Chapter 2

The Nature of Matter

CALIFORNIA Standards Preview

S 8.3 Each of the more than 100 elements of matter has distinct properties and a distinct atomic structure. All forms of matter are composed of one or more of the elements. As a basis for understanding this concept:

b. Students know that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements.

S 8.5 Chemical reactions are processes in which atoms are rearranged into different combinations of molecules. As a basis for understanding this concept:

b. Students know the idea of atoms explains the conservation of matter: In chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same.

c. Students know chemical reactions usually liberate heat or absorb heat.

S 8.9 Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

a. Plan and conduct a scientific investigation to test a hypothesis.

This "junk sculpture" of an armadillo is made entirely of metal can lids.

Video Preview

Discovery Channel School

Introduction to Matter

S 8.3

Focus on the
BIG Idea

What is chemistry?

Check What You Know

Suppose you have a whole cookie. You break the cookie into tiny pieces and crumbs. Then, you weigh all the pieces and crumbs. How do you think the weight of the whole cookie compares to the total weight of all the cookie crumbs?

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Prefixes

A prefix is a word part that is added at the beginning of a root word to change its meaning. For example, the prefix *com-* means "with," or "together." In the word *combine*, the prefix *com-* is added to the root word *bind* to form *combine*,meaning "to bind together."

com	**+**	**bind**	**=**	**combine**
together		tie		bind or tie together

The following prefixes will help you learn new words in this chapter.

Prefix	Meaning	Example Word
com-	With, together	Compound
hetero-	Different	Heterogenous
homo-	Same	Homogenous
endo-	In, within	Endogenous
exo-	Out	Exothermic

Apply It!

The Greek root *therm* means "heat." Use the table to learn the meaning of the prefix *endo-* . Then predict the meaning of the adjective *endothermic*. Read Section 1 to see if your predicted definition is accurate or needs to be changed.

Chapter 2 Vocabulary

Section 1 (page 58)

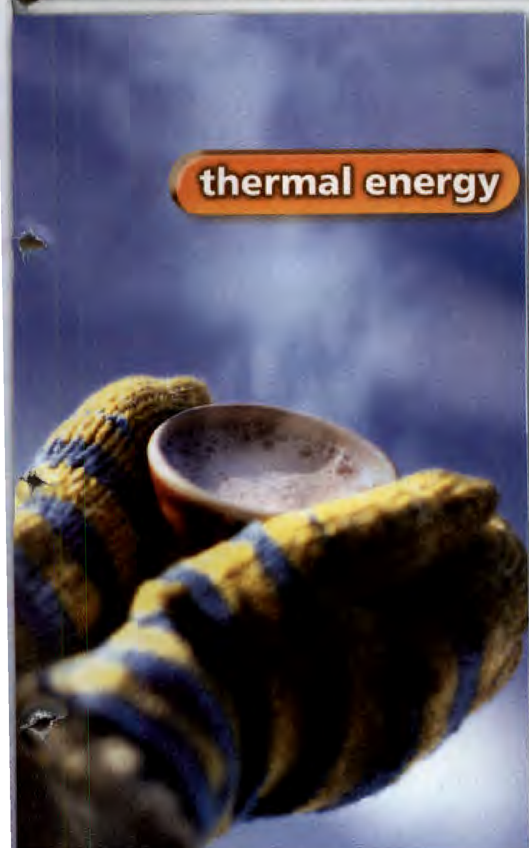
matter
substance
physical property
chemical property
element
atom
chemical bond
molecule
compound
chemical formula
mixture
heterogeneous mixture
homogeneous mixture
solution

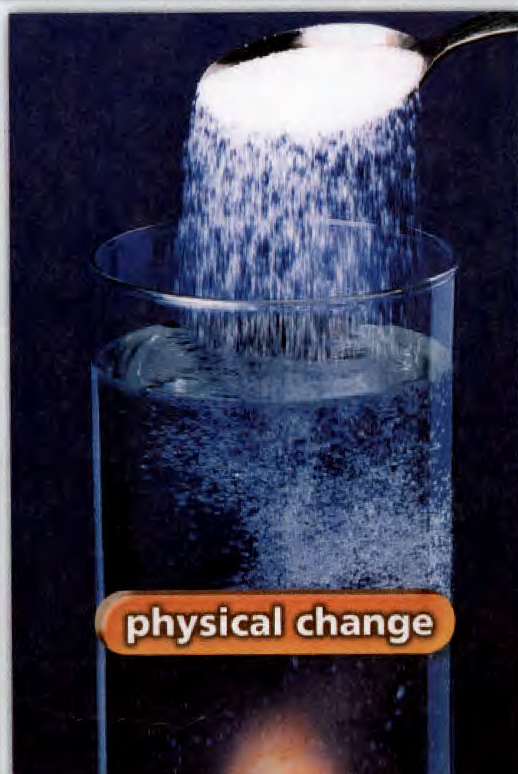
Section 2 (page 68)

physical change
chemical change
law of conservation of matter

Section 3 (page 73)

energy
temperature
thermal energy
endothermic change
exothermic change
chemical energy
electromagnetic energy
electrical energy
electrode





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How to Read Science

Reading Skill

Identify the Main Idea

The main idea is the most important—or biggest—idea in a passage of text. Sometimes the main idea is stated directly. At other times, you must identify the main idea yourself.

Here are some tips.

- Look at the heading or subheading.
- Distinguish the important information.
- Identify a few important details about the topic.
- State the main idea of the passage.

Read the paragraph on page 58. Identify the main idea and supporting details. You can keep track of this information by using a graphic organizer like the one below.

Main Idea		
Matter is anything that has mass and takes up space.		
Detail	**Detail**	**Detail**
The stuff around you is matter.		

Apply It!

In your notebook, copy and complete the graphic organizer.

As you read the chapter, look for the main ideas and supporting details in paragraphs.

Lab zone

Standards Investigation

S 8.3.b

Classify Changes in Matter

Look around. All sorts of changes are taking place. You might observe a fence rusting or a puddle of water evaporating. As you will learn in this chapter, changes in matter can be physical or chemical. In this investigation, you will keep a log of the changes that occur around you.

Your Goal

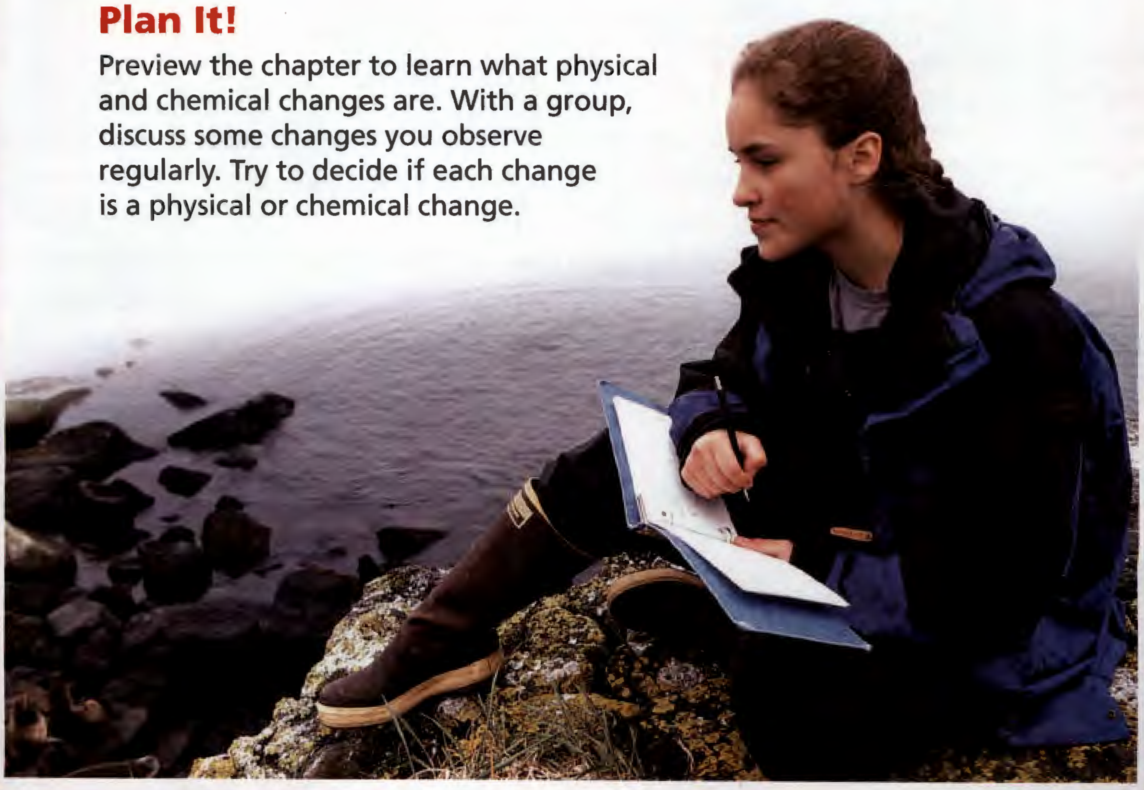
To identify and observe physical and chemical changes in your daily life and to record evidence for those changes

To complete the investigation, you must

- determine what evidence indicates that a change has taken place
- record observations of the different changes you notice in your life during one week
- classify the changes you observe as physical or chemical
- follow the safety guidelines in Appendix A

Plan It!

Preview the chapter to learn what physical and chemical changes are. With a group, discuss some changes you observe regularly. Try to decide if each change is a physical or chemical change.



shiny, flexible toy when shaped into a flat wire and coiled.

