Chapter

2

Introduction to Matter

The BIG Idea

Properties of Matter

What is chemistry?

Chapter Preview

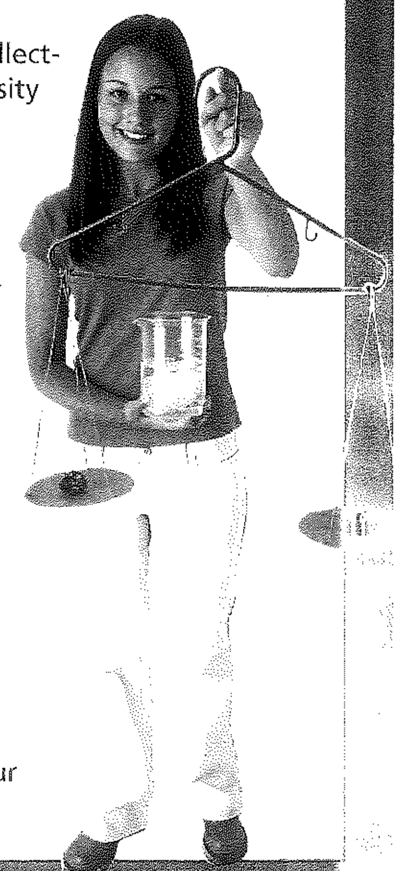
1. **Describing Matter**
   Discover What Is a Mixture?
   Skills Activity Interpreting Data
   Math Skills Ratios
2. **Measuring Matter**
   Discover Which Has More Mass?
   Skills Lab Making Sense of Density
3. **Changes in Matter**
   Discover Is a New Substance Formed?
   Skills Activity Inferring
   Active Art Conserving Matter
   Analyzing Data Comparing Energy Changes
   Science and Society Transporting Hazardous Chemicals
4. **Energy and Matter**
   Discover Where Was the Energy?
   Try This Dropping the Ball
   At-Home Activity Tracking Energy Changes
   Skills Lab Isolating Copper by Electrolysis

This "junk sculpture" of a dog was made from recycled materials. ▶

Lab zone™ Chapter Project

Design and Build a Density-Calculating System

How do you find the density of something if you don't have a balance to measure its mass? Suppose you can't use a graduated cylinder to measure the volume of such items as honey or table sugar. Can you build your own balance and devise a way to find the volume of items that are not easily measured with a ruler?



Your Goal To design and build a device for collecting data that can be used to calculate the density of powdered solids and liquids

To complete the project, you must

- build a device to measure accurately the masses of powdered solids and liquids
- develop a method to measure volume without using standard laboratory equipment
- obtain data you can use to calculate the density of items
- follow the safety guidelines in Appendix A

Plan It! Preview the chapter to find out how mass, volume, and density are related. Research how balances are constructed and how they work. Build a balance out of the materials supplied by your teacher. Then devise a container with a known volume that you can use to find the volumes of your test materials. When your teacher approves your plan, test your system. Redesign and retest your system to improve its accuracy and reliability.

Section 1

Describing Matter

Reading Preview

Key Concepts

- What kinds of properties are used to describe matter?
- What are elements, and how do they relate to compounds?
- What are the properties of a mixture?

Key Terms

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

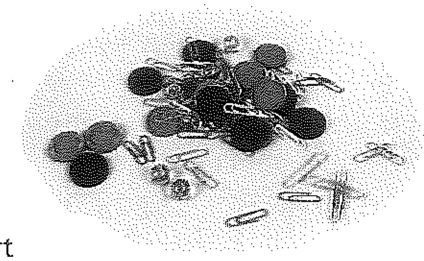
Target Reading Skill

Building Vocabulary

A definition states the meaning of a word or phrase by telling its most important feature or function. After you read the section, use what you have learned to write a definition of each Key Term in your own words.

Lab zone Discover Activity

What Is a Mixture?



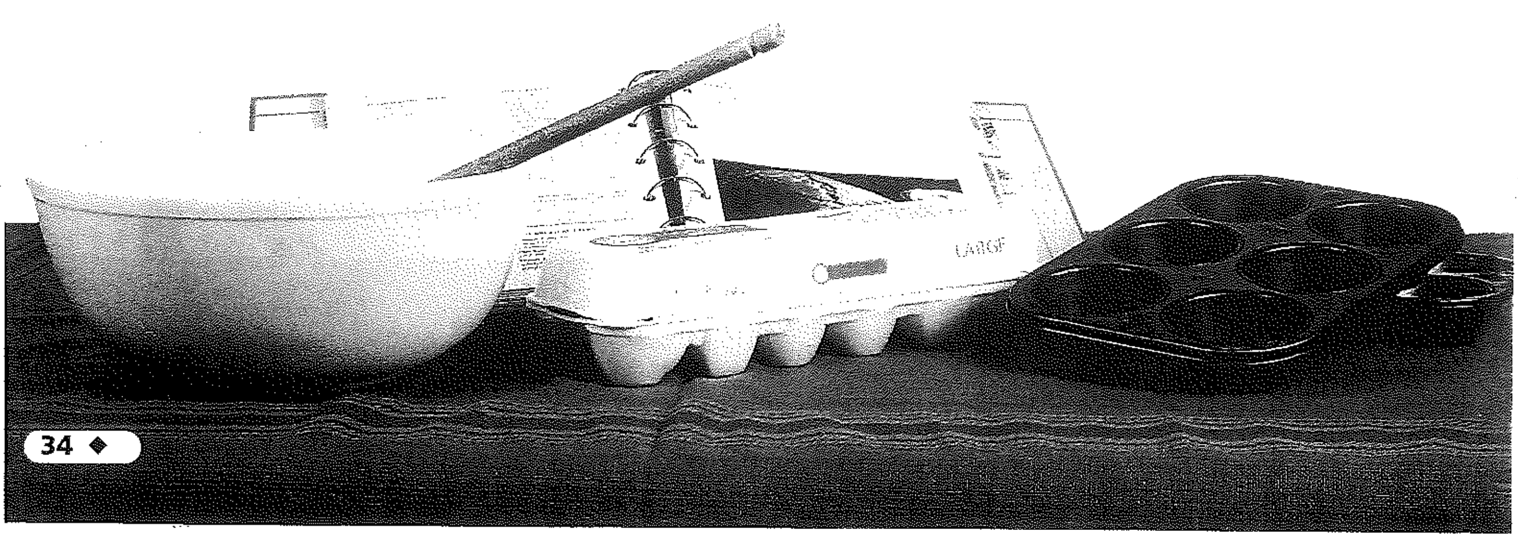
1. Your teacher will give you a handful of objects, such as checkers, marbles, and paper clips of different sizes and colors.
2. Examine the objects. Then sort them into at least three groups. Each item should be grouped with similar items.
3. Describe the differences between the unsorted handful and the sorted groups of objects. Then make a list of the characteristics of each sorted group.

Think It Over

Forming Operational Definitions The unsorted handful of objects represents a mixture. Your sorted groups represent substances. Using your observations, infer what the terms *mixture* and *substance* mean.

You have probably heard the word *matter* many times. Think about how often you hear the phrases "As a matter of fact, ..." or "Hey, what's the matter?" In science, this word has a specific 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.



Properties of Matter

Even though air and plastic are both matter, no one has to tell you they are different materials. Matter can have many different properties, or characteristics. Materials can be hard or soft, rough or smooth, hot or cold, liquid, solid, or gas. Some materials catch fire easily, but others do not burn. **Chemistry** is the study of the properties of matter and how matter changes.

The properties and changes of any type of matter depend on its makeup. Some types of matter are substances and some are not. In chemistry, a **substance** is a single kind of matter that is pure, meaning it always has a specific makeup—or composition—and a specific set of properties. For example, table salt has the same composition and properties no matter where it comes from—seawater or a salt mine. On the other hand, think about the batter for blueberry muffins. It contains flour, butter, sugar, salt, blueberries, and other ingredients shown in Figure 1. While some of the ingredients, such as sugar and salt, are pure substances, the muffin batter is not. It consists of several ingredients that can vary with the recipe.

Every form of matter has two kinds of properties—physical properties and chemical properties. A physical property of oxygen is that it is a gas at room temperature. A chemical property of oxygen is that it reacts with iron to form rust. You'll read more about physical and chemical properties in the next two pages.

FIGURE 1
Substances or Not?
Making muffin batter involves mixing together different kinds of matter. The batter itself is not a pure substance. Classifying *Why are salt, sugar, and baking soda pure substances?*

Pure Substances
Table salt, table sugar, and baking soda are pure substances.

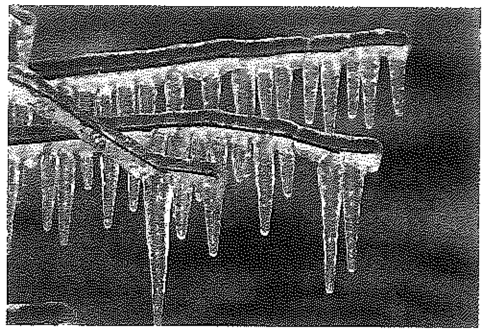
Not Substances
Flour, baking powder, milk, eggs, and fruit are not pure substances.

FIGURE 2

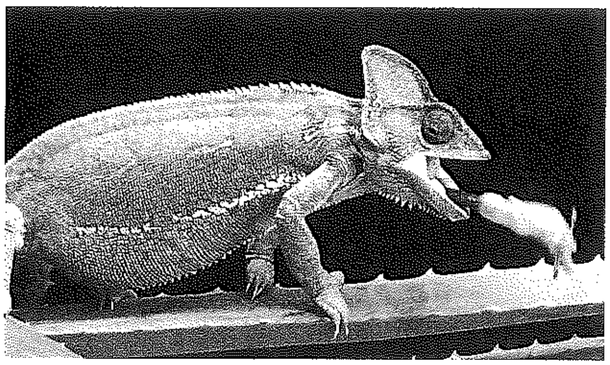
Physical Properties

The physical properties of matter help you identify and classify matter in its different forms.

Applying Concepts *Why is melting point a physical property?*



▲ **Physical State**
Above 0°C, these icicles of solid water will change to liquid.



◄ **Texture and Color**
Bumpy texture and bright colors are physical properties of this hungry chameleon.

▲ **Flexibility**
Metal becomes a 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

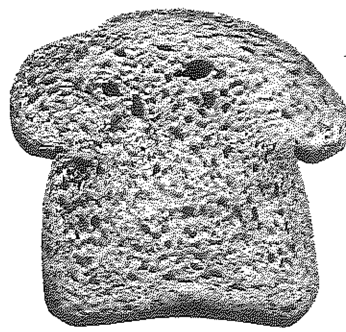
Physical Properties of Matter A **physical property** is a characteristic of a pure substance that can be observed without changing it into another substance. For example, a physical property of water is that it freezes at a temperature of 0°C. When liquid water freezes, it changes to solid ice, but it is still water. 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.

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.

