes into* homes? In most places, this needs to be treated, too. Here's a little more information about how water gets purified before it flows through pipes to your home.

In order for water to be made safe to drink, the water must go through a step-by-step purification process. The first step is straining, which involves removing large objects like trash, leaves, and other debris. Even after straining, there are still smaller particles that are either suspended or dissolved in the water. Many of these are removed in the next step of the process.

Special chemicals called *flocculants* are added to the water, which is then sent to a sedimentation tank. Here, the added chemicals interact with tiny dirt particles suspended in the water, causing them to clump together and sink to the bottom. The chemicals also react with substances that are dissolved in water. This chemical reaction forms a *precipitate*, which is solid and will not dissolve in water. The precipitate also sinks to the bottom.

The cleaner water from the top of the sedimentation tank goes to a series of filters, where it flows through layers of sand and gravel. These filters collect particles that did not sink.

Finally fluoride and a disinfectant are added to make the water healthy and safe to drink.

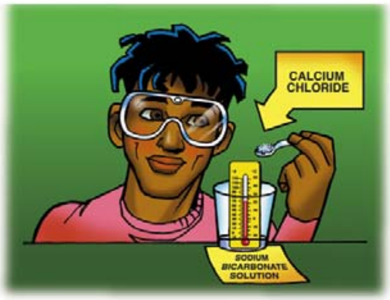

STRAIN TO
REMOVE
DEBRIS
ADD
FLOCCULANT
ALLOW CLUMPS
AND PRECIPITATES
TO FORM
AND SINK
FILTER WATER
THROUGH SEVERAL
LAYERS OF SAND
AND GRAVEL
ADD DISINFECTANT
AND FLUORIDE

Antarctica

Lesson 4
Temperature change

TEACHER GUIDE

Lesson summary



Students meet scientist Jason Williams, an industrial chemist who designs the materials and processes for making solar cells. He explains that during the summers, Antarctic days are very long, sometimes lasting a couple of weeks or more. That makes solar energy an abundant natural resource near the South Pole. Solar cells convert energy from the sun into electrical energy. Converting energy from one form to another is an important process. In the activity, students will conduct two chemical reactions that convert chemical energy into thermal energy.

Key concepts

- A change in temperature is a clue that a chemical reaction may have occurred.
- When the temperature increases during a chemical reaction, it is called an *exothermic reaction*.
- When the temperature decreases during a chemical reaction, it is called an *endothermic reaction*.
- It takes energy to break chemical bonds in the reactants.
- Energy is released when chemical bonds form in the products.

Safety

Be sure you and the students wear properly fitting goggles. Read and follow all safety warnings on the labels of the sodium bicarbonate, citric acid, calcium chloride, and universal indicator containers. Also follow the warnings on the packaging of the foot warmer. Have students wash their hands after the activity.

Proper disposal

At the end of the lesson, have students pour their used solutions in a waste container. The resulting solution from the final demo should be placed in this container, too. Then dispose of all of this liquid waste down the drain or according to local regulations. The left-over sodium bicarbonate, citric acid, and calcium chloride powders can be disposed of with the classroom trash. The used foot warmer may be disposed of with the classroom trash. Wipe up spills with paper towels and dispose of them with the classroom trash.

The chemistry continues

Find more related hands-on activities at **www.acs.org/iyckit** to further explore the concepts introduced in this lesson.

Introduction

1. Introduce students to a scientist, his work, and students' mission.
Distribute the student activity sheets, pages 62–70. In this lesson, students meet industrial chemist Jason Williams. He develops the materials that make up solar cells. He explains that there is an abundant supply of sunshine during the Antarctic summers. Because scientists work on the continent in the summer, there is also a higher demand for electricity. Solar panels convert energy from the sun into electrical energy. Students will conduct two chemical reactions that explore the conversion of chemical energy into thermal energy.

Teacher demonstration

2. Do a demonstration to introduce students to the idea that the temperature can increase dramatically in some chemical reactions.
Show students a foot warmer. Tell them these products work because of a chemical reaction that begins as soon as the package is opened. One of the foot warmer's main ingredients is very fine iron powder. Moisture and oxygen from the air react with the iron and release heat as part of a chemical reaction. This reaction is basically the same as rusting, but it happens much faster.

You will need

- 1 foot warmer

Preparation instructions

- Open the packaging for the foot warmer about a half hour before you meet the students. If using scissors to open the package, be sure that you do not accidentally cut the foot warmer.

Procedure

1. Pass the foot warmer around so that students can feel that it is warm.

Expected results

The foot warmer will begin to warm up slowly but will remain warm for a few hours.