Lab zone Skills Activity

Interpreting Data

Melting point is the temperature at which a solid becomes a liquid. Boiling point is the temperature at which a liquid becomes a gas. Look at the data listed below. Identify each substance's physical state at room temperature (approximately 20°C). Is it a gas, a liquid, or a solid? Explain your conclusions.

Substance	Melting Point (°C)	Boiling Point (°C)
Water	0	100
Ethanol	–117	79
Propane	–190	–42
Table salt	801	1,465

Physical Properties of Matter A **physical property** is a characteristic of a pure substance that can be observed without changing it into another substance. For example, a physical property of water is that it freezes at a temperature of 0°C. When liquid water freezes, it changes to solid ice, but it is still water. Density, hardness, texture, and color are some other physical properties of matter. When you describe a substance as a solid, a liquid, or a gas, you are stating another physical property. Whether or not a substance dissolves in water is a physical property, too. Sugar will dissolve in water, but iron will not. Stainless steel is mostly iron, so you can stir sugar into your tea with a stainless steel spoon.

Physical properties can be used to classify matter. For example, two properties of metals are luster and the ability to conduct heat and electricity. Some metals, such as iron, can be attracted by a magnet. Metals are also flexible, which means they can be bent into shapes without breaking. They can also be pressed into flat sheets and pulled into long, thin wires. Other materials such as glass, brick, and concrete will break into small pieces if you try to bend them or press them thinner.

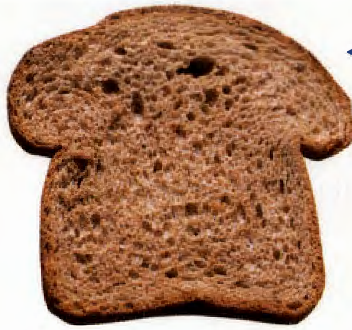
meaning. **Matter** is anything that has mass and takes up space. All the "stuff" around you is matter, and you are matter too. Air, plastic, metal, wood, glass, paper, and cloth—all of these are matter.

▼ **Paper, ceramic, wood, metal, and foam are all forms of matter.**

FIGURE 3

Chemical Properties

The chemical properties of different forms of matter cannot be observed without changing a substance into a new substance.



◀ **New Substances, New Properties** Gases produced during baking create spaces in freshly made bread.

◀ **Flammability** Wood fuels a fire, producing heat, gases, and ash.

Ability to React ▶ Iron can form rust, turning a once shiny car into a crumbling relic.

Chemical Properties of Matter Unlike physical properties of matter, some properties can't be observed just by looking at or touching a substance. A **chemical property** is a characteristic of a pure substance that describes its ability to change into different substances. To observe the chemical properties of a substance, you must try to change it to another substance. Like physical properties, chemical properties are used to classify substances. For example, a chemical property of methane (natural gas) is that it can catch fire and burn in air. When it burns, it combines with oxygen in the air and forms new substances, water and carbon dioxide. Burning, or flammability, is a chemical property of methane as well as the substances in wood or gasoline.

One chemical property of iron is that it will combine slowly with oxygen in air to form a different substance, rust. Silver will react with sulfur in the air to form tarnish. In contrast, a chemical property of gold is that it does *not* react easily with oxygen or sulfur. Bakers make use of a chemical property of the substances in bread dough. With the help of yeast added to the dough, some of these substances can produce a gas, which causes the bread to rise.

Reading Checkpoint **What is a chemical property?**

FIGURE 4
Examples of Elements
Some elements have familiar uses. Many elements are solids at room temperature, but some are gases or liquids.

Elements

What is matter made of? Why is one kind of matter different from another kind of matter? Educated people in ancient Greece debated these questions. Around 450 B.C., a Greek philosopher named Empedocles proposed that all matter was made of four "elements"—air, earth, fire, and water. He thought that all other matter was a combination of two or more of these four elements. The idea of four elements was so convincing that people believed it for more than 2,000 years.

What Is an Element? In the late 1600s, experiments by the earliest chemists began to show that matter was made up of many more than four elements. Now, scientists know that all matter in the universe is made of slightly more than 100 different substances, still called elements. An **element** is a pure substance that cannot be broken down into any other substances by chemical or physical means. **Elements are the simplest substances.** Each element can be identified by its specific physical and chemical properties.

You are already familiar with some elements. Aluminum, which is used to make foil and outdoor furniture, is an element. Pennies are made from zinc, another element. Then the pennies are given a coating of copper, also an element. With each breath, you inhale the elements oxygen and nitrogen, which make up 99 percent of Earth's atmosphere. Elements are often represented by one- or two-letter symbols, such as C for carbon, O for oxygen, H for hydrogen, and Zn for zinc.

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Particles of Elements—Atoms What is the smallest possible piece of an element? Suppose you could keep tearing a piece of aluminum foil in half over and over again. Would you reach a point where you have the smallest possible piece of aluminum? The answer is yes. Since the early 1800s, scientists have known that all matter is made of atoms. An **atom** is the basic particle from which all elements are made. Different elements have different properties because their atoms are different. Experiments in the early 1900s showed that an atom is made of even smaller parts. Look at the diagram of a carbon atom in Figure 5. The atom has a positively charged center, or nucleus, that contains smaller particles. It is surrounded by a "cloud" of negative charge. You will learn more about the structure of atoms in Chapter 4.

When Atoms Combine Atoms of most elements have the ability to combine with other atoms. When atoms combine, they form a **chemical bond,** which is a force of attraction between two atoms. In many cases, atoms combine to form larger particles called **molecules** (MAHL uh kyoolz)—groups of two or more atoms held together by chemical bonds. A molecule of water, for example, consists of an oxygen atom chemically bonded to two hydrogen atoms. Two atoms of the same element can also combine to form a molecule. Oxygen molecules consist of two oxygen atoms. Figure 6 shows models of three molecules. You will see similar models throughout this book.

Reading Checkpoint What is a molecule?

FIGURE 5
Modeling an Atom
Pencil "lead" is made of mostly graphite, a form of carbon. Two ways to model atoms used in this book are shown here for carbon.

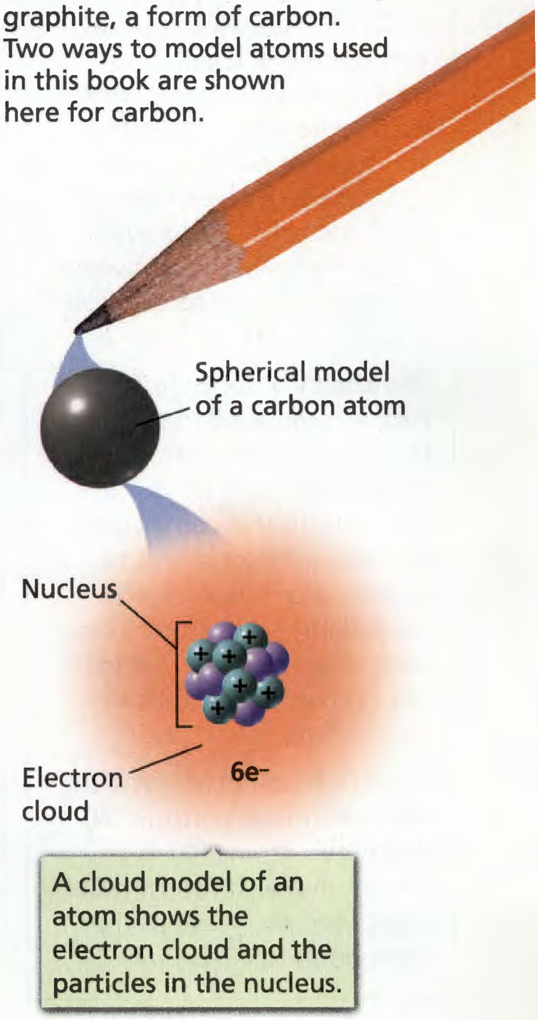
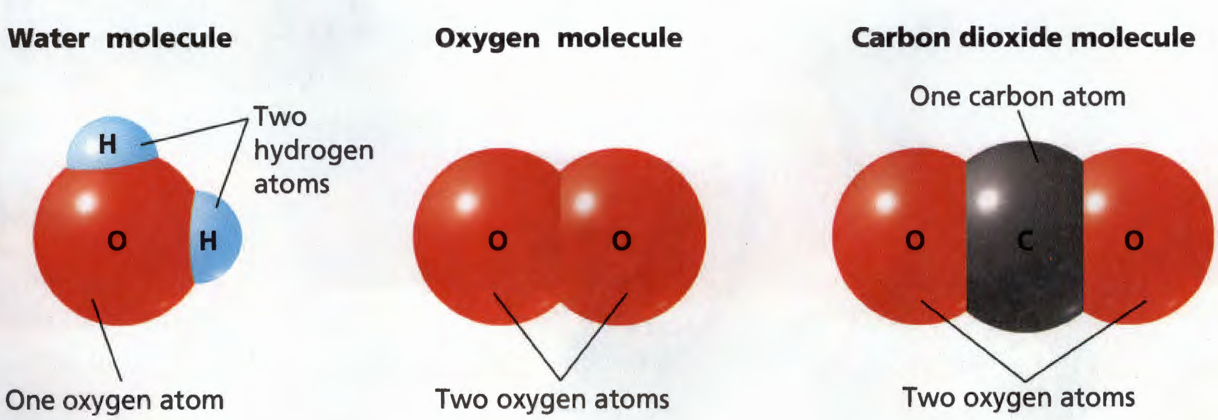


FIGURE 6
Modeling Molecules
Models of molecules often consist of colored spheres that stand for different kinds of atoms.
Observing *How many atoms are in a molecule of carbon dioxide?*



Math Skills

Ratios A ratio compares two numbers. It tells you how much you have of one item compared to how much you have of another. For example, a cookie recipe calls for 2 cups of flour to every 1 cup of sugar. You can write the ratio of flour to sugar as 2 to 1, or 2 : 1.