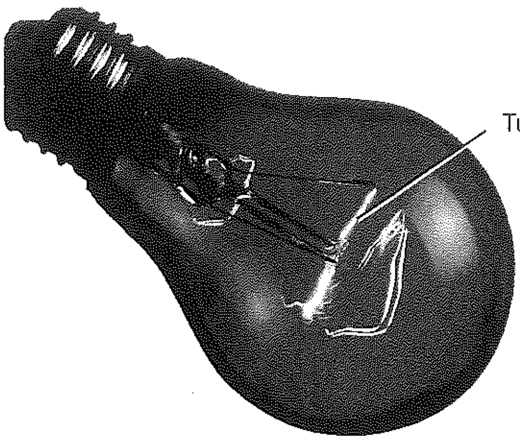
Ability to React
Iron can form rust, turning a once shiny car into a crumbling relic.

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 must you do in order to observe a chemical property of a substance?**

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, and H for hydrogen.

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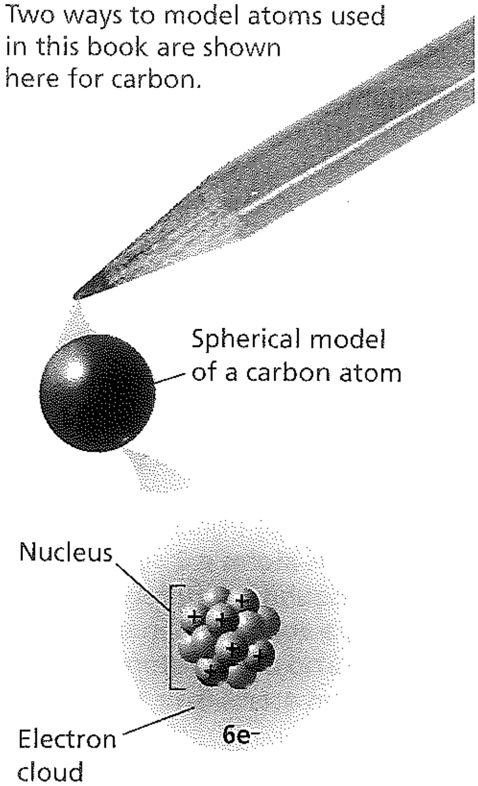
Particles of Elements—Atoms What is the smallest possible piece of matter? Suppose you could keep tearing a piece of aluminum foil in half over and over again. Would you reach a point where you have the smallest possible piece of aluminum? The answer is yes. Since the early 1800s, scientists have known 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.

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.

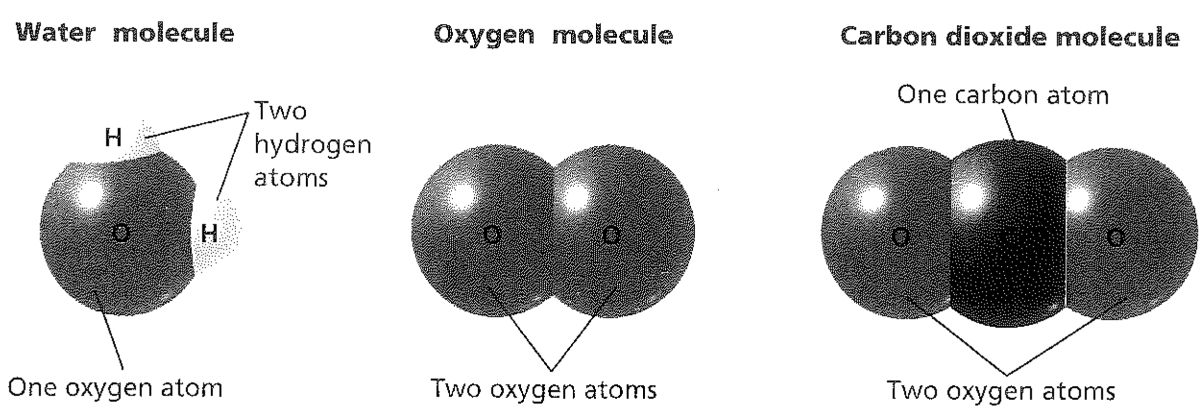
Reading Checkpoint What is a molecule?

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.



A cloud model of an atom shows the electron cloud and the particles in the nucleus.

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?**

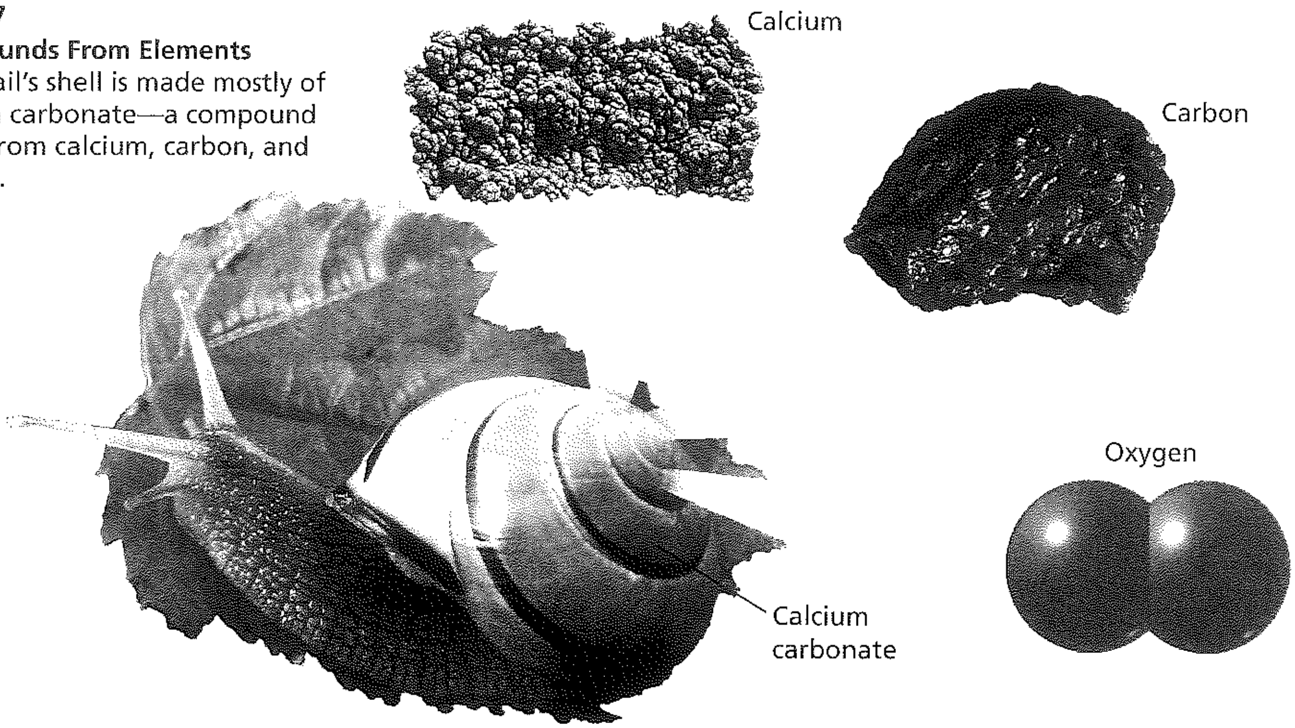


FIGURE 7
Compounds From Elements
This snail's shell is made mostly of calcium carbonate—a compound made from calcium, carbon, and oxygen.

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.

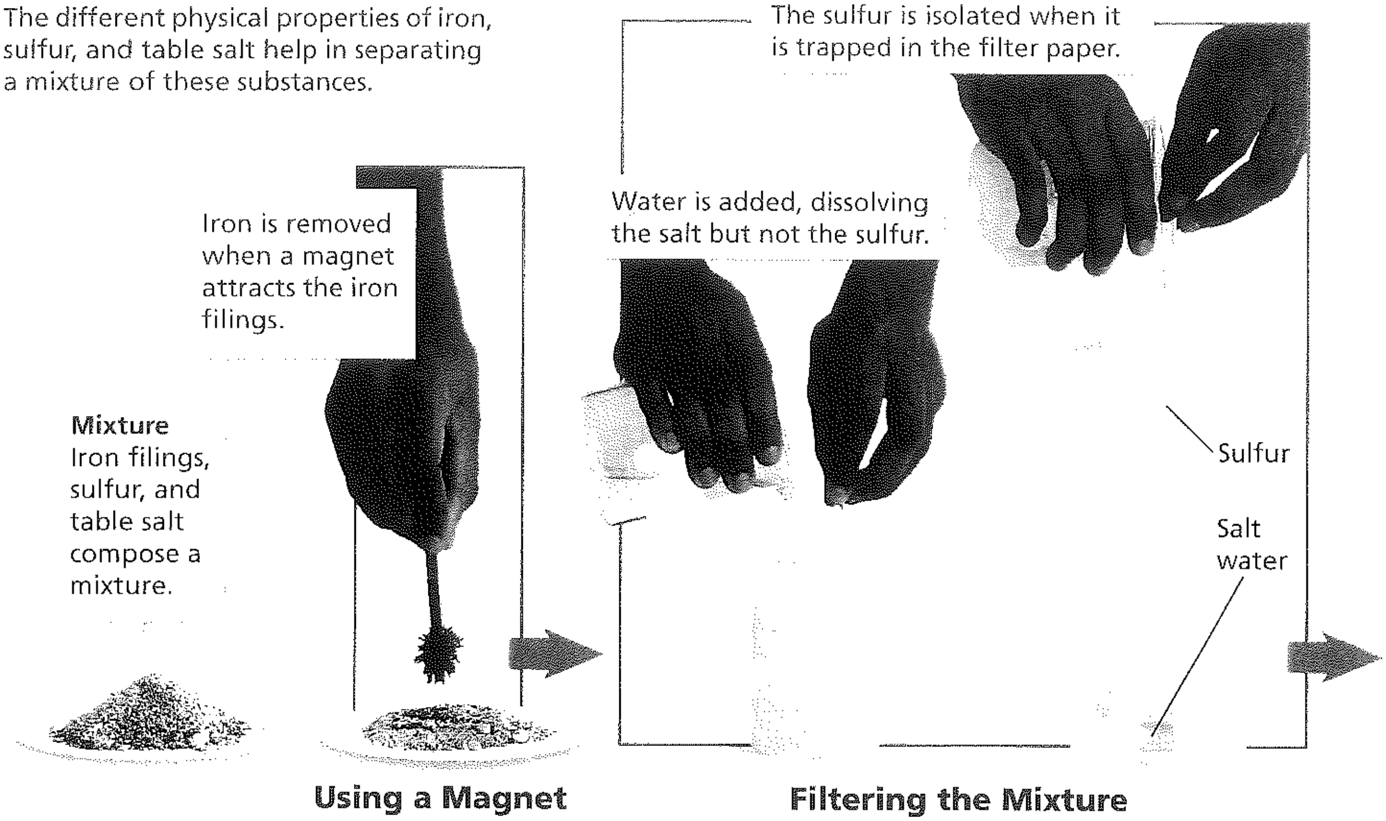
Homogeneous Mixtures The substances in a **homogeneous mixture** (hoh moh JEE nee us), are so evenly mixed that you can't see the different parts. Suppose you stir a teaspoon of sugar into a glass of water. After stirring for a little while, the sugar dissolves, and you can no longer see crystals of 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