Tell students that there is always a change in temperature during chemical reactions. Sometimes they are dramatic, like with the foot warmer. Other times, the change is so slight that you might not notice it.

Ask students to predict

- **Do you think it is possible for the temperature of a chemical reaction to go down?**
  Students may not be sure at this point, but the temperature can increase or decrease during a chemical reaction.

Explain that if the temperature goes up, the reaction is called an *exothermic* reaction. More heat energy *exits*. If the temperature goes down, the reaction is called an *endothermic* reaction. More heat energy goes *in* to make the chemical reaction happen.

Ask students

- **Is the chemical reaction between the iron filings and the oxygen and water in the air an endothermic or exothermic reaction?**
  Exothermic.

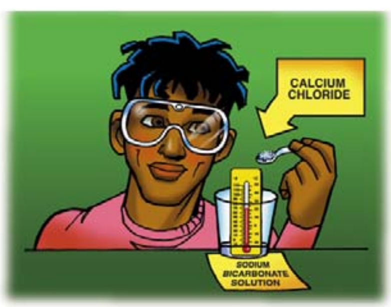
Student activity

3. Have students use a thermometer to observe the temperature changes in two different chemical reactions.
Review with students how to read a thermometer. Let students know that they will measure both the starting temperature and either the highest or lowest temperature reached using the Celsius scale.

Activity summary

Information on how to conduct this activity is included on the student activity sheet on pages 64–65. Students will monitor temperature changes during two different chemical reactions. The temperature decreases during one chemical reaction and increases in the other.

Preparation instructions



- Use the pre-made stickers to label one set of portion cups *citric acid*, *calcium chloride,* and *sodium bicarbonate* for each group. If you conducted lessons 1 and 3, reuse these labeled cups.
- Place 1 teaspoon of citric acid, calcium chloride, and sodium bicarbonate in their labeled cups.
- Use scissors to clip the bottom of the plastic backing off each thermometer so that the bottom of the plastic lines up with the bottom of the red bulb. This way, the amount of liquid used in the activity will cover the bulb of the thermometer completely.

Expected results

- *Chemical reaction between citric acid solution and sodium bicarbonate*
  There will be bubbling, and the temperature will decrease.
- *Chemical reaction between sodium bicarbonate solution and calcium chloride*
  There will be bubbling, and the temperature will increase.

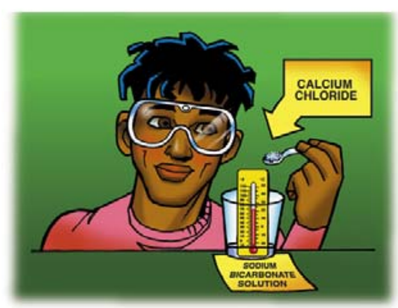
Have groups share their starting and final temperature for each reaction. Also have them classify each as either an *endothermic* or *exothermic* reaction. The temperature decreases in endothermic reactions and increases in exothermic reactions.

Student activity

4. Have students conduct the chemistry challenge by adjusting reactants to get the temperature between 40° and 50° C.

Ask students

- **What do you think will happen if you used more calcium chloride in the exothermic reaction?**
  Increasing the amount of the calcium chloride will cause the temperature to increase more.



Activity summary

Students should refer to their activity sheet for guidance on how to conduct this activity. They will conduct the exothermic reaction again but this time with the goal of getting the highest temperature somewhere between 40° and 50° C. They will record the amount of calcium chloride used and the highest temperature reached. You may wish to limit either the time or the number of trials students conduct.

Expected results

Adding more calcium chloride will cause a greater increase in temperature.

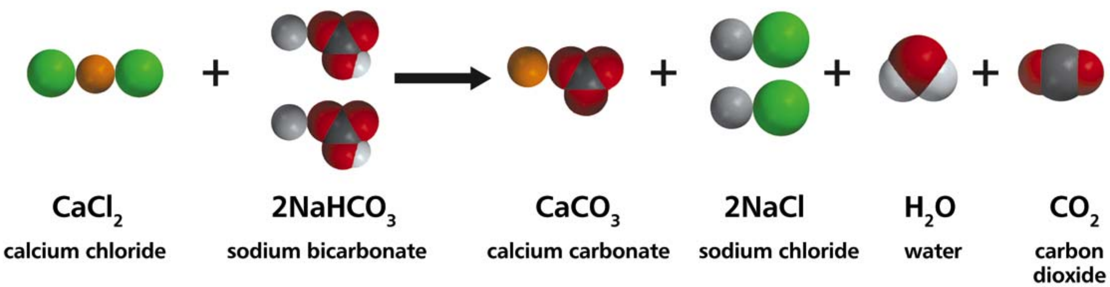
Class discussion

5. Discuss the "big chemistry idea" to help students understand what makes a chemical reaction either endothermic or exothermic.