The chemical formula for rust, a compound made from the elements iron (Fe) and oxygen (O), may be written as Fe_2O_3. In this compound, the ratio of iron atoms to oxygen atoms is 2 : 3. This compound is different from FeO, a compound in which the ratio of iron atoms to oxygen atoms is 1 : 1.

Practice Problem What is the ratio of nitrogen atoms (N) to oxygen atoms (O) in a compound with the formula N_2O_5? Is it the same as the compound NO_2? Explain.

Compounds

All matter is made of elements, but most elements in nature are found combined with other elements. A **compound** is a pure substance made of two or more elements chemically combined in a set ratio. A compound may be represented by a **chemical formula**, which shows the elements in the compound and the ratio of atoms. For example, part of the gas you exhale is carbon dioxide. Its chemical formula is CO_2. The number *2* below the symbol for oxygen tells you that the ratio of carbon to oxygen is 1 to 2. (If there is no number after the element's symbol, the number *1* is understood.) If a different ratio of carbon atoms and oxygen atoms are seen in a formula, you have a different compound. For example, carbon monoxide—a gas produced in car engines—has the formula CO. Here, the ratio of carbon atoms to oxygen atoms is 1 to 1.

When elements are chemically combined, they form compounds having properties that are different from those of the uncombined elements. For example, the element sulfur is a yellow solid, and the element silver is a shiny metal. But when silver and sulfur combine, they form a compound called silver sulfide, Ag_2S. You would call this black compound *tarnish*. Table sugar ($C_{12}H_{22}O_{11}$) is a compound made of the elements carbon, hydrogen, and oxygen. The sugar crystals do not resemble the gases oxygen and hydrogen or the black carbon you see in charcoal.

Reading Checkpoint What information does a chemical formula tell you about a compound?

FIGURE 7
Compounds From Elements
This snail's shell is made mostly of calcium carbonate—a compound made from calcium, carbon, and oxygen.

Mixtures

Elements and compounds are pure substances, but most of the materials you see every day are not. Instead, they are mixtures. A **mixture** is made of two or more substances—elements, compounds, or both—that are together in the same place but are not chemically combined. Mixtures differ from compounds in two ways. **Each substance in a mixture keeps its individual properties. Also, the parts of a mixture are not combined in a set ratio.**

Think of a handful of moist soil such as that in Figure 8. If you look at the soil through a magnifier, you will find particles of sand, bits of clay, maybe even pieces of decaying plants. If you squeeze the soil, you might force out a few drops of water. A sample of soil from a different place probably won't contain the same amount of sand, clay, or water.

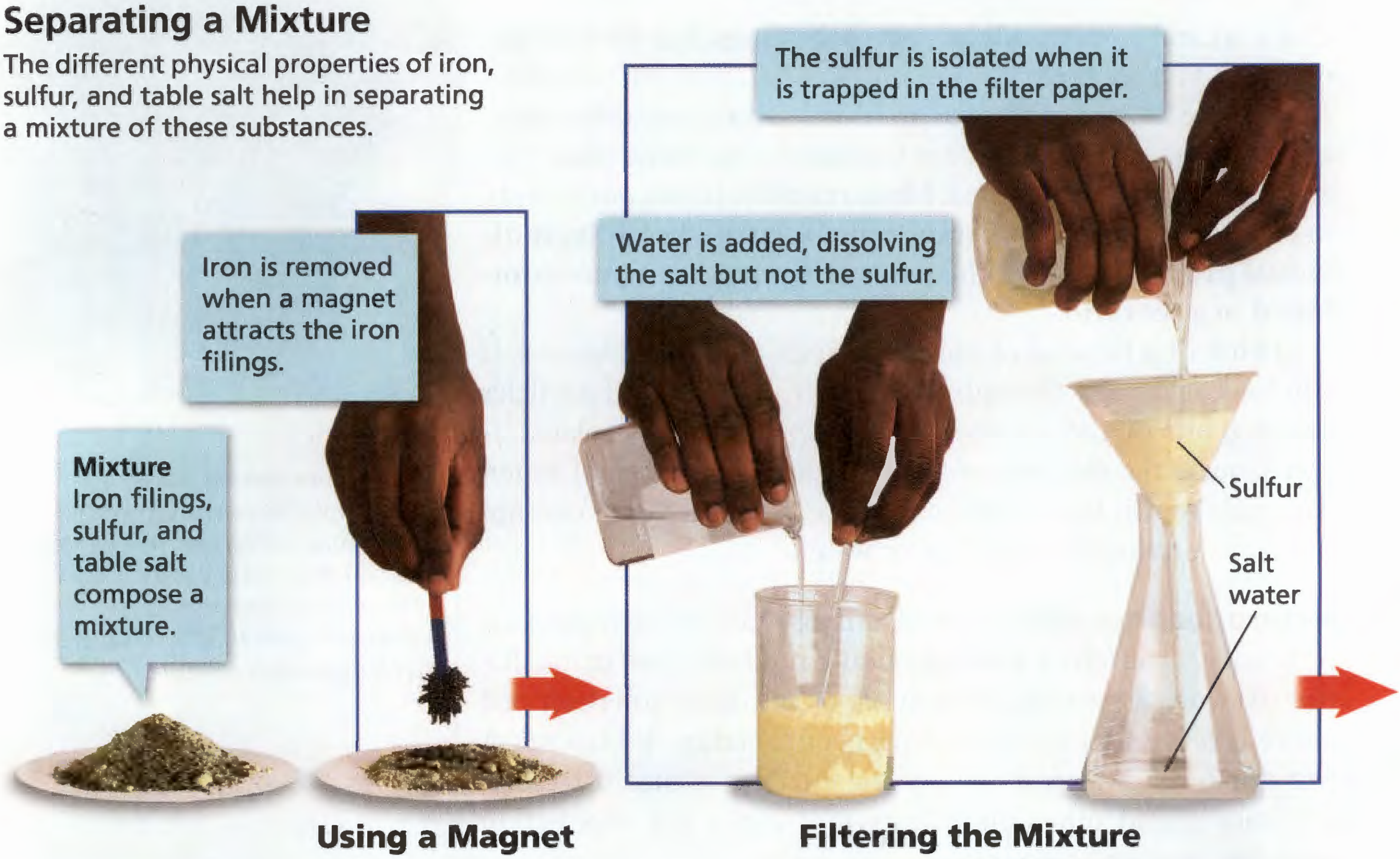
FIGURE 8
Heterogeneous Mixture
Soil from a flowerpot in your home may be very different from the soil in a nearby park.
Interpreting Photographs
What tells you that the soil is a heterogeneous mixture?

Heterogeneous Mixtures A mixture can be heterogeneous or homogeneous. In a **heterogeneous mixture** (het ur uh JEE nee us), you can see the different parts. The damp soil described above is one example of a heterogeneous mixture. So is a salad. Just think of how easy it is to see the pieces of lettuce, tomatoes, cucumbers, and other ingredients that cooks put together in countless ways and amounts.

Homogeneous Mixtures The substances in a **homogeneous mixture** (hoh moh JEE nee us), are so evenly mixed that you can't see the different parts. Suppose you stir a teaspoon of sugar into a glass of water. After stirring for a little while, the sugar dissolves, and you can no longer see crystals of sugar in the water. You know the sugar is there, though, because the sugar solution tastes sweet. A **solution** is an example of a homogeneous mixture. A solution does not have to be a liquid, however. Air is a solution of nitrogen gas (N_2) and oxygen gas (O_2), plus small amounts of a few other gases. A solution can even be solid. Brass is a solution of the elements copper and zinc.

FIGURE 9
Homogeneous Mixture
A swimmer blows bubbles of air—a homogeneous mixture of gases.

FIGURE 10
Separating a Mixture
The different physical properties of iron, sulfur, and table salt help in separating a mixture of these substances.