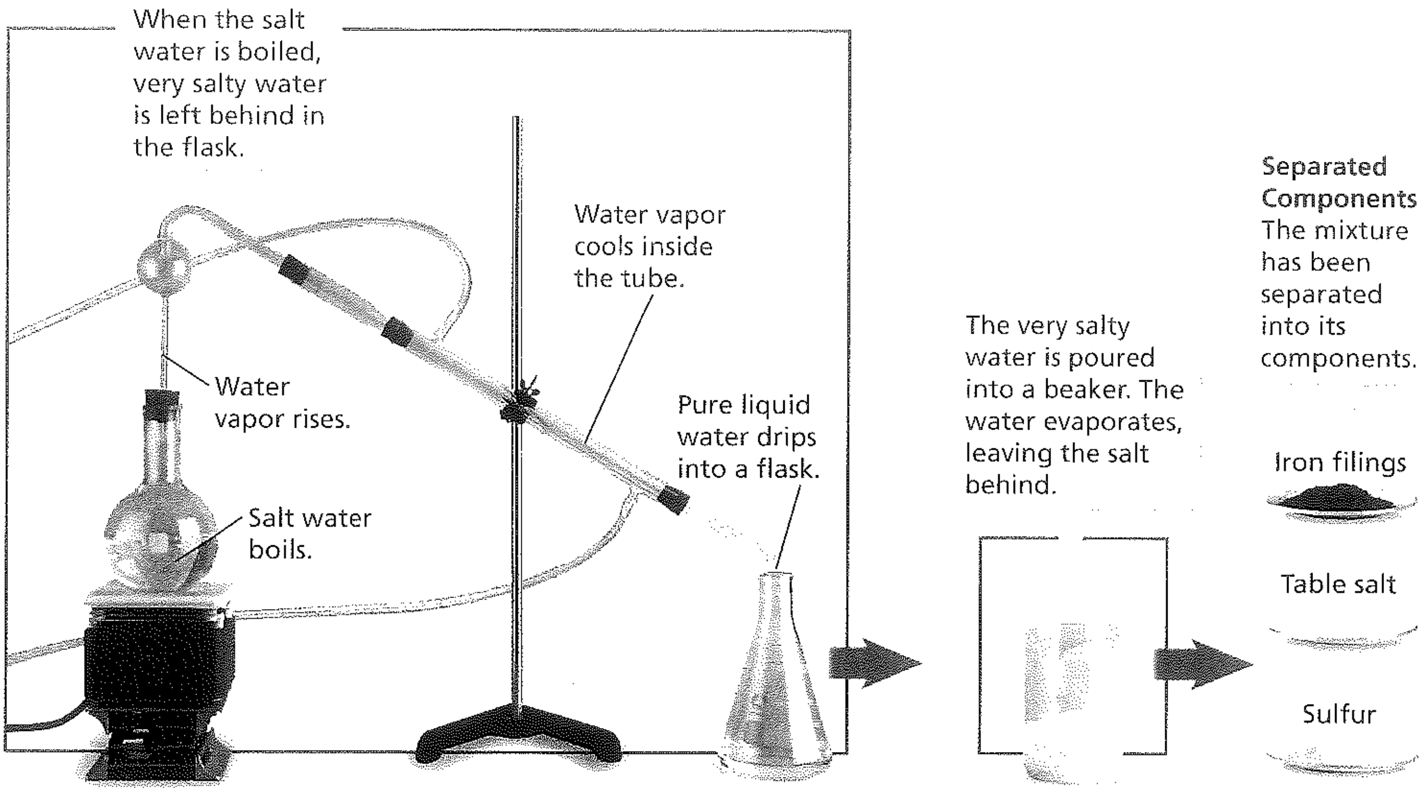
The different physical properties of iron, sulfur, and table salt help in separating a mixture of these substances.



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

Target Reading Skill **Building Vocabulary** Use your definitions to help answer the questions.

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 a sugar compound with 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

Measuring Matter

Reading Preview

Key Concepts

- What is the difference between weight and mass?
- What units are used to express the amount of space occupied by matter?
- How is the density of a material determined?

Key Terms

- weight • mass
- International System of Units
- volume • density

Target Reading Skill

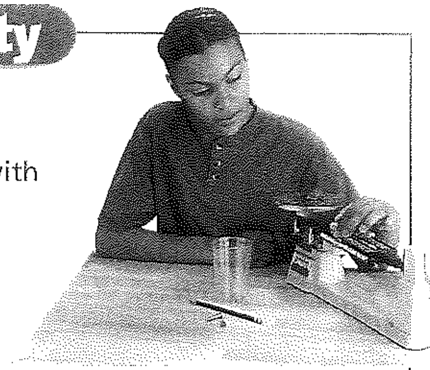
Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Weight and Mass

Question	Answer
How are weight and mass different?	Weight is a measure of . . .

Lab zone Discover Activity

Which Has More Mass?



1. Your teacher will provide you with some small objects. Look at the objects, but do not touch them.
2. Predict which object is lightest, which is second lightest, and so on. Record your predictions.
3. Use a triple-beam balance to find the mass of each object.
4. Based on the masses, list the objects from lightest to heaviest.

Think It Over

Drawing Conclusions How did your predictions compare with your results? Are bigger objects always heavier than smaller objects? Why or why not?

Here's a riddle for you: Which weighs more, a pound of feathers or a pound of sand? If you answered "a pound of sand," think again. Both weigh exactly the same—one pound.

There are all sorts of ways to measure matter, and you use these measurements every day. Scientists rely on measurements as well. In fact, scientists work hard to make sure their measurements are as accurate as possible.

Weight and Mass

Suppose you want to measure your weight. To find the weight, you step on a scale like the one shown in Figure 11. Your body weight presses down on the springs inside the scale. The more you weigh, the more the springs compress, causing the pointer on the scale to turn farther, giving a higher reading. However, your scale would not indicate the same weight if you took it to the moon and stepped on it. You weigh less on the moon, so the springs of the scale would not be compressed as much by your weight.

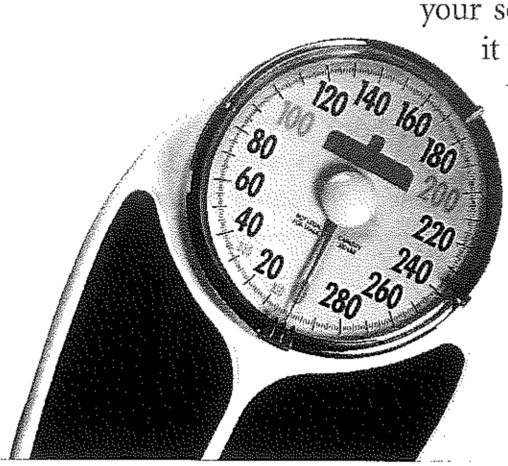


FIGURE 11
Measuring Weight
If you stood on this scale on the moon, it would show that your weight there is less than on Earth.

Weight Your **weight** is a measure of the force of gravity on you. On Earth, all objects are attracted toward the center of the planet by the force of Earth's gravity. On another planet, the force of gravity on you may be more or less than it is on Earth. On the moon, you would weigh only about one-sixth of your weight on Earth.

Mass Why do you weigh less on the moon than on Earth? The force of gravity depends partly on the mass of an object. The **mass** of an object is the measurement of the amount of matter in the object. If you travel to the moon, the amount of matter in your body—your mass—does not change. But, the mass of the moon is much less than the mass of Earth, so the moon exerts much less gravitational force on you. **Unlike weight, mass does not change with location, even when the force of gravity on an object changes.** For this reason scientists prefer to measure matter by its mass rather than its weight. The mass of an object is a physical property.

Units of Mass To measure the properties of matter, scientists use a system called the **International System of Units.** This system is abbreviated "SI" after its French name, *Système International.* The SI unit of mass is the kilogram (kg). If you weigh 90 pounds on Earth, your mass is about 40 kilograms. Although you will see kilograms used in this textbook, usually you will see a smaller unit—the gram (g). There are exactly 1,000 grams in a kilogram. A nickel has a mass of 5 grams, and a baseball has a mass of about 150 grams.

Reading Checkpoint **What is the SI unit of mass?**

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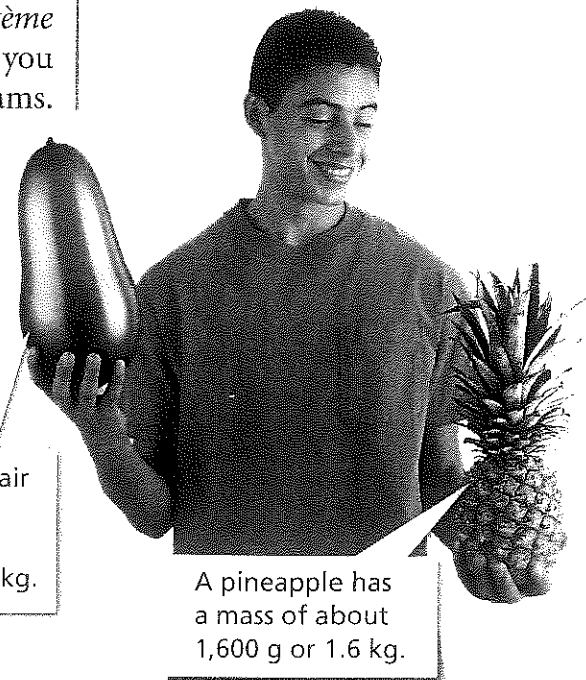
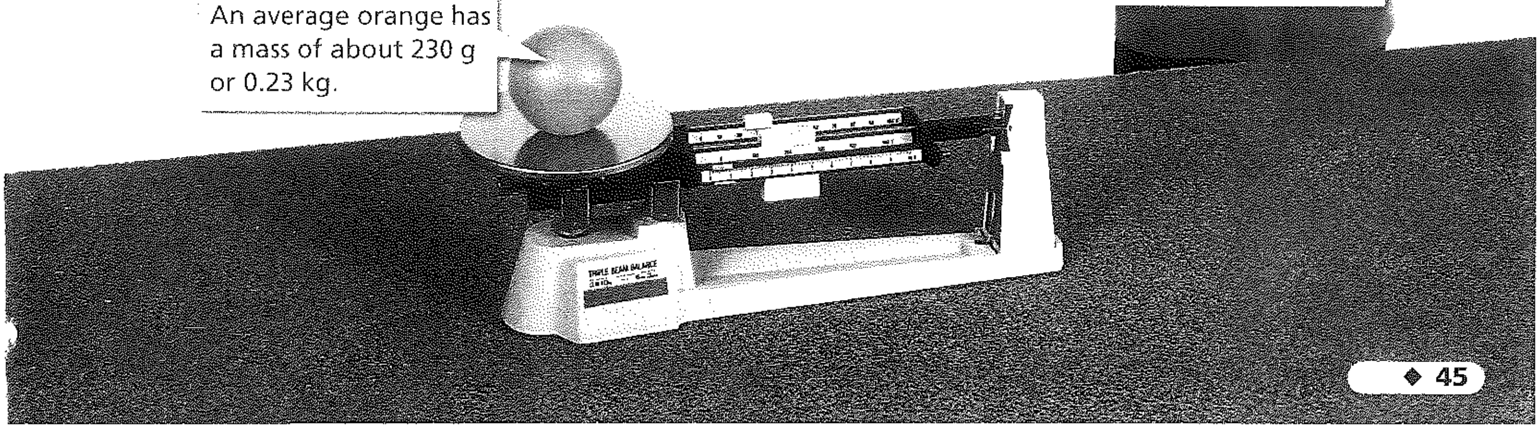
Equating Units of Mass