The big chemistry idea on the student activity sheet revisits the idea that in a chemical reaction atoms or groups of atoms in the reactants rearrange and re-bond to form the products. It also describes endothermic and exothermic reactions in terms of the energy used and released as bonds between atoms break and form.

Tell students that when the temperature of a chemical reaction increases, the reaction is called an *exothermic* reaction. The first part of the word, *exo*, means out or out of and *thermic* has to do with heat or energy. So an exothermic reaction means that more energy goes out or is released by the reaction than goes into it. This leaves the reaction mixture at a higher temperature.

- A chemical reaction is endothermic when it takes more energy to break the bonds in the reactants than is released when the new bonds form to make the products.
- A chemical reaction is exothermic when more energy is released when the new bonds form to make the products than is used to break the bonds in the reactants.



Ask students

- **What do you know about the amount of energy required to break the bonds of the reactants compared to the amount of energy released when the products are formed?**
  More energy was released when the bonds in the products formed than was required to break the bonds in the reactants.

6. Have students answer the question in order to get a word for the quote.

Have students answer the question and use the chart to get the word for the quote. On the activity sheet, the scientist gives some congratulatory words and tells students that they have all the words needed to solve the quote. Decide as a class what the quote is. Then type it in at **www.acs.org/iyckit** to enter your class into a drawing for a prize.

Teacher demonstration

7. Pour solutions from cup to cup and have students identify the clues of chemical change.

In this demonstration, you will pour the entire contents of one cup into another that contains a small amount of citric acid, then sodium carbonate, then calcium chloride, and then citric acid again. As you pour the contents of one cup into the next, have students identify each of the clues of chemical change. Bring closure to all of the hands-on explorations students have conducted in this kit with this colorful demonstration.

You will need

- Goggles
- Universal indicator
- Citric acid
- Sodium carbonate
- Calcium chloride
- Water
- Thermometer
- Small metric measuring cup
- Small scoop
- Small spoon
- 5 clear plastic cups

Scoop

Spoon

Preparation instructions

Line up 5 clear plastic cups. Place the following in each of 5 cups:

- First cup—30 mL water and 30 drops of universal indicator
- Second cup—1 scoop of citric acid
- Third cup—1 spoon of sodium carbonate
- Fourth cup—1 spoon of calcium chloride
- Fifth cup—1 spoon of citric acid

Procedure

1. Place the thermometer into the green indicator solution and make a note of the temperature.
2. Move the thermometer to the second cup and pour all of the green indicator solution into the cup. Swirl and make a note of the temperature.
3. Move the thermometer to the third cup and pour all of this solution into the next cup. Swirl and make a note of the temperature.
4. Move the thermometer to the fourth cup and pour all of this solution into the next cup. Swirl and make a note of the temperature.
5. Move the thermometer to the fifth cup and pour the entire contents of the cup into the next cup. Swirl and make a note of the temperature.

Expected results

- Cup 1—Solution is green.
- Cup 2—Solution turns pink.
- Cup 3—Solution turns purple.
- Cup 4—Solution turns a chalky blue and the temperature increases.
- Cup 5—Solution bubbles, turns orange, and becomes clear.

Ask students

- **Which clues of chemical change did you observe?**
  A color change, production of a gas, a slight change in temperature, and the formation of a precipitate.

Application

Give students the reading on page 69. Explain that exothermic chemical reactions are used by military troops in remote locations so that they can have hot meals when they are in the field. Meals-Ready-to-Eat, or MREs, use a chemical reaction to warm up a pouch of food in about 10 minutes.

Lesson 4
Temperature change

S T U D E N T   A C T I V I T Y   S H E E T

Name: ____________________________

Meet the scientist

Continent: Antarctica
Scientist: Jason Williams

Thanks for coming to see me at the bottom of the world. My name is Jason Williams, and I am a chemist from the United States. I am here in Antarctica with a set of solar panels that I helped develop. As a chemist, my team and I built each *solar cell,* starting with tiny molecules. Solar cells convert the sun's energy into electricity. Our challenge was to make solar cell material better so that it converts the sun's energy into electricity more efficiently than before. We are also working on a way to make solar cells without using, or being left with, substances that are harmful to the environment.

There is no better place on Earth for solar energy than Antarctica! At least that's true in the summertime! From about October to March, which is summer down here, "days" are very long. In fact, during the month of December at the location where my panels will be installed, the sun stays up 24 hours per day for more than two weeks!