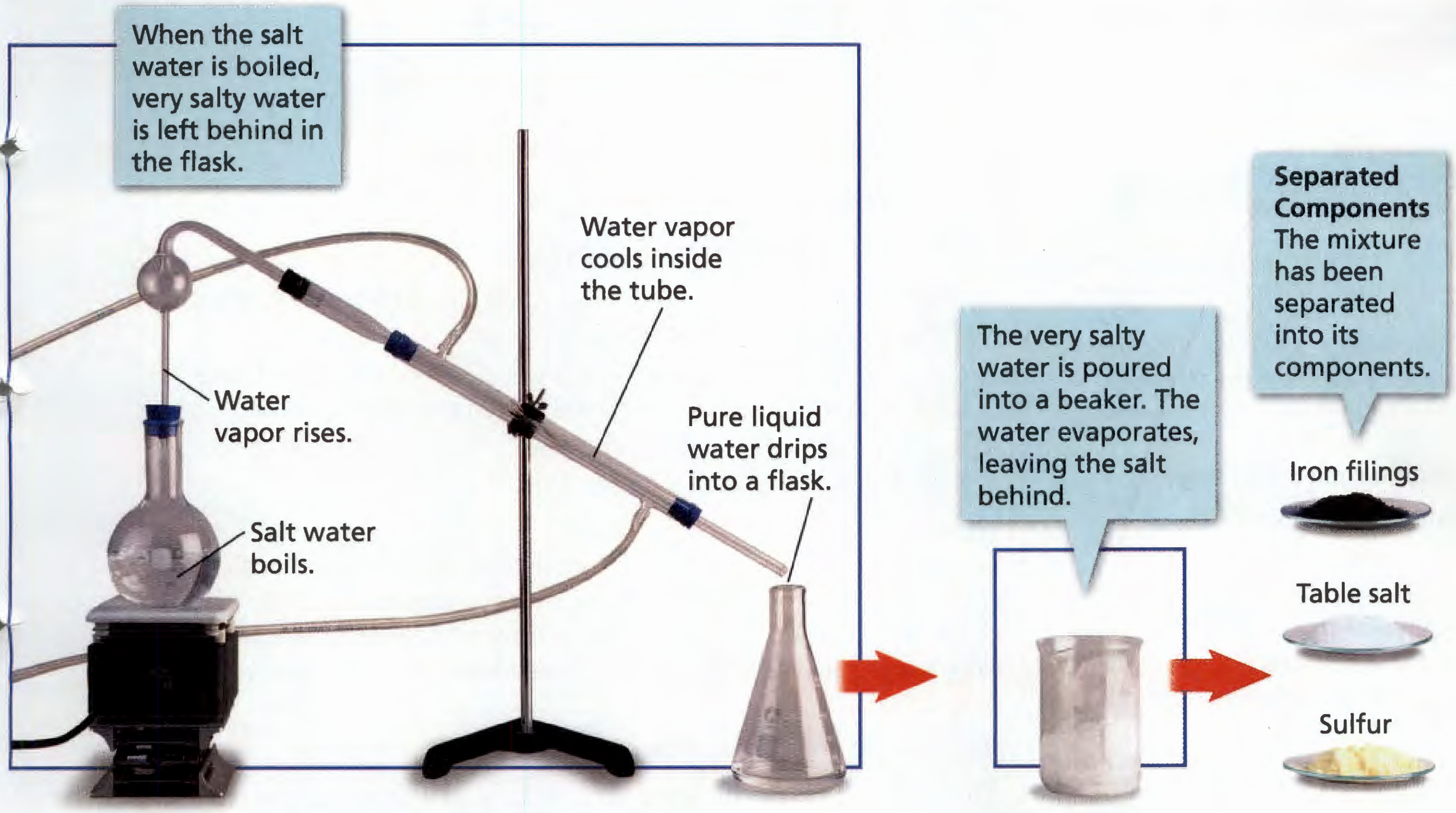


Video Field Trip
Discovery Channel School
Introduction to Matter

Separating Mixtures Compounds and mixtures differ in yet another way. A compound can be difficult to separate into its elements. But, a mixture is usually easy to separate into its components because each component keeps its own properties. Figure 10 illustrates a few of the ways you can use the properties of a mixture's components to separate them. These methods include magnetic attraction, filtration, distillation, and evaporation.

In the Figure, iron filings, powdered sulfur, and table salt start off mixed in a pile. Iron is attracted to a magnet, while sulfur and salt are not. Salt can be dissolved in water, but sulfur will not dissolve. So, pouring a mixture of salt, sulfur, and water through a paper filter removes the sulfur.

Now the remaining solution can be distilled. In distillation, a liquid solution is boiled. Components of the mixture that have different boiling points will boil away at different temperatures. As most of the water boils in Figure 10, it is cooled and then collected in a flask. Once the remaining salt water is allowed to dry, or evaporate, only the salt is left.



Distilling a Liquid Solution

Evaporation

Section 1 Assessment

S 8.3.b, E-LA: Reading: 8.1.0

Vocabulary Skill **Prefixes** How does knowing the meaning of the prefixes *hetero-* and *homo-* help you remember the Key Terms *heterogeneous mixture* and *homogeneous mixture?*

Reviewing Key Concepts

1. a. **Explaining** What is the difference between chemical properties and physical properties?
   b. **Classifying** A metal melts at 450°C. Is this property of the metal classified as chemical or physical? Explain your choice.
   c. **Making Judgments** Helium does not react with any other substance. Is it accurate to say that helium has no chemical properties? Explain.
2. a. **Reviewing** How are elements and compounds similar? How do they differ?
   b. **Applying Concepts** Plants make the sugar glucose, which has the formula $C_6H_{12}O_6$. What elements make up this compound?
3. a. **Identifying** How does a heterogeneous mixture differ from a homogeneous mixture?
   b. **Drawing Conclusions** Why is it correct to say that seawater is a mixture?
   c. **Problem Solving** Suppose you stir a little baking soda into water until the water looks clear again. How could you prove to someone that the clear material is a solution, not a compound?

Math Practice

4. **Ratios** Look at the following chemical formulas: H_2O_2 and H_2O. Do these formulas represent the same compound? Explain.

Section 2

Changes in Matter

CALIFORNIA
Standards Focus

S 8.5.b Students know the idea of atoms explains the conservation of matter: In chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same.

- What is a physical change?
- What is a chemical change?

Key Terms

- physical change
- chemical change
- law of conservation of matter

Lab zone Standards Warm-Up

Is a New Substance Formed?

1. Obtain a piece of chalk about the size of a pea. Observe it and record its properties.
2. On a piece of clean paper, crush the piece of chalk with the back of a metal spoon. Describe the changes that occur.
3. Place some of the crushed chalk into the bowl of the spoon. Add about 8 drops of vinegar. Describe what happens.

Think It Over

Drawing Conclusions Chalk is mostly a single substance, calcium carbonate. Do you think a new substance was formed when the chalk was crushed? Do you think a new substance was formed when vinegar was added? Provide evidence for your answers.

You look up from the sand sculpture you and your friends have been working on all afternoon. Storm clouds are gathering, and you know the sand castle may not last long. You pull on a sweatshirt to cover the start of a sunburn and begin to pack up. The gathering of storm clouds, the creation of sand art, and your sunburn are examples of changes in matter. Chemistry is mostly about changes in matter. In this section, you will read about some of those changes.

Sand has been transformed into art. ▶

Physical Change

In what ways can matter change? A **physical change** is any change that alters the form or appearance of matter but does not make any substance in the matter into a different substance. For example, a sand artist may change a formless pile of sand into a work of art. However, the sculpture is still made of sand. **A substance that undergoes a physical change is still the same substance after the change.**

Changes of State As you may know, matter occurs in three familiar states—solid, liquid, and gas. Suppose you leave a small puddle of liquid water on the kitchen counter. When you come back two hours later, the puddle is gone. Has the liquid water disappeared? No, a physical change happened. The liquid water changed into water vapor (a gas) and mixed with the air. A change in state, such as from a solid to a liquid or from a liquid to a gas, is an example of a physical change.

Changes in Shape or Form Is there a physical change when you dissolve a teaspoon of sugar in water? To be sure, you would need to know whether or not the sugar has been changed to a different substance. For example, you know that a sugar solution tastes sweet, just like the undissolved sugar. If you pour the sugar solution into a pan and let the water dry out, the sugar will remain as a crust at the bottom of the pan. The crust may not look exactly like the sugar before you dissolved it, but it's still sugar. So, dissolving is also a physical change. Other examples of physical changes are bending, crushing, breaking, chopping, and anything else that changes only the shape or form of matter. The methods of separating mixtures—filtration and distillation—that you read about in Section 1 also involve physical changes.

Reading Checkpoint **Why is the melting of an ice cube called a physical change?**

FIGURE 11
Change of State
At room temperature, the element iodine is a purple solid that easily becomes a gas.
Classifying *Why is the change in the iodine classified as a physical change?*

Aluminum

Table sugar

FIGURE 12
Change in Form
Crushing aluminum soda cans doesn't change the aluminum into another metal (left). When table sugar dissolves in a glass of water, it is still sugar (right).

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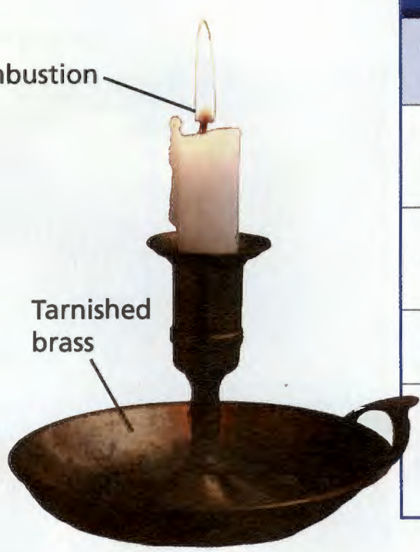
Chemical Change

A second kind of change occurs when a substance is transformed into a different substance. A change in matter that produces one or more new substances is a **chemical change,** or a chemical reaction. In some chemical changes, a single substance simply changes to one or more other substances. For example, when hydrogen peroxide is poured on a cut on your skin, it breaks down into water and oxygen gas.

In other chemical changes, two or more substances combine to form different substances. For example, iron metal combines with oxygen from the air to form the substance iron oxide, which you call rust. **Unlike a physical change, a chemical change produces new substances with properties different from those of the original substances.**

Examples of Chemical Change One familiar chemical change is the burning of natural gas on a gas stove. Natural gas is mostly the compound methane, CH_4. When it burns, methane combines with oxygen in the air and forms new substances. These new substances include carbon dioxide gas, CO_2, and water vapor, H_2O, which mix with air and are carried away. Both of these new substances can be identified by their properties, which are different from those of the methane. The chemical change that occurs when fuels such as natural gas, wood, candle wax, and gasoline burn in air is called combustion. Other processes that result in chemical change include electrolysis, oxidation, and tarnishing. The table in Figure 13 describes each of these kinds of chemical changes.