1 kg = 1,000 g
1 g = 0.001 kg

FIGURE 12
Measuring Mass
A triple-beam balance measures mass in grams. Calculating *How do you convert a mass in grams to the equivalent mass in kilograms? (Hint:* Look at the table.*)*

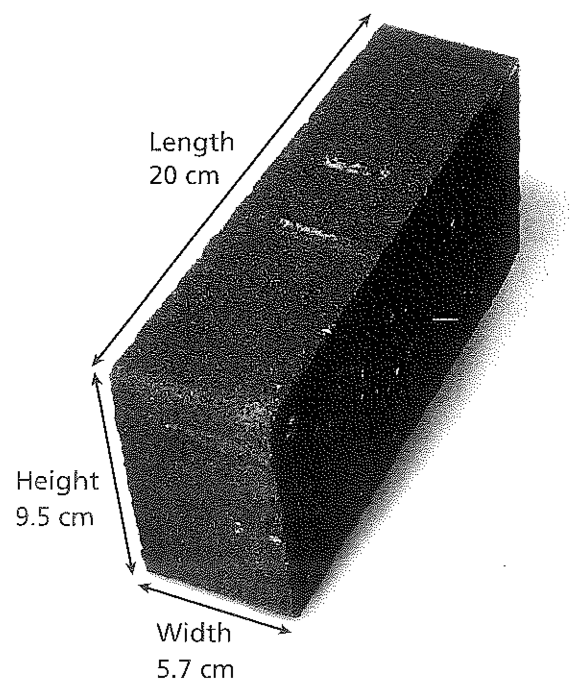




Equating Units of Volume

1 L = 1,000 mL
1 mL = 0.001 L
1 mL = 1 cm^3

FIGURE 13
Finding Volume
The volume of a regular solid can be found by measuring its dimensions and multiplying the values.
Interpreting Tables *What volume of water in milliliters would this brick displace if submerged?*



Volume = 20 cm x 9.5 cm x 5.7 cm
= 1,083 cm^3

Volume

You learned in Section 1 that all matter has mass and takes up space. The amount of space that matter occupies is called its **volume.** It's easy to see that solids and liquids take up space. Gases have volume, too. Watch a balloon as you blow into it. You're actually increasing the volume of gas in the balloon with your breath.

Units of Volume **Common units of volume include the liter (L), milliliter (mL), and cubic centimeter (cm^3).** Some plastic soda bottles hold 1 liter of liquid. Volumes smaller than a liter are usually given in milliliters. A milliliter is one one-thousandth of a liter and is exactly the same volume as 1 cubic centimeter. A teaspoonful of water has a volume of about 5 milliliters, and an ordinary can of soda contains 355 milliliters of liquid. In the laboratory, volumes of liquid are usually measured with a graduated cylinder.

Calculating Volume The volumes of solid objects are usually expressed in cubic centimeters. Suppose you want to know the volume of a rectangular object, such as the brick shown in Figure 13. First, you measure the brick's length, width, and height (or thickness). Then, you multiply these values.

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Height}$$

Measurements always have units. So, when you multiply the three measurements, you must multiply the units as well as the numbers.

$$\text{Units} = \text{cm} \times \text{cm} \times \text{cm} = \text{cm}^3$$

How can you measure the volume of an irregular object, such as a piece of fruit or a rock? One way is to submerge the object in water in a graduated cylinder. The water level will rise by an amount that is equal to the volume of the object in milliliters.

Reading Checkpoint **How are milliliters related to cubic centimeters?**

Density

Samples of two different materials may have the same volume, but they don't necessarily have the same mass. Remember the riddle about the sand and the feathers? A kilogram of sand takes up much less space than a kilogram of feathers. The volumes differ because sand and feathers have different densities—an important property of matter. **Density** relates the mass of a material in a given volume. Often, density is expressed as the number of grams in one cubic centimeter. For example, the density of water at room temperature is stated as "one gram per cubic centimeter (1 g/cm^3)." This value means that every gram of water has a volume of 1 cm^3. Notice that the word *per* is replaced by the fraction bar in the units of density. **The bar tells you that you can determine the density of a sample of matter by dividing its mass by its volume.**

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Math Sample Problem

Calculating Density

A small block of wood floats on water. It has a mass of 200 g and a volume of 250 cm^3. What is the density of the wood?

1 Read and Understand

What information are you given?

Mass of block = 200 g

Volume of block = 250 cm^3

2 Plan and Solve

What quantity are you trying to calculate?

The density of the block = ▒

What formula contains the given quantities and the unknown quantity?

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Perform the calculation.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{200\text{ g}}{250\text{ cm}^3} = 0.80\text{ g/cm}^3$$

3 Look Back and Check

Does your answer make sense?

The density is lower than 1.0 g/cm^3, which makes sense because the block can float.

Math Practice

1. A sample of liquid has a mass of 24 g and a volume of 16 mL. What is the density of the liquid?
2. A piece of solid metal has a mass of 43.5 g and a volume of 15 cm^3. What is the density of the metal?

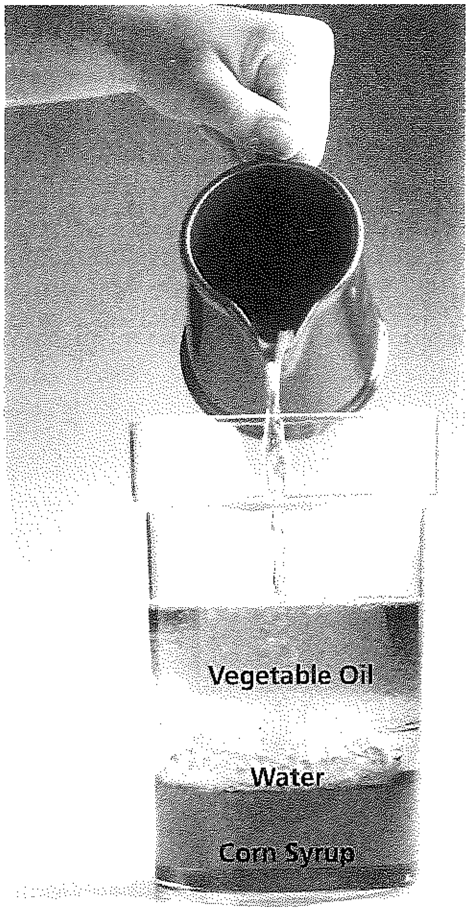


FIGURE 14
Density Layers
The density of water is less than corn syrup but greater than vegetable oil.

Sinking or Floating? Suppose you have a solid block of wood and a solid block of iron. When you drop both blocks into a tub of water, you can see right away that the wood floats and the iron sinks. You know the density of water is 1 g/cm^3. Objects with densities greater than that of water will sink. Objects with lesser densities will float. So, the density of this wood is less than 1 g/cm^3. The density of the iron is greater than 1 g/cm^3.

Watch a bottle of oil-and-vinegar salad dressing after it has been shaken. You will see oil droplets rising above the vinegar. Finally, the oil forms a separate layer above the vinegar. What can you conclude? You're right if you said that the oil is less dense than vinegar.

Using Density Density is a physical property of a substance. So, density can be used to identify an unknown substance. For example, suppose you were hiking in the mountains and found a shiny, golden-colored rock. How would you know if the rock was really gold? Later at home, you could look up the density of gold at room temperature. Then measure the mass and volume of the rock and find its density. If the two densities match, you would have quite a find!

Reading Checkpoint **Why does the oil in some salad dressings rise to the top of the bottle?**

Section 2 Assessment

Target Reading Skill Asking Questions Use the answers you wrote in your graphic organizer about the headings to answer the questions below.

Reviewing Key Concepts

1. a. Defining What is mass?
   b. Explaining Why is mass more useful than weight for measuring matter?
2. a. Identifying What property of matter is measured in cubic centimeters?
   b. Comparing and Contrasting How are milliliters related to liters?
   c. Calculating A plastic box is 15.3 cm long, 9.0 cm wide, and 4.5 cm high. What is its volume? Include units in your answer.
3. a. Listing What measurements must you make to find the density of a sample of matter?
   b. Explaining How can you determine whether a solid object is more dense or less dense than water?
   c. Problem Solving Propose a way to determine the density of air.

Math Practice

4. Calculating Density A piece of metal has a volume of 38 cm^3 and a mass of 277 g. Calculate the density of the metal, and identify it based on the information below.

Iron	7.9 g/cm^3	Tin	7.3 g/cm^3
Lead	11.3 g/cm^3	Zinc	7.1 g/cm^3

Lab zone **Skills Lab**

Making Sense of Density

Problem

Does the density of a material vary with volume?

Skills Focus

drawing conclusions, measuring, controlling variables

Materials

- balance
- water
- paper towels
- metric ruler
- graduated cylinder, 100-mL
- wooden stick, about 6 cm long
- ball of modeling clay, about 5 cm wide
- crayon with paper removed

Procedure

1. Use a balance to find the mass of the wooden stick. Record the mass in a data table like the one shown above right.
2. Add enough water to a graduated cylinder so that the stick can be completely submerged. Measure the initial volume of the water.
3. Place the stick in the graduated cylinder. Measure the new volume of the water.
4. The volume of the stick is the difference between the water levels in Steps 2 and 3. Calculate this volume and record it.
5. The density of the stick equals its mass divided by its volume. Calculate and record its density.
6. Thoroughly dry the stick with a paper towel. Then carefully break the stick into two pieces. Repeat Steps 1 through 5 with each of the two pieces.
7. Repeat Steps 1 through 6 using the clay rolled into a rope.
8. Repeat using the crayon.