Antarctica's research stations become bustling communities during the summer. About 5,000 scientists live and work here at that time of year. They study climate change, animals, glaciers, and more. Researchers need electricity for their computers and other equipment. Long periods of sunlight and a high demand for electricity make Antarctica an ideal place to use solar energy.

The trick to making solar cells work is to find a good way to convert one kind of energy to another. Lots of important devices do something similar. A light bulb converts electrical energy into light energy. A battery converts chemical energy into electrical energy, which can be converted into sound energy by a radio or iPod. Solar cells turn the sun's energy into electricity.

In your final activity, you will convert energy between chemical and thermal energy using chemical reactions that change temperature!

Lesson 4
Temperature change

S T U D E N T   A C T I V I T Y   S H E E T

Name: ___________________________

Temperature changes are a clue that a chemical reaction is occurring.

- If the temperature increases during the chemical reaction, it is called an *exothermic* reaction.
- If the temperature decreases during a chemical reaction, it is called an *endothermic* reaction.

Use a thermometer while you conduct the following chemical reactions to find out which one is exothermic and which one is endothermic.

You will need

- Goggles
- Citric acid
- Sodium bicarbonate
- Calcium chloride
- Water
- Thermometer
- Small metric measuring cup
- Small scoop
- 2 small spoons
- 2 small clear plastic cups

Scoop

Spoon

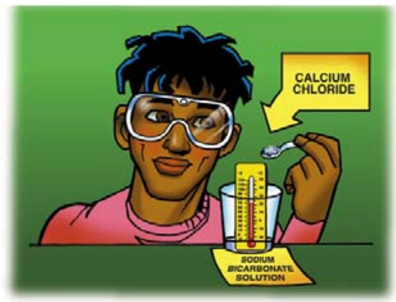
Procedure

Citric acid solution and sodium bicarbonate

1. Place 10 mL of water in a clear plastic cup.
2. Add 2 small scoops of citric acid and swirl until the citric acid dissolves.
3. Place a thermometer in the citric acid solution. Record this starting temperature in the chart on the next page.
4. With the thermometer still in the solution, add 1 spoon of sodium bicarbonate and swirl. Record the most extreme temperature reached.

Sodium bicarbonate solution and calcium chloride

5. Place 10 mL of water in a clear plastic cup.
6. Add 2 small scoops of sodium bicarbonate and swirl until the sodium bicarbonate dissolves.
7. Place a thermometer in the sodium bicarbonate solution. Record this starting temperature in the chart.
8. With the thermometer still in the solution, add 1 spoon of calcium chloride and swirl. Record the most extreme temperature reached.



How much does the temperature change in each chemical reaction?

Chemical reaction	Citric acid solution and sodium bicarbonate	Sodium bicarbonate solution and calcium chloride
Starting temperature		
Final temperature		
Difference in temperature		
Did the temperature go up or down?		
Is this reaction endothermic or exothermic?		

Your chemistry challenge

Conduct a chemical reaction so that the highest temperature reached is between 40° and 50° C. You will only adjust the amount of one reactant—calcium chloride. GOOD LUCK!

The rules

Start with a sodium bicarbonate solution made by dissolving 2 scoops sodium bicarbonate in 10 mL water, then add the amount of calcium chloride you and your group agree on.

How much calcium chloride does it take to make the temperature increase to between 40° and 50°C?

Amount of calcium chloride		
Starting temperature		
Final temperature		

The big chemistry idea

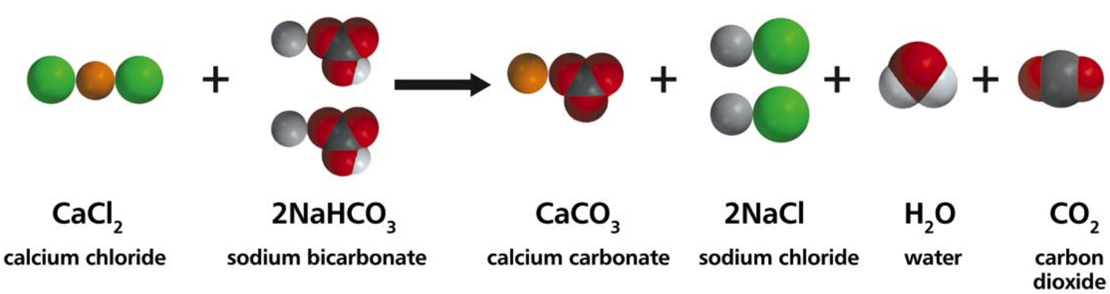
Remember that, during a chemical reaction, certain atoms or groups of atoms break their bonds, rearrange, and then form new bonds to make the products. As you can imagine, it takes energy to break bonds. When the chemical bonds in the products form, energy is released.