FIGURE 13
Four examples of chemical change are listed in the table.
Interpreting Photographs *What fuel is undergoing combustion in the photograph?*



Examples of Chemical Change

Chemical Change	Description	Example
Combustion	Rapid combination of a fuel with oxygen; produces heat, light, and new substances	Gas, oil, or coal burning in a furnace
Electrolysis	Use of electricity to break a compound into elements or simpler compounds	Breaking down water into hydrogen and oxygen
Oxidation	Slow combination of a substance with oxygen	Rusting of an iron fence
Tarnishing	Slow combination of a bright metal with sulfur or another substance, producing a dark coating on the metal	Tarnishing of brass

Conservation of Matter A candle may seem to "go away" when it is burned, or water may seem to "disappear" when it changes to a gas. However, scientists long ago proved otherwise. In the 1770s, a French chemist, Antoine Lavoisier, carried out experiments in which he made accurate measurements of mass both before and after a chemical change. His data showed that no mass was lost or gained during the change. The fact that matter is not created or destroyed in any chemical or physical change is called the **law of conservation of matter.** Remember that mass measures the amount of matter. So, this law is sometimes called the law of conservation of mass.

Suppose you could collect all the carbon dioxide and water produced when methane burns, and you measured the mass of all of this matter. You would find that it equaled the mass of the original methane plus the mass of the oxygen that was used in the burning. No mass is lost, because during a chemical change, atoms are not lost or gained, only rearranged. A model for this reaction is shown in Figure 15.

Reading Checkpoint **Why is combustion classified as a chemical change?**

FIGURE 14
Using Methane
Natural gas, or methane, is the fuel used in many kitchen ranges. When it burns, no mass is lost.

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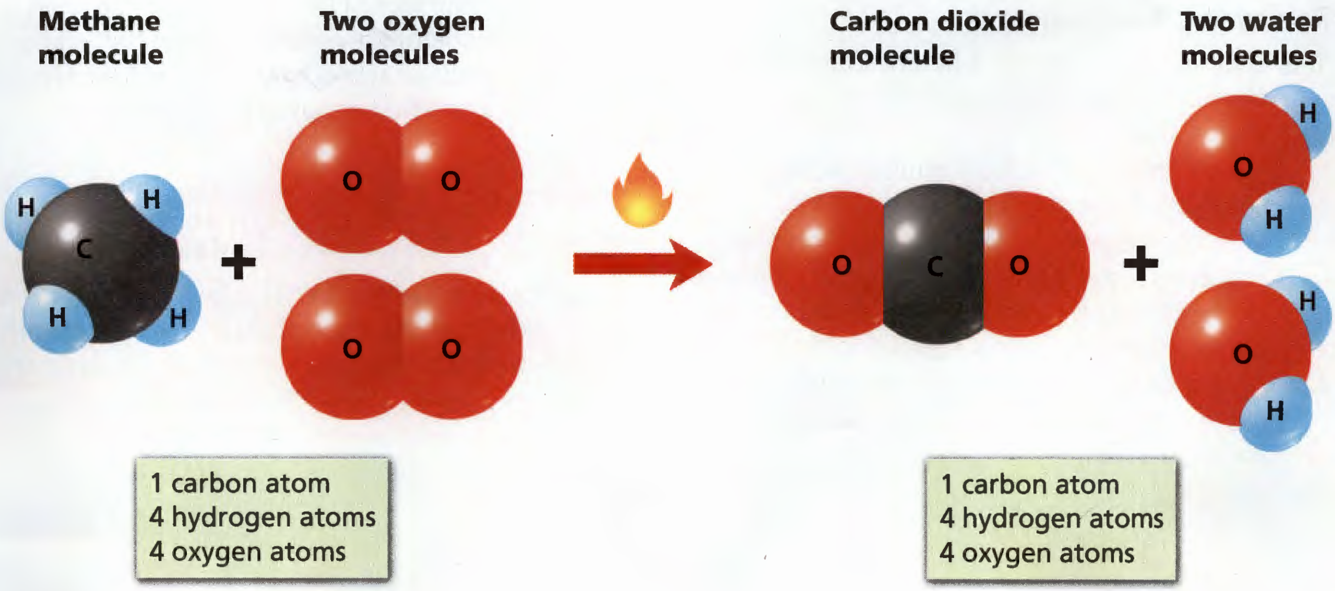
FIGURE 15
Conserving Matter
The idea of atoms explains the law of conservation of matter. For every molecule of methane that burns, two molecules of oxygen are used. The atoms are rearranged in the reaction, but they do not disappear.



Reviewing Math: Algebra and Equations 7.1.5

Math Analyzing Data

Is Matter Conserved?

Propane (C_3H_8) is a fuel that is often used in camping stoves. When propane burns, it reacts with oxygen, producing carbon dioxide gas and water vapor. The data table shows how much carbon dioxide is produced when different amounts of propane burn in oxygen.

1. **Interpreting Data** Based on the data in the table, how do you know that carbon dioxide is not the only substance formed in this chemical change?
2. **Calculating** Copy the data table and add a new column on the right. In the new column, enter how much water vapor is produced for each amount of propane burned.

Propane Combustion

Mass of C_3H_8 Reacted (g)	Mass of O_2 Reacted (g)	Mass of CO_2 Produced (g)
44	160	132
250	909	750
400	1,455	1,200
465	1,691	1,395

3. **Graphing** Use the data in the table to make a graph. Plot the mass of C_3H_8 reacted on the horizontal axis, and the mass of CO_2 produced on the vertical axis.
4. **Reading Graphs** Use the graph to predict how much CO_2 would be produced if 100 grams of propane burned in oxygen.

Section 2 Assessment

S 8.5.b, E-LA: Reading 8.2.4, Writing 8.2.4

Target Reading Skill **Identify Main Ideas** Review the text about Conservation of Matter on page 71. Identify two or three details that support the main idea that matter is conserved.

Reviewing Key Concepts

1. a. **Listing** Identify three different kinds of physical change that could happen to a plastic spoon.
   b. **Explaining** Why is the boiling of water considered a physical change?
   c. **Making Judgments** Which of the following processes is not a physical change: drying wet clothes, cutting snowflakes out of paper, lighting a match from a matchbook?
2. a. **Defining** What evidence would you look for to determine whether a chemical change has occurred?
   b. **Applying Concepts** Why is the electrolysis of water classified as a chemical change but the freezing of water is not?
   c. **Problem Solving** Explain why the mass of a rusted nail would be greater than the mass of the nail before it rusted. Assume that all the rust is still attached to the nail. (*Hint:* The nail rusts when exposed to the air.)

Writing in Science

Persuasive Letter Write a letter to persuade a friend that the formation of a gas does not necessarily mean that a chemical change has occurred.

Section 3

Energy and Matter

CALIFORNIA Standards Focus

S 8.5.c Students know chemical reactions usually liberate heat or absorb heat.

- What are some forms of energy that are related to changes in matter?
- How is chemical energy related to chemical change?

Key Terms

- energy
- temperature
- thermal energy
- endothermic change
- exothermic change
- chemical energy
- electromagnetic energy
- electrical energy
- electrode

Lab zone Standards Warm-Up

Where Was the Energy?

1. Add 20 mL of tap water to an empty soda can. Measure the temperature of the water with a thermometer. (*Hint*: Tilt the can about 45 degrees to cover the bulb of the thermometer with water.)
2. Bend a paper clip into the shape shown in the photograph.
3. Stick a small ball of modeling clay into the center of an aluminum pie pan. Then stick the straight end of the paper clip into the ball.
4. Place one mini marshmallow on the flat surface formed by the top of the paper clip. Light the marshmallow with a match.
5. Use tongs to hold the can about 2 cm over the burning marshmallow until the flame goes out.
6. Measure the water temperature.

Think It Over

Drawing Conclusions How can you account for any change in the water's temperature? What evidence of a chemical change did you observe?

Do you feel as if you are full of energy today? **Energy** is the ability to do work or cause change. Every chemical or physical change in matter includes a change in energy. A change as simple as bending a paper clip requires energy. When ice changes to liquid water, it absorbs energy from the surrounding matter. When candle wax burns, it gives off energy.

Like matter, energy is never created or destroyed in chemical reactions. Energy can only be transformed—that is, changed from one form to another.

◀ **When charcoal burns, it releases energy in the forms of heat and light.**

FIGURE 16
Flow of Thermal Energy
Thermal energy from a hot cup of cocoa can warm cold hands on a chilly day.
Developing Hypotheses
How will the flow of thermal energy affect the cocoa?

Forms of Energy

How do you know when something has energy? You might think that a battery has energy because it keeps a wristwatch working. And you would be right. Maybe you would think that the sun has energy because it gives off light. Again you would be right.

Energy is all around you, and it comes in many forms. **Forms of energy related to changes in matter include thermal energy, chemical energy, electromagnetic energy, and electrical energy.**

Thermal Energy Think of how it feels when you walk inside an air-conditioned building from the outdoors on a hot day. Whew! Did you exclaim about the change in temperature? **Temperature** is a measure of the average energy of random motion of particles of matter. The particles of gas in the warm outside air have greater average energy of motion than the particles of air in the cool building.