Data Table

Object	Mass (g)	Volume Change (cm^3)	Density (g/cm^3)
Wooden stick			
Whole			
Piece 1			
Piece 2			
Modeling clay			
Whole			
Piece 1			
Piece 2			
Crayon			
Whole			
Piece 1			
Piece 2			

Analyze and Conclude

1. Measuring For each object you tested, compare the density of the whole object with the densities of the pieces of the object.
2. Drawing Conclusions Use your results to explain how density can be used to identify a material.
3. Controlling Variables Why did you dry the objects in Step 6?
4. Communicating Write a paragraph explaining how you would change the procedure to obtain more data. Tell how having more data would affect your answers to Questions 1 and 2 above.

Design an Experiment

Design an experiment you could use to determine the density of olive oil. With your teacher's permission, carry out your plan.

Section 3

Changes in Matter

Reading Preview

Key Concepts

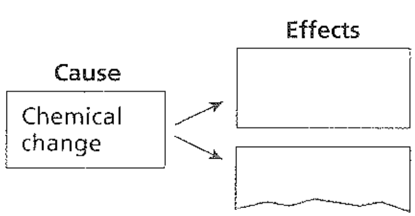
- What is a physical change?
- What is a chemical change?
- How are changes in matter related to changes in energy?

Key Terms

- physical change
- chemical change
- law of conservation of mass
- energy
- temperature
- thermal energy
- endothermic change
- exothermic change

Target Reading Skill

Relating Cause and Effect A cause makes something happen. An effect is what happens. As you read, identify two effects caused by a chemical change. Write the information in a graphic organizer like the one below.



Lab zone Discover Activity

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 15
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

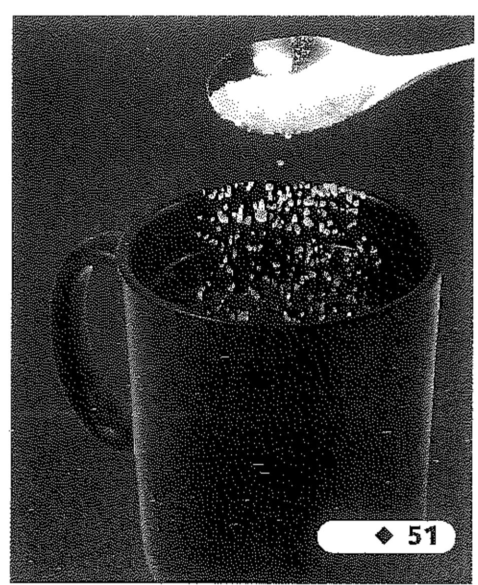


FIGURE 16
Change in Form
Crushing aluminum soda cans doesn't change the aluminum into another metal (left). When table sugar dissolves in a glass of water, it is still sugar (right).

Inferring

Make a list of changes in matter that you observe during a single day. These changes may occur in your environment (such as changes in the weather), as a result of people's activities (such as cooking or driving a car), or in other situations. Try to classify each change on your list as a physical change or a chemical change. Then briefly explain your choice.

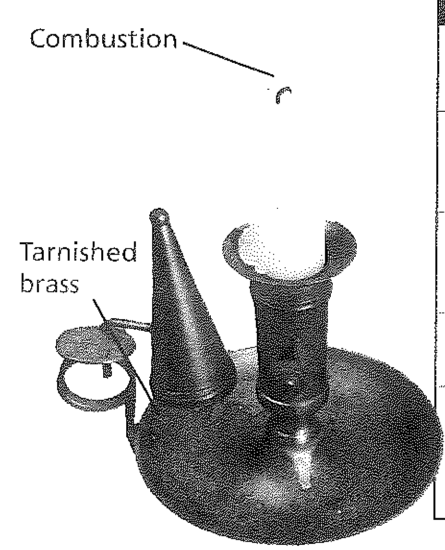
Chemical Change

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 17 describes each of these kinds of chemical changes.

FIGURE 17
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 Mass 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 mass.** Remember that mass measures the amount of matter. So, this law is sometimes called the law of conservation of matter.

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 19.

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

FIGURE 18
Using Methane
Natural gas, or methane, is the fuel used in many kitchen ranges. When it burns, no mass is lost.

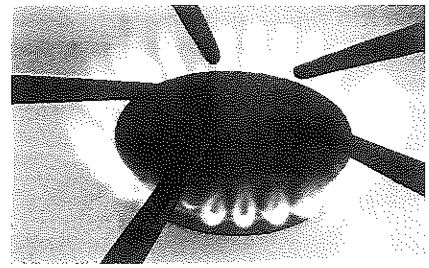


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FIGURE 19
Conserving Matter
The idea of atoms explains the law of conservation of matter. For every molecule of methane that burns, two molecules of oxygen are used. The atoms are rearranged in the reaction, but they do not disappear.

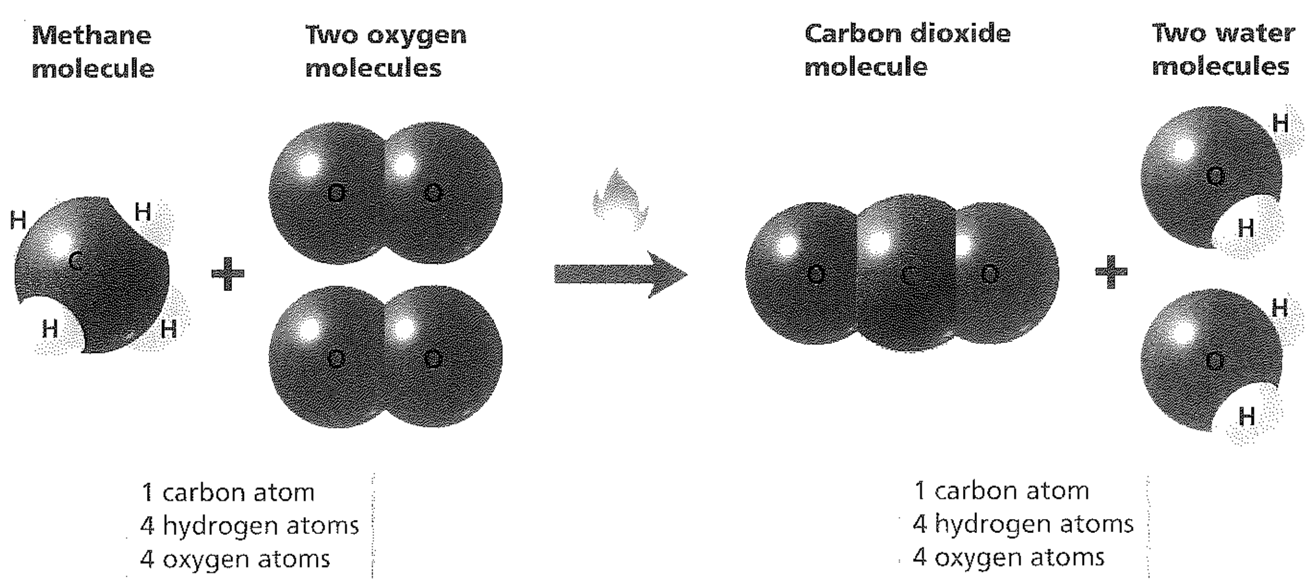
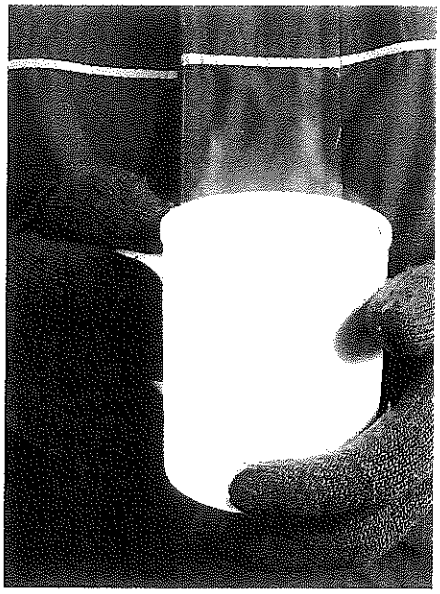


FIGURE 20
Flow of Thermal Energy
Thermal energy from a hot cup of cocoa can warm cold hands on a chilly day.
Developing Hypotheses *How will the flow of thermal energy affect the cocoa?*



Matter and Thermal Energy

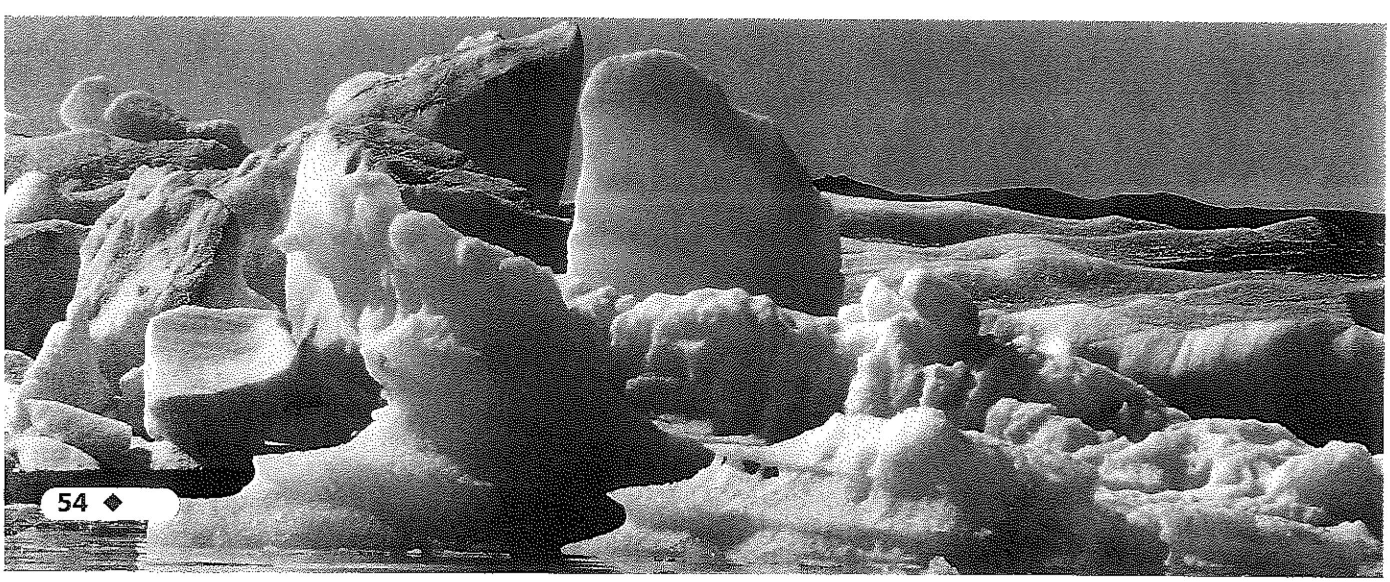
Do you feel as if you are full of energy today? **Energy** is the ability to do work or cause change. **Every chemical or physical change in matter includes a change in energy.** A change as simple as bending a paper clip takes energy. When ice changes to liquid water, it absorbs energy from the surrounding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

Temperature and 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.