The amount of energy needed to break bonds compared to the amount of energy released when bonds are formed is usually different.

If it takes more energy to break the bonds in the reactants than is released when bonds form in the products, then the temperature goes down. This is called an *endothermic* reaction.

If more energy is released when bonds form in the products than was used to break the bonds of the reactants, then the temperature goes up. This is called an *exothermic* reaction.

Look at this chemical equation for the reaction you conducted to answer the question below.



Is more energy released when the products are formed than is used to break the bonds in the reactants?

Get your word for the quote

In which direction did the temperature go after you mixed baking soda and citric acid?

1. Up
2. Down
3. Stayed the same

If you answered:	Your word for the quote is:
1	Stomach
2	Mind
3	Brain

Go to *Solve the science quote* on page 70 and write down your word in the chart next to the name of this lesson. You now have all the words needed to reveal the quote!

Goodbye

Awesome! Now that you're full of chemistry know-how, you can head back to school. It's time to fill in all the blanks and find out what that quote says about science.

Next destination **– School!**

Lesson 4
Temperature change

STUDENT ACTIVITY SHEET

Name: ___________________________

Chemical reaction in action!

When Jason and other scientists in Antarctica are far from a research station, they use a chemical reaction to warm their portable meals. The same concept also helps soldiers in the armed forces get a hot meal while serving on the front lines.

Soldiers need hot food, which gives them energy and lifts their spirits. But they are often far away from the nearest kitchen, and they can't carry bulky cooking equipment. Fortunately, soldiers carry with them an important weapon to meet this daunting challenge: chemistry.

Special packaged meals called MREs (Meals Ready to Eat) were first introduced in the 1970s. Today, they are still distributed to U.S. service members so that they can have hot meals, even when they are in remote locations.

MREs work by using a chemical reaction that quickly produces heat when activated. Every MRE includes a small pouch that contains the metal magnesium, ground up into very small pieces. Usually some iron filings are mixed with the magnesium. Adding water to the pouch causes the magnesium filings to quickly oxidize, or rust. This process generates enough heat to allow soldiers to heat prepared food rations.

Conclusion
Solve the science quote

STUDENT ACTIVITY SHEET

Name: ___________________________

Solve the science quote

Name of the activity	Word for the quote
1. Production of a gas	
2. Color change	
3. Forming a precipitate	
4. Temperature change	

Home again

It's been a wild ride. Now that you're back at school, it's time for the last step. Using the words you picked up along the way, fill in the blanks in the order that makes the most sense.

"All the _____________ is a _____________ to the _____________ _____________."

Dr. Martin H. Fischer
Chemist and physician

Free Teaching Resources from ACS

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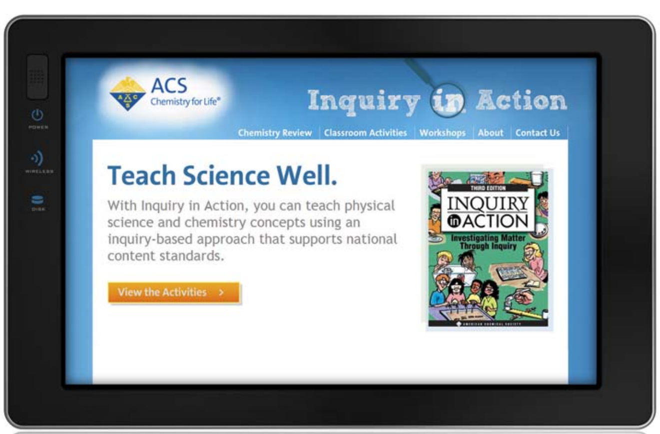
At **middleschoolchemistry.com**, you can view and download fully developed lesson plans that you can use to teach an entire middle school chemistry unit. Each activity, as well as the entire 691-page book, is available for free download in PDF format. The website also has a multimedia section, complete with molecular model animations and videos, and information on upcoming workshops.

Inquiry in Action

At **inquiryinaction.org**, you can view and download free inquiry-based physical science activities that support national science content standards. Each activity, as well as the entire 470-page book, is available for free download in PDF format. The website also has a chemistry background section, complete with molecular model animations and videos, and information on upcoming workshops.



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www.acs.org/chemmatters

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Grades 6–8

www.middleschoolchemistry.com

www.acs.org/iyc2011

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www.inquiryinaction.org

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made me rejoice like a child."

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