Thermal energy is the total energy of all of the particles in an object. Most often, you experience thermal energy when you describe matter—such as the air in a room—as feeling hot or cold. Temperature and thermal energy are not the same thing, but temperature is related to the amount of thermal energy an object has. Thermal energy always flows from warmer matter to cooler matter.

When matter changes, the most common form of energy released or absorbed is thermal energy. For example, ice absorbs thermal energy from its surroundings when it melts. That's why you can pack food and drinks in an ice-filled picnic cooler to keep them cold. The melting of ice is an **endothermic change,** a change in which energy is taken in. Changes in matter can also occur when energy is given off. An **exothermic change** releases energy. Combustion is a chemical change that releases energy in the form of heat and light. You've taken advantage of an exothermic change if you've ever warmed your hands near a wood fire.

FIGURE 17
An Endothermic Change
An iceberg melting in the ocean absorbs thermal energy from the surrounding water.

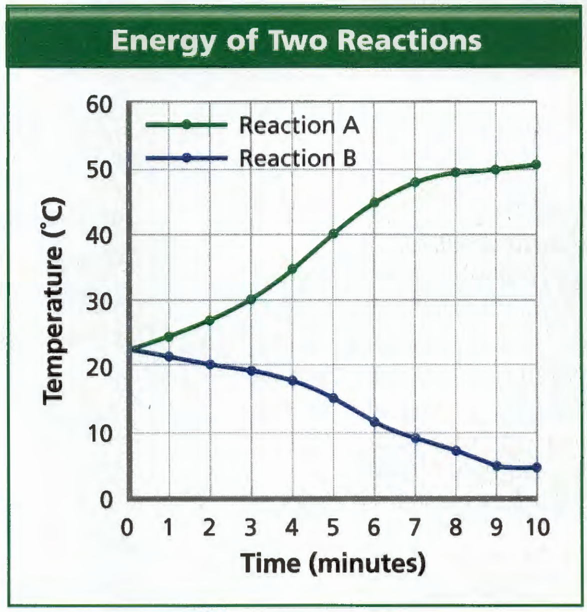
Reviewing Math: Algebra and Functions 7.1.5

Math Analyzing Data

Comparing Energy Changes

A student observes two different chemical reactions, one in beaker A and the other in beaker B. The student measures the temperature of each reaction every minute. The student then plots the time and temperature data and creates the following graph.

1. **Reading Graphs** What do the numbers on the x-axis tell you about the length of the experiment?
2. **Comparing and Contrasting** How did the change in temperature in beaker B differ from that in beaker A?
3. **Interpreting Data** Which reaction is exothermic? Explain your reasoning.
4. **Calculating** Which reaction results in a greater change in temperature over time?



Chemical Energy The energy stored in the chemical bonds between atoms is a form of energy called **chemical energy.** Chemical energy is stored in the foods you eat, in the gasoline used to fuel cars, and even in the cells of your body.

When a chemical change occurs, chemical bonds are broken and new bonds are formed. If the change is exothermic, some of the chemical energy is transformed and released in a variety of other forms. Chemical changes usually involve transformations between chemical energy and thermal energy. For example, when a match burns, some of the chemical energy contained in the compounds of the match is transformed into thermal energy.

Reading Checkpoint **Where is chemical energy stored?**

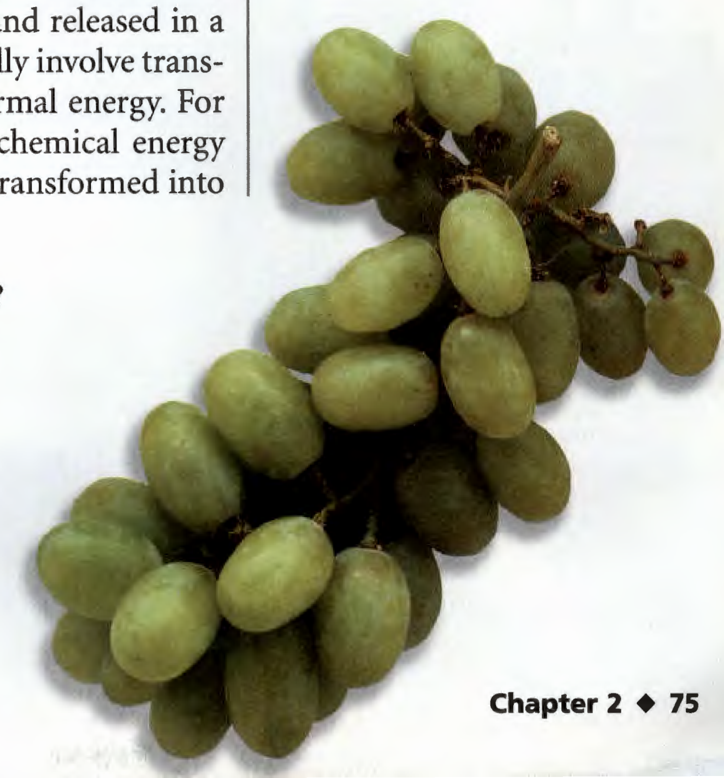


FIGURE 18
Chemical Energy
The particles in these grapes contain chemical energy. Your body can use this energy after you eat them.

Go Online SciLINKS NSTA
For: Links on matter and energy
Visit: www.SciLinks.org
Web Code: scn-1114

Electromagnetic Energy You probably know that energy reaches Earth in the form of sunlight. Energy from the sun can increase the temperature of the surface of a sidewalk or change your skin by burning it. Visible light is one example of **electromagnetic energy** (or electromagnetic radiation), a form of energy that travels through space as waves. Radio waves, infrared "rays" from heat lamps, the waves that heat food in a microwave oven, ultraviolet rays, and X-rays are other types of electromagnetic energy.

Chemical changes can give off electromagnetic energy, such as the light from a wood fire. Also, both chemical and physical changes in matter may be *caused* by electromagnetic energy. For example, a microwave oven can change a frozen block of spaghetti and sauce into a hot meal—a physical change.

Reading Checkpoint **What is electromagnetic energy?**

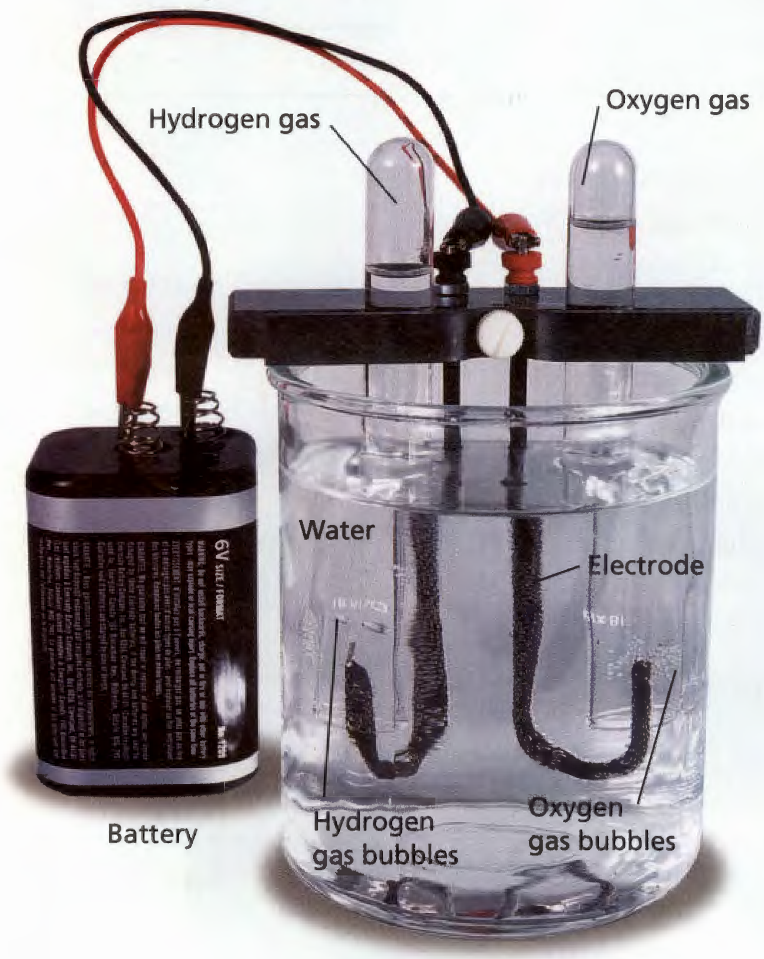


FIGURE 19
Electrolysis of Water
Electrical energy can be used to break down water, H_2O, into its elements. Bubbles of oxygen gas and hydrogen gas form at separate electrodes.
Drawing Conclusions *Why is the volume of hydrogen formed twice that of oxygen?*

Electrical Energy Recall from Section 1 that an atom consists of a positively charged nucleus surrounded by a negatively charged cloud. This "cloud" symbolizes moving, negatively charged particles called electrons. **Electrical energy** is the energy of electrically charged particles moving from one place to another. Electrons move from one atom to another in many chemical changes.

Electrolysis—a chemical change you first read about in Section 2—involves electrical energy. In electrolysis, two metal strips called **electrodes** are placed in a solution, but the electrodes do not touch. Each electrode is attached to a wire. The wires are connected to a source of electrical energy, such as a battery. As electric current flows through the wires, atoms of one kind lose electrons at one electrode in the solution. At the other electrode, atoms of a different kind gain electrons. New substances form at both of the electrodes as a result.