Thermal Energy and Changes in 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 21
An Endothermic Change
An iceberg melting in the ocean absorbs thermal energy from the surrounding water.



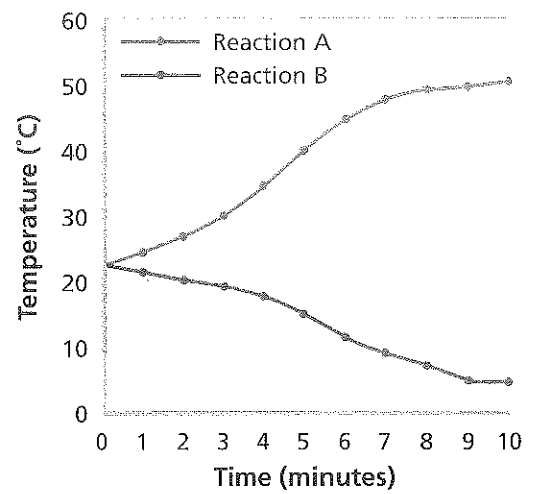
Math Analyzing Data

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?

Energy of Two Reactions



Section 3 Assessment

Target Reading Skill

Relating Cause and Effect Refer to your graphic organizer about chemical change to help you answer Question 2 below.

Reviewing Key Concepts

1. a. Listing Identify three different kinds of physical change that could happen to a plastic spoon.
   b. 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.)
3. a. Reviewing What is thermal energy?
   b. Explaining 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?

Writing in Science

Persuasive Letter Write a letter to persuade a friend that a change in temperature does not necessarily mean that a chemical change has occurred.

Transporting Hazardous Chemicals

Each year, millions of tons of hazardous substances criss-cross the country by truck and rail. These substances can be poisonous, flammable, and even explosive. The chemical industry tries to make the transport of hazardous substances safe, and problems are rare. But when spills do happen, these compounds can damage the environment and threaten human lives. How can hazardous substances be transported safely?

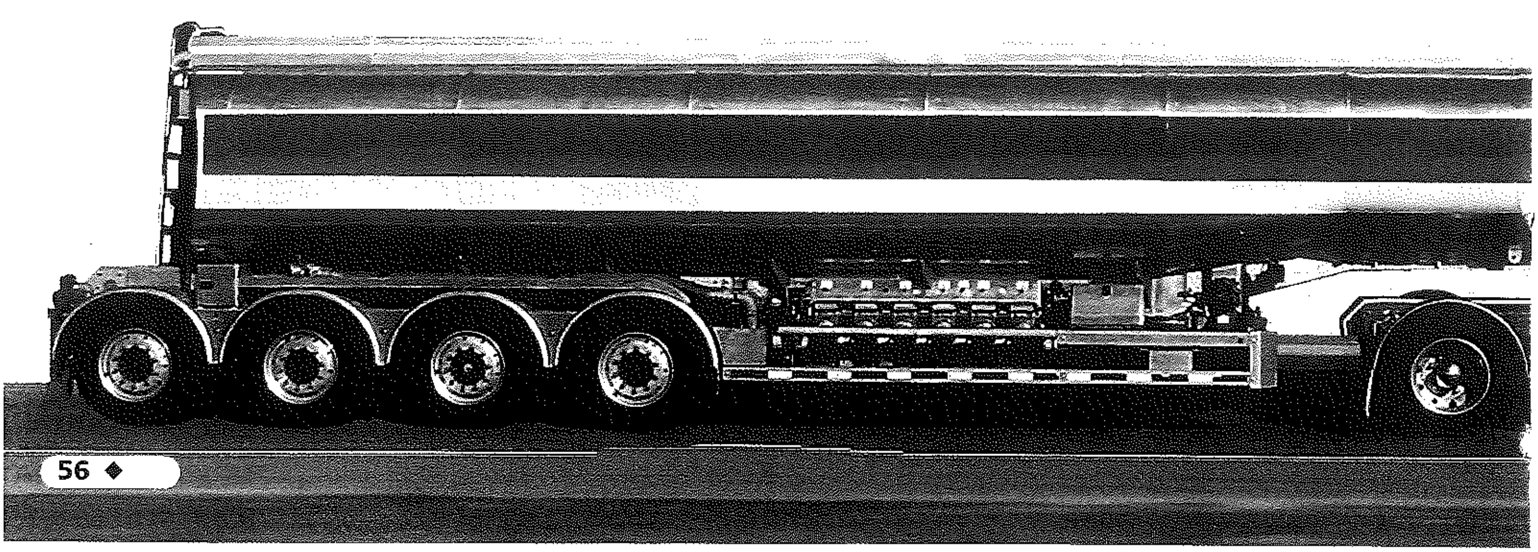
Why Do People Transport Hazardous Substances?

Useful products are made from the hazardous materials that trucks and trains carry. For example, CDs are made from plastics. To produce plastics, manufacturers use compounds such as benzene and styrene. Benzene fumes are poisonous and flammable. Styrene can explode when exposed to air. Public health experts say it is important to find safe substitutes for dangerous substances. But finding alternatives is difficult and expensive.

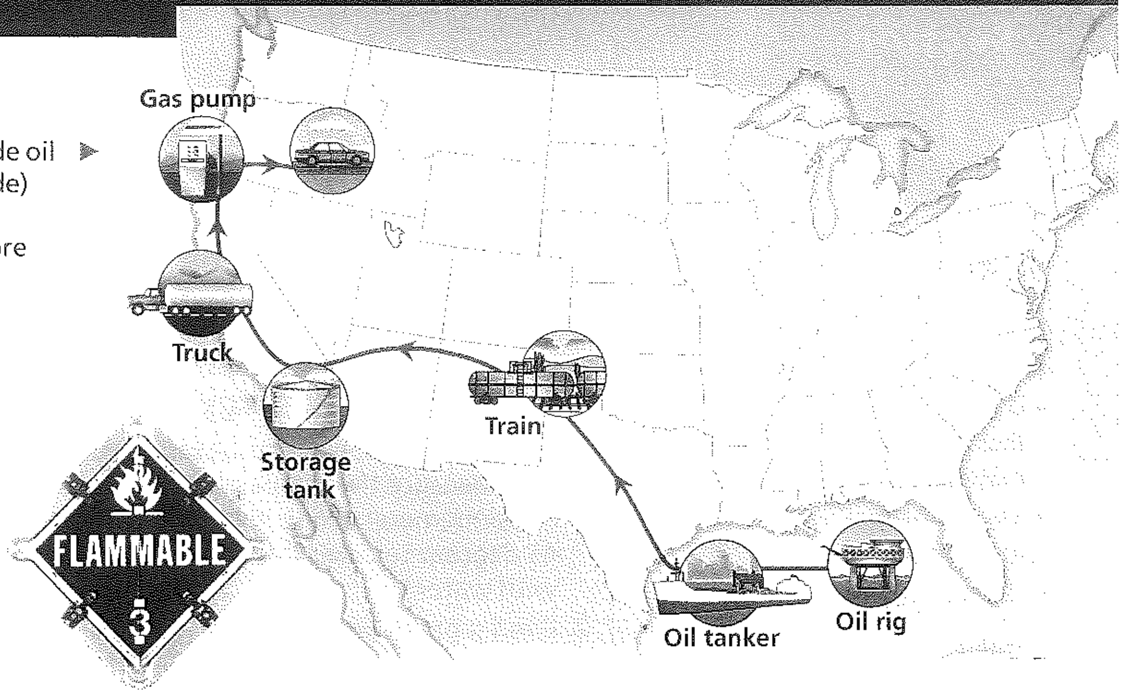
What Are the Risks?

Since 2000, the number of accidents in the United States involving hazardous chemical releases has dropped steadily from more than 350 to less than 20 in 2003. Still, public health experts say that some substances are too hazardous to transport on roads and railroads. An accidental release near a city could harm many people.

Some people say that vehicles carrying hazardous substances should be restricted to isolated roads. However, many factories that use the chemical compounds are located in cities. Chemicals often must be transported from where they are made to where they are used. For example, trucks and trains must transport gasoline to every neighborhood and region of the country.



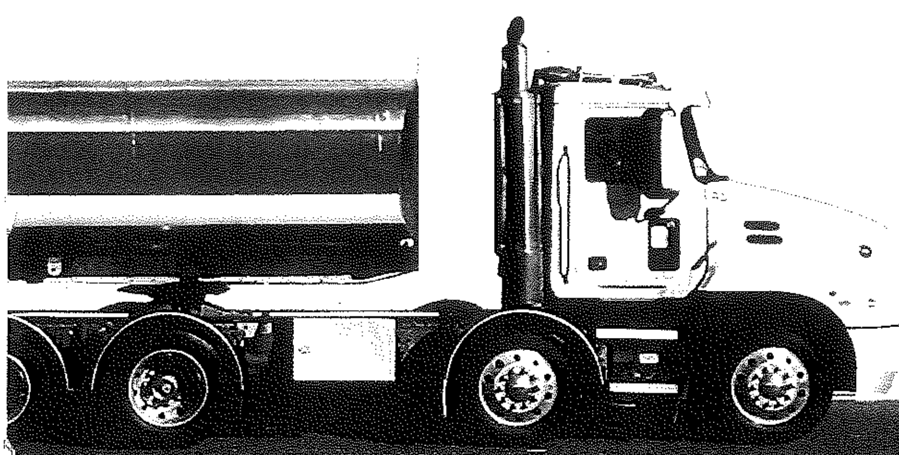
Gasoline (or the crude oil from which it is made) may be transported great distances before reaching a local gas station.



How Should Transportation Be Regulated?

Manufacturers that use hazardous chemicals say that there already are adequate laws. The Hazardous Materials Transportation Act requires carriers of hazardous substances to follow strict labeling and packaging rules. They must keep records of what they carry and where they travel. Local emergency officials in communities near transportation routes must also be trained to handle accidents involving these substances.

On the other hand, public health experts say there are not enough inspectors to check all trucks and trains and make sure rules are followed. But hiring more inspectors would cost additional tax money.



You Decide

1. **Identify the Problem**
   In your own words, explain the problem of safely transporting hazardous substances.

2. **Analyze the Options**
   Examine the pros and cons of greater regulation of the transport of hazardous substances. In each position, consider the effects on chemical industries and on the public.

3. **Find a Solution**
   You are the emergency planning director in your city. Create regulations for transporting hazardous substances through your community.

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Section 4

Integrating Physics

Energy and Matter

Reading Preview

Key Concepts

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

Key Terms

- kinetic energy
- potential energy
- chemical energy
- electromagnetic energy
- electrical energy
- electrode

Target Reading Skill

Identifying Main Ideas As you read Forms of Energy, write the main idea in a graphic organizer like the one below. Then write three supporting details that give examples of the main idea.

Main Idea

There are many forms of energy.

Detail | Detail | Detail

Lab zone Discover Activity

Where Was the Energy?

1. Add about 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

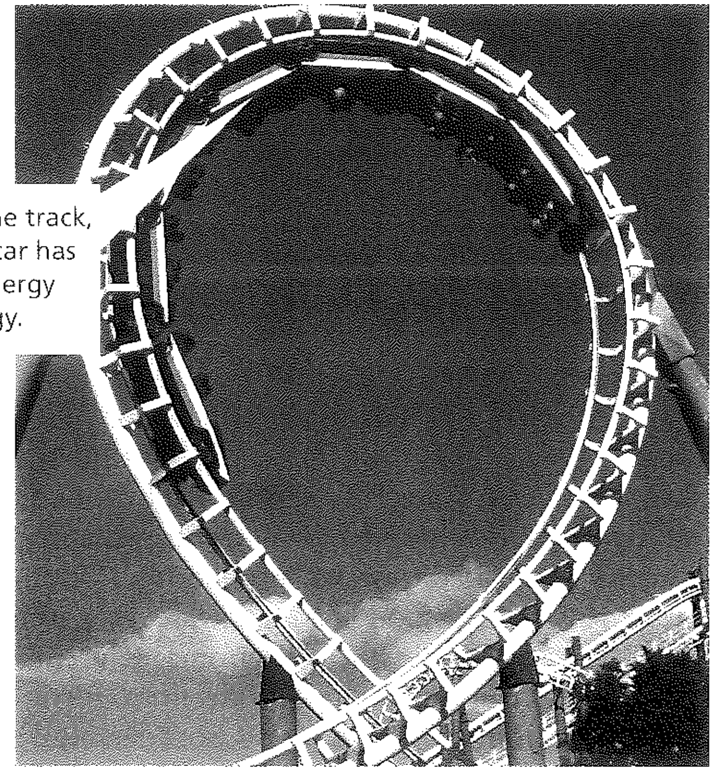
Drawing Conclusions How can you account for any change in the water's temperature? What evidence of a chemical change did you observe? What forms of energy were released when the marshmallow burned? Where did the energy come from?

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

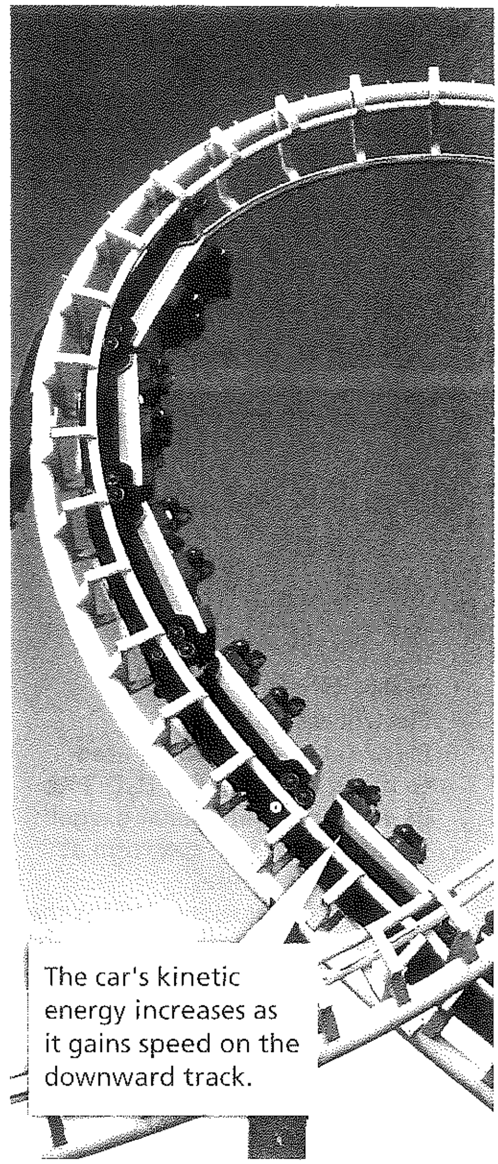
Forms of Energy

How do you know when something has energy? You would probably say that a basketball flying toward the hoop has energy because it is moving, and you'd be right. You can be sure that the player who threw the ball also has energy. Maybe you would mention light and heat from a burning candle. Again you would be right.

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



Near the top of the track, the slow-moving car has more potential energy than kinetic energy.



The car's kinetic energy increases as it gains speed on the downward track.

FIGURE 22
Energy Changes
The thrills of a roller coaster ride start with the transformation of potential energy into kinetic energy. **Applying Concepts** *Where did the potential energy of the car come from?*

Kinetic Energy and Potential Energy In Section 3, you learned that energy is the ability to do work or cause change. All matter has energy of at least one form. **Kinetic energy** is the energy of matter in motion. A rolling bowling ball has kinetic energy and can do work by knocking down bowling pins. If you drop the bowling ball on your toe, you'll experience the work done by the kinetic energy of the falling ball. Even though you can't see them, the smallest particles of matter have kinetic energy because they are in constant, random motion. Recall from Section 3 that the kinetic energy of particles contributes to the thermal energy of a substance.

Suppose you push your bike to the top of a hill. That action takes energy, doesn't it? But the energy isn't wasted. In a way, it is now stored in you and in the bike. This stored energy will change to kinetic energy as you enjoy an exciting coast back down the hill. As you went up the hill, you increased the potential energy of both you and the bike. **Potential energy** is the energy an object has because of its position. When a diver climbs up to a diving board, she increases her potential energy. When you stretch a rubber band, your action gives potential energy to the rubber band to snap back and do work.

Lab zone Try This Activity

Dropping the Ball

1. Work with a partner. Using a meter stick as a guide, hold a ball about 0.5 m off the floor. Let go of the ball and note how high it bounces.
2. Repeat Step 1 from heights of 1 m, 1.5 m, and 2 m.

Inferring When does the ball have the most potential energy? When does it have the most kinetic energy?

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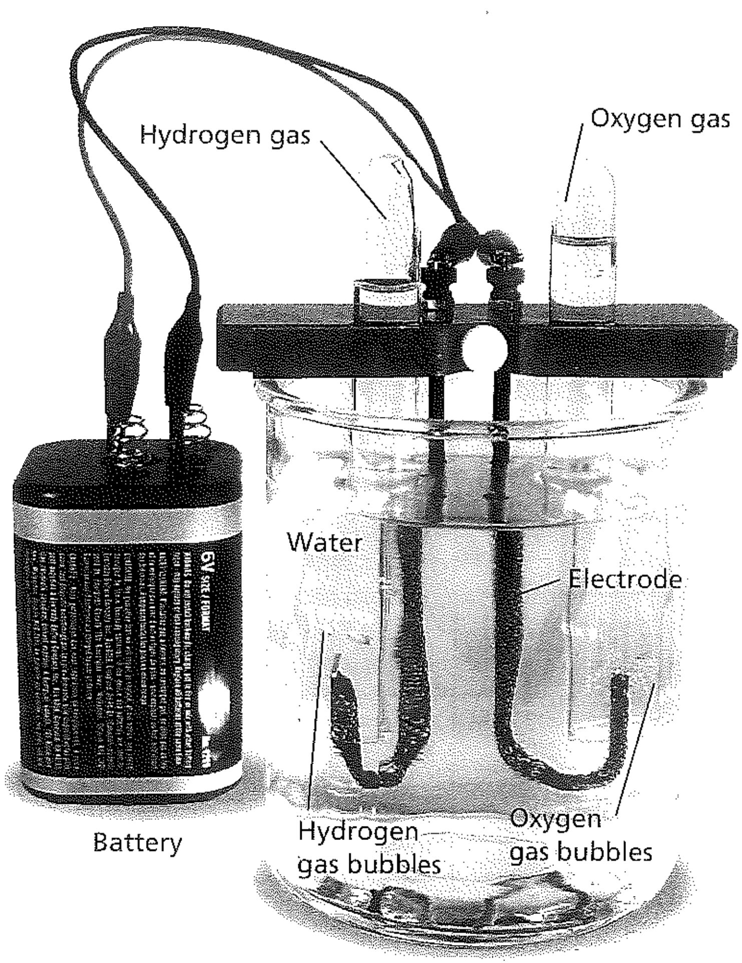
Chemical Energy The internal energy stored in the chemical bonds between atoms is a form of potential energy that is sometimes called **chemical energy.** When a chemical change occurs, these bonds are broken and new bonds are formed. If the change is exothermic, some of the chemical energy is transformed and released in a variety of other forms. As you read in Section 3, one of those forms is often thermal energy.

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,** 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.

FIGURE 23
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 3—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. When the energy begins to flow, 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 as a result.

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

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 the kinetic energy of your moving muscles. 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?**

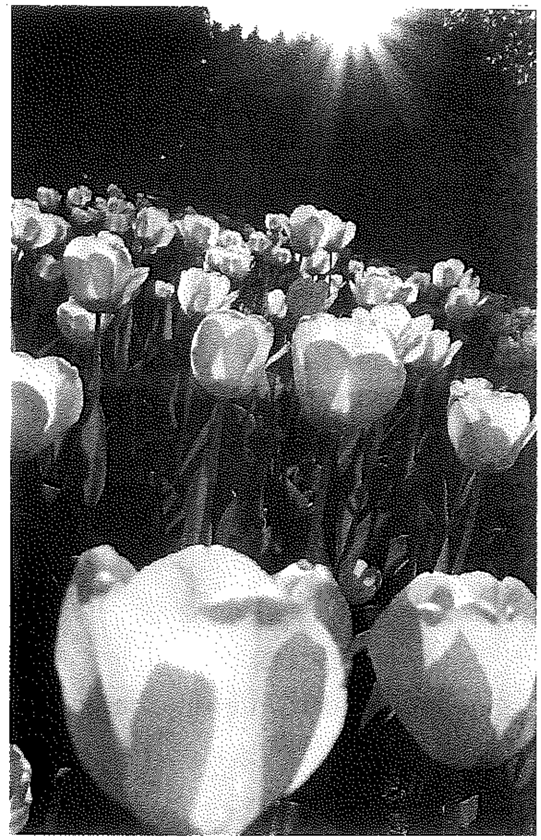


FIGURE 24
Photosynthesis
Photosynthesis is a series of chemical changes in which plants convert electromagnetic energy from the sun into chemical energy.

Section 4 Assessment

Target Reading Skill Identifying Main Ideas Use your graphic organizer to help you answer Question 1 below.