Transforming Energy

The burning of a fuel is a chemical change that transforms chemical energy and releases it as thermal energy and electromagnetic energy. When you push a bike (and yourself) up a hill, chemical energy from foods you ate is transformed into energy of motion. Similarly, other forms of energy can be transformed, or changed, *into* chemical energy. **During a chemical change, chemical energy may be changed to other forms of energy. Other forms of energy may also be changed to chemical energy.**

One of the most important energy transformations on Earth that involves chemical energy is photosynthesis. During photosynthesis, plants transform electromagnetic energy from the sun into chemical energy as they make molecules of sugar. These plants, along with animals and other living things that eat plants, transform this chemical energy once again. It becomes the energy needed to carry out life activities. The carrots you have for dinner may supply the energy you need to go for a walk or read this book.

Reading Checkpoint **What type of energy transformation occurs during photosynthesis?**

FIGURE 20
Photosynthesis
Photosynthesis is a series of chemical changes in which plants convert electromagnetic energy from the sun into chemical energy.

Section 3 Assessment

S 8.5.c, E-LA: Reading 8.1.0, Math: 7AF1.5

Vocabulary Skill **Prefixes** Use what you've learned about the prefixes *endo-* and *exo-* to explain the difference between *endothermic change* and *exothermic change.*

Reviewing Key Concepts

1. a. **Listing** What are four forms of energy related to changes in matter?
   b. **Explaining** What is thermal energy? How can you tell whether one glass of water has more thermal energy than another, identical glass of water?
   c. **Inferring** How might you cause an endothermic chemical change to begin and keep going?
2. a. **Reviewing** What happens to chemical energy during a chemical change?
   b. **Relating Cause and Effect** What are the two main forms of energy given off when paper burns, and where does the energy come from?
   c. **Sequencing** Describe the energy changes that link sunshine to your ability to turn a page in this book.

Lab zone At-Home Activity

Tracking Energy Changes
Volunteer to help cook a meal for your family. As you work, point out energy transformations, especially those that involve chemical energy. Explain to a family member what chemical energy is and what other forms of energy it can be changed into. Talk about energy sources for cooking and other tools and appliances used to prepare food. Try to identify foods that change chemically when they are cooked.

Lab zone **Skills Lab**

Isolating Copper by Electrolysis

S 8.3.b, 8.9.a

Problem

How can electrical energy be used to isolate copper metal?

Skills Focus

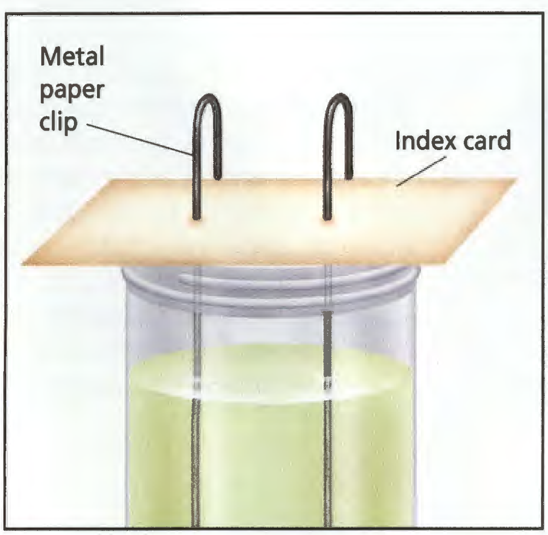
making models, inferring, observing, interpreting data

Materials

- glass jar, about 250 mL
- two metal paper clips
- 6-volt battery
- index card
- wires with alligator clips or a battery holder with wires
- copper chloride solution (0.6 *M*), 100 mL

Procedure

1. Unbend a paper clip and make a hook shape as shown in the diagram. Push the long end through an index card until the hook just touches the card.



2. Repeat Step 1 with another paper clip so that the paper clips are about 3 cm apart. The paper clips serve as your electrodes.
3. Pour enough copper chloride ($CuCl_2$) solution into a jar to cover at least half the length of the paper clips when the index card is set on top of the jar. **CAUTION:** *Copper chloride solution can be irritating to the skin and eyes. Do not touch it with your hands or get it into your mouth. The solution can stain skin and clothes.*
4. Place the index card on top of the jar. If the straightened ends of the paper clips are not at least half covered by the copper chloride solution, add more solution.
5. Attach a wire to one pole of a battery. Attach a second wire to the other pole. Attach each of the other ends of the wires to a separate paper clip, as shown in the diagram. Do not allow the paper clips to touch one another.
6. Predict what you think will happen if you allow the setup to run for 2 to 3 minutes. (*Hint:* What elements are present in the copper chloride solution?)
7. Let the setup run for 2 to 3 minutes or until you see a deposit forming on one of the electrodes. Also look for bubbles.
8. Disconnect the wires from both the battery and the paper clips. Bring your face close to the jar and gently wave your hand toward your nose. Note any odor.

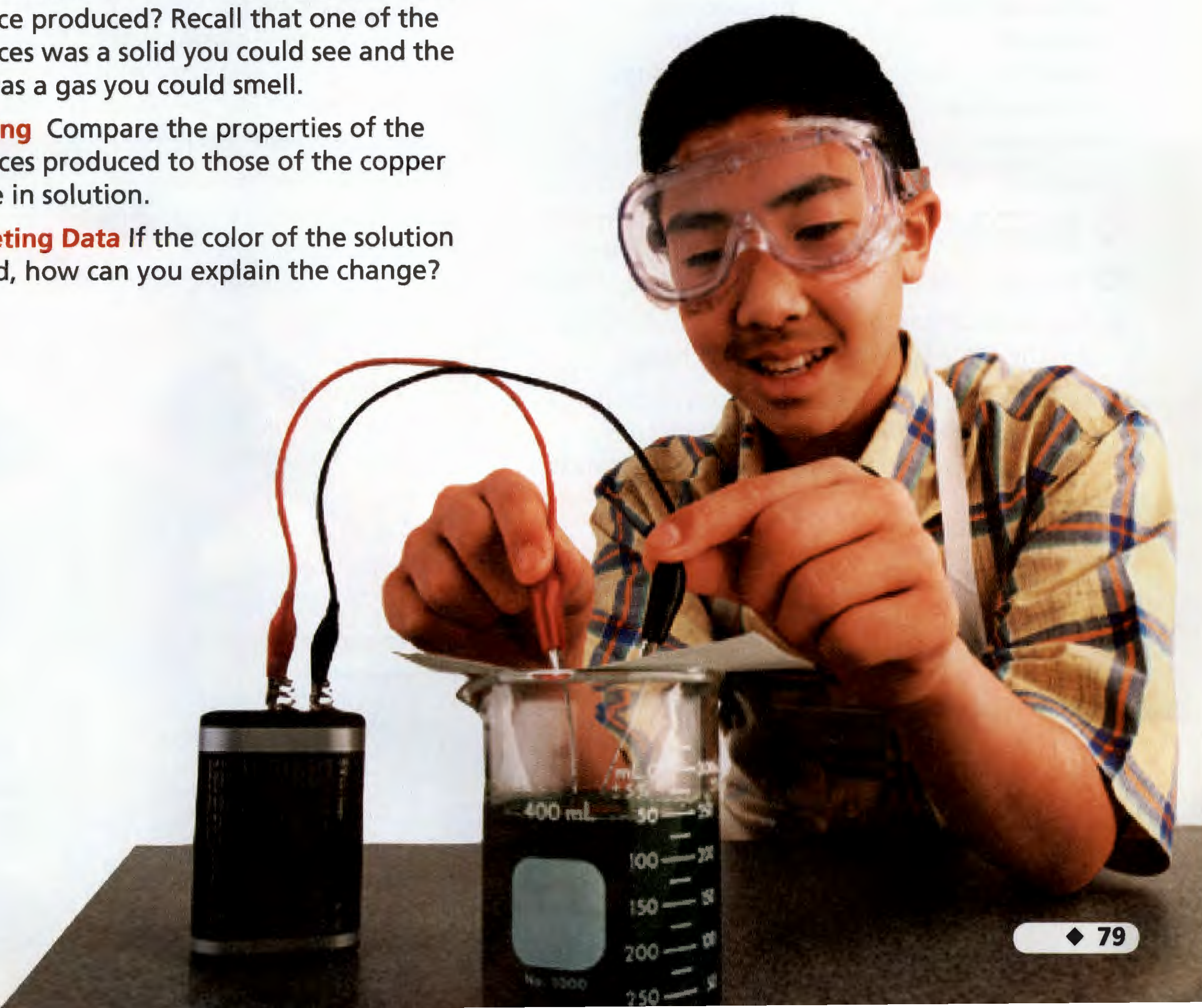
9. Note whether the color of the solution has changed since you began the procedure.
10. Note the color of the ends of the electrodes.
11. Discard the solution as directed by your teacher, and wash your hands.

Analyze and Conclude

1. **Making Models** Make a labeled diagram of your laboratory setup. Indicate which electrode is connected to the positive (+) side of the battery and which is connected to the negative (–) side.
2. **Inferring** Based on your observations, what substances do you think were produced at the electrodes? On which electrode was each substance produced? Recall that one of the substances was a solid you could see and the other was a gas you could smell.
3. **Observing** Compare the properties of the substances produced to those of the copper chloride in solution.
4. **Interpreting Data** If the color of the solution changed, how can you explain the change?
5. **Inferring** Based on your observations, does electrolysis produce a chemical change? Explain your reasoning.
6. **Communicating** Write a paragraph describing what you think happened to the copper chloride solution as the electric current flowed through it.

Design an Experiment

What do you think would happen if you switched the connections to the battery without disturbing the rest of the equipment? Design an experiment to answer this question. *Obtain your teacher's permission before carrying out your investigation.*



Chapter 2 Study Guide

The BIG Idea Chemistry is the study of the properties of matter and how matter changes.

1 Describing Matter

Key Concepts S 8.3.b

- Every form of matter has two kinds of properties—physical properties and chemical properties.
- Elements are the simplest substances.
- When elements are chemically combined, they form compounds having properties that are different from those of the uncombined elements.
- Each substance in a mixture keeps its individual properties. Also, the parts of a mixture are not combined in a set ratio.

Key Terms

matter
substance
physical property
chemical property
element
atom
chemical bond
molecule
compound
chemical formula
mixture
heterogeneous mixture
homogeneous mixture
solution

2 Changes in Matter

Key Concepts S 8.5.b

- A substance that undergoes a physical change is still the same substance after the change.
- Unlike a physical change, a chemical change produces new substances with properties different from those of the original substances.

Key Terms

physical change
chemical change
law of conservation of matter

3 Energy and Matter

Key Concepts S 8.5.c

- Forms of energy related to changes in matter include chemical, electromagnetic, electrical, and thermal energy.
- During a chemical change, chemical energy may be changed to other forms of energy. Other forms of energy may also be changed to chemical energy.

Key Terms

energy
temperature
thermal energy
endothermic change
exothermic change
chemical energy
electromagnetic energy
electrical energy
electrode

Review and Assessment

Go Online PHSchool.com
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Visit: PHSchool.com
Web Code: cxa-1020

Target Reading Skill

Identify Main Idea Review Section 3 on Energy and Matter. Then, complete the graphic organizer to the right.

Main Idea

Energy comes in many forms

Detail	Detail	Detail

Reviewing Key Terms

Choose the letter of the best answer.

1. The ability to dissolve in water and to conduct electricity are examples of
   a. physical properties.
   b. chemical changes.
   c. chemical properties.
   d. chemical bonding.
2. Water is an example of
   a. an element.
   b. a homogeneous mixture.
   c. a compound.
   d. a heterogeneous mixture.
3. When matter changes, the most common form of energy released or absorbed is
   a. electrical energy.
   b. thermal energy.
   c. chemical energy.
   d. electromagnetic energy.
4. New substances are always formed when matter undergoes a
   a. change in shape.
   b. physical change.
   c. change in temperature.
   d. chemical change.
5. Chemical energy is the energy
   a. of temperature.
   b. stored in the bonds between atoms.
   c. of moving, electrically charged particles.
   d. that travels through space as waves.

Complete the following sentences so that your answers clearly explain the key terms.

6. The pencil you write with is an example of **matter**, which is defined as anything that ________ .
7. Different substances can be classified by their **chemical properties**, or properties that ________ .
8. All matter is made up of slightly more than 100 different **elements**, which are pure substances that ________ .
9. Chemist Antoine Lavoisier's experiments demonstrated the **law of conservation of matter**, which states that ________ .
10. The melting of ice is an example of an **endothermic change**, or a change in which ________ .

Writing in Science

How-to Paragraph Suppose you are preparing for a long journey on the ocean or in space. Write a journal entry that describes your plan for having fresh, drinkable water throughout your entire trip.

Video Assessment
Discovery Channel School
Introduction to Matter

Review and Assessment

Checking Concepts

11. What are three ways that compounds and mixtures differ?

12. How does a physical change differ from a chemical change?

13. How are changes in matter related to changes in energy?

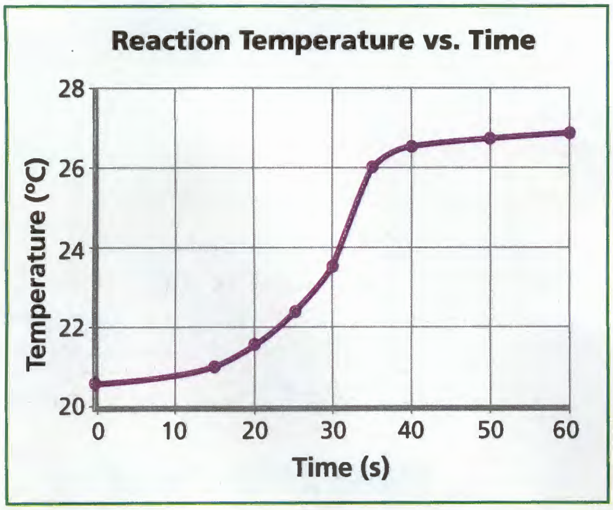
14. How do you know that the burning of candle wax is an exothermic change?

Thinking Critically

15. **Classifying** Which of the following is a solution: pure water, fruit punch, cereal and milk in a bowl? Explain how you know.

16. **Problem Solving** Suppose you dissolve some table salt in a glass of water. How could you prove to someone that the dissolving was a physical change, not a chemical change?

17. **Interpreting Graphs** A student has two liquids at the same temperature. The liquids react with one another when mixed. The graph below shows the change in temperature after the two liquids are mixed. Did the reaction absorb or release thermal energy? Explain your answer.



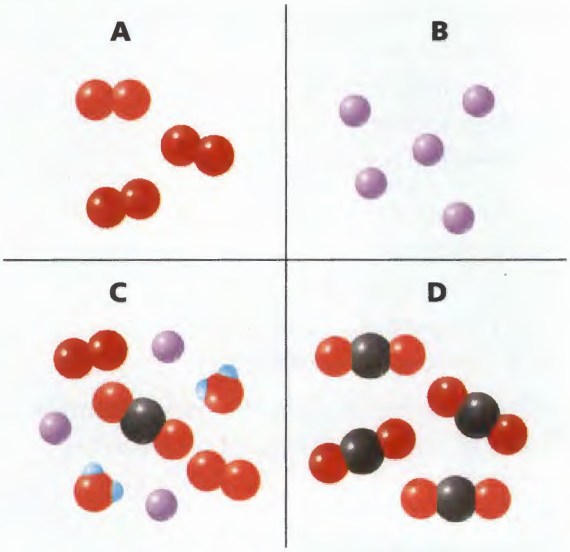
Math Practice

18. **Ratios** The elements phosphorus and oxygen form a compound with the formula P_2O_5. What is the ratio of phosphorus atoms to oxygen atoms in the compound?

Applying Skills

Use the information and the diagrams below to answer Questions 19–22.

Each diagram below represents a different kind of matter. Each ball represents an atom. Balls of the same color represent the same kind of atom.



19. **Interpreting Diagrams** Which diagrams represent a single element? Explain.

20. **Classifying** Which diagrams represent pure substances? Explain.

21. **Interpreting Data** How do the molecules in diagram A differ from those in diagram D?

22. **Interpreting Diagrams** Which diagram represents a mixture? Explain.

Lab zone Standards Investigation

Performance Assessment Compare the changes you recorded in your log with those of your classmates. Defend your opinions as to whether or not your observations describe physical or chemical changes.

Choose the letter of the best answer.

1. What is the best title for the chart below?
A Chemical Properties of Some Compounds
B Physical Properties of Some Elements
C The Periodic Table of the Elements
D Gases Found in Air **S 8.3.b**

?	
Helium	Colorless; less dense than air
Iron	Attracted to a magnet; melting point of 1,535°C
Oxygen	Odorless; gas at room temperature

A scientist did an experiment, described by the words and symbols below. Use the information to answer Questions 2 to 4.

hydrogen + oxygen → water + energy

2. The scientist found that 2 grams of hydrogen reacted completely with 16 grams of oxygen. What was the total mass of water produced?
A 8 grams
B 14 grams
C 18 grams
D 32 grams
S 8.5.b

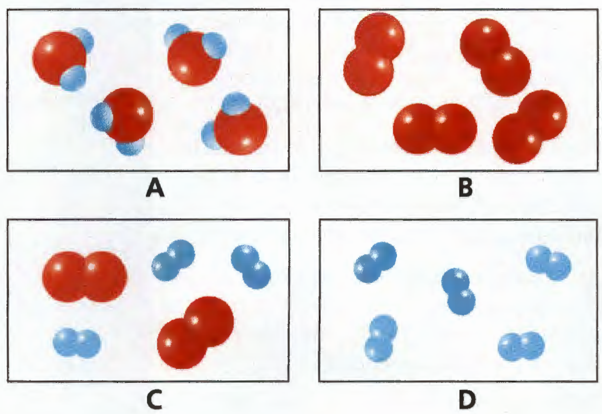
3. The properties of the water produced by the reaction are
A different from the properties of both hydrogen and oxygen.
B the same as the properties of both hydrogen and oxygen.
C the same as the properties of hydrogen, but different from the properties of oxygen.
D the same as the properties of oxygen, but different from the properties of hydrogen.
S 8.3.b

4. Which pair of terms best describes the type of change that occurred in the reaction?
A chemical and exothermic
B chemical and endothermic
C physical and exothermic
D physical and endothermic **S 8.5.c**

5. The fact that matter is neither created nor destroyed in any chemical or physical change is called the
A law of exothermic change.
B law of endothermic change.
C law of thermal change.
D law of conservation of matter. **S 8.5.b**

6. How would you classify the burning of natural gas?
A exothermic chemical change
B endothermic chemical change
C exothermic physical change
D endothermic physical change **S 8.5.c**

7. Which diagram best represents a mixture of two kinds of gas molecules?
S 8.3.b



Apply the BIG Idea

8. Water is a compound with the chemical formula H_2O. Compare a physical change involving water with a chemical change involving water. How do the changes differ?
S 8.3.b