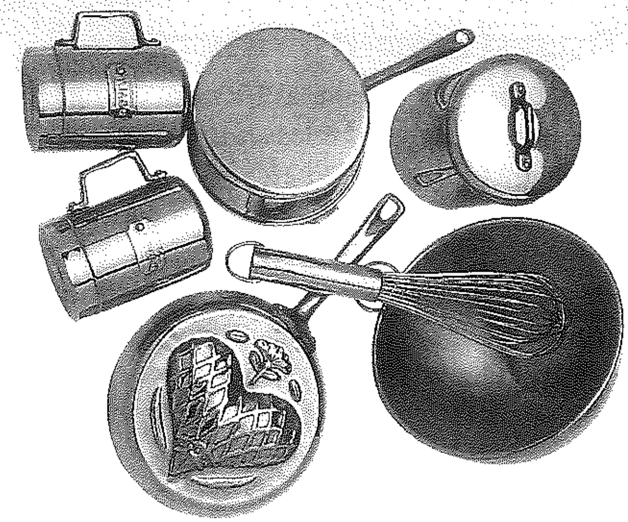
Reviewing Key Concepts

1. a. Listing What are six forms of energy related to changes in matter?
   b. Classifying Which form of energy is represented by a book lying on a desk? Which form of energy is represented by a book falling off a desk?
   c. Making Generalizations What happens to energy when matter undergoes a chemical or physical change?
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

Problem

How can electrical energy be used to isolate copper metal?

Skills Focus

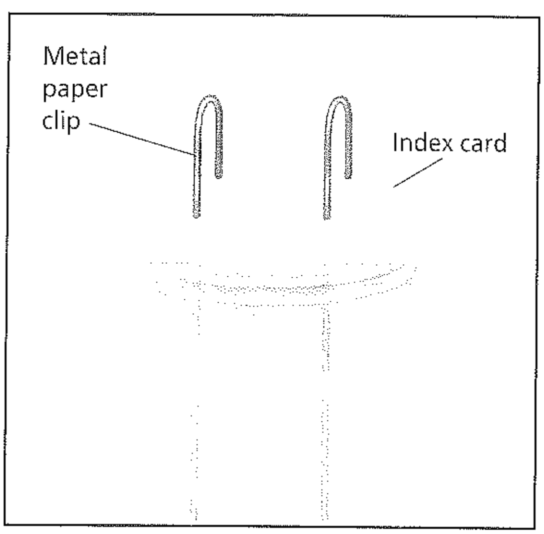
making models, inferring, observing, interpreting data

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 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.

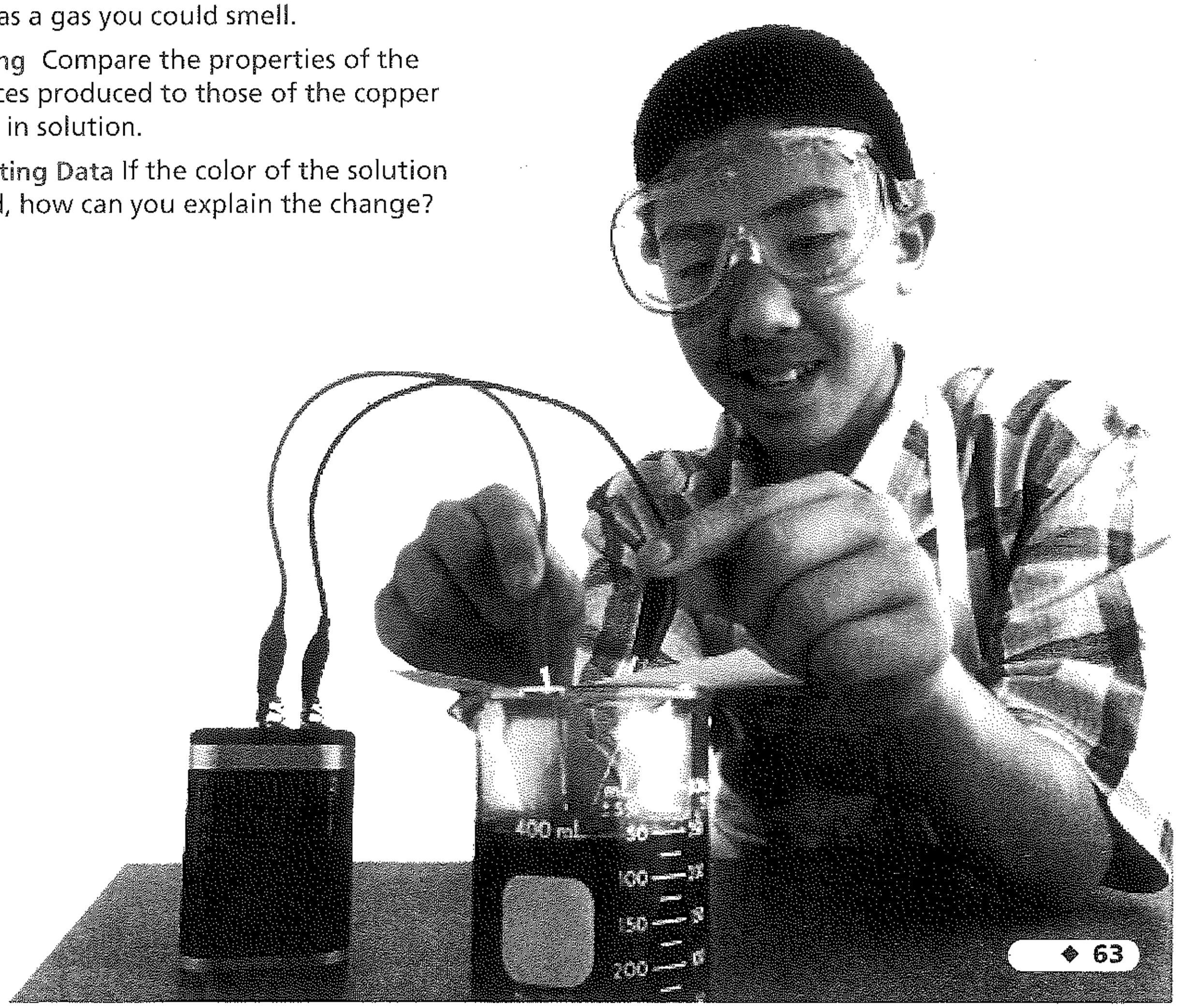
10. Note the color of the ends of the electrodes.
11. Discard the solution as directed by your teacher, and wash your hands.

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 **Properties of Matter** Chemistry is the study of the properties of matter and how matter changes.

1 Describing Matter

Key Concepts

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

2 Measuring Matter

Key Concepts

- Unlike weight, mass does not change with location, even when the force of gravity on an object changes.
- Common units of volume include the liter (L), milliliter (mL), and cubic centimeter (cm^3).
- Volume $=$ Length $\times$ Width $\times$ Height
- Density $= \dfrac{\text{Mass}}{\text{Volume}}$

Key Terms

weight
mass
International System of Units
volume
density

3 Changes in Matter

Key Concepts

- 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.
- Every chemical or physical change in matter includes a change in energy.

Key Terms

physical change
chemical change
law of conservation of mass
energy
temperature
thermal energy
endothermic change
exothermic change

4 Energy and Matter

Key Concepts

- Forms of energy related to changes in matter include kinetic, potential, 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

kinetic energy
potential energy
chemical energy
electromagnetic energy
electrical energy
electrode

Review and Assessment

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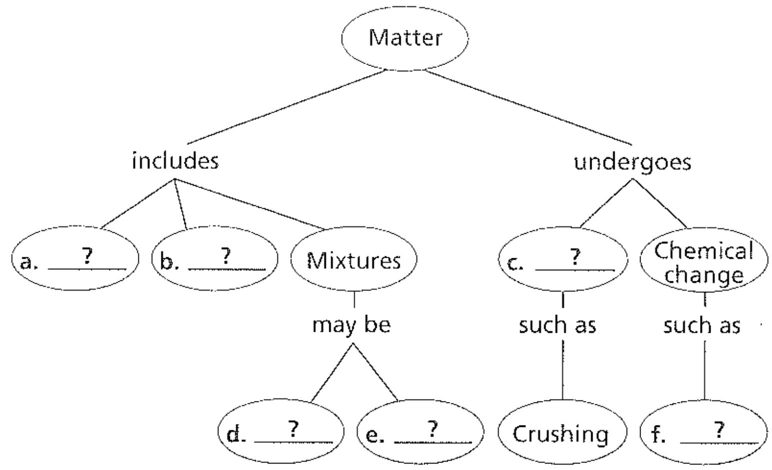
Organizing Information

Concept Mapping Copy the concept map about matter onto a separate sheet of paper. Then complete the map by adding in the correct missing words or phrases. (For more on Concept Mapping, see the Skills Handbook.)



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. Density relates the mass of a material to the material's
   a. temperature. b. volume.
   c. weight. d. length.
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 potential energy of
   a. temperature.
   b. bonds between atoms.
   c. electricity.
   d. light.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Energy is anything that has mass and takes up space.
7. A mixture is made of two or more elements that are chemically combined.
8. The weight of an object changes if the force of gravity changes.
9. Energy is taken in during an exothermic change.
10. Light is an example of electromagnetic energy.

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.

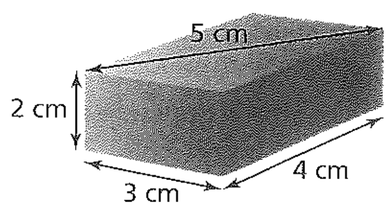
Review and Assessment

Checking Concepts

11. What are three ways that compounds and mixtures differ?
12. What two quantities do you need to measure in order to determine the density of an object?
13. What can you infer about the density of a material if a sample of it floats in water?
14. How do you know that the burning of candle wax is an exothermic change?
15. What is kinetic energy? Give an example of a use of kinetic energy that you saw today.

Thinking Critically

16. Classifying Which of the following is a solution: pure water, fruit punch, cereal and milk in a bowl? Explain how you know.
17. Making Judgments Which measurement shown in the diagram is not needed to find the volume of the box? Explain.



18. Inferring Ice has a lower density than liquid water. How does the volume of a kilogram of water change when it freezes to ice?
19. 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?

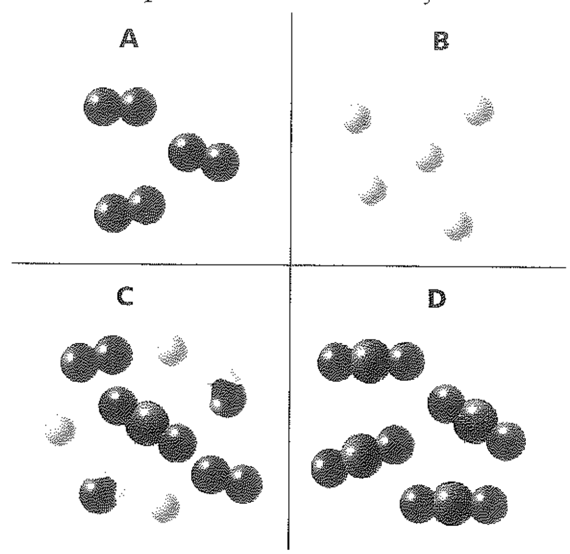
Math Practice

20. 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?
21. Calculating Density A piece of magnesium metal has a mass of 56.5 g and a volume of 32.5 cm^3. What is the density of the magnesium?

Applying Skills

Use the information and the diagrams below to answer Questions 22–25. Some questions may have more than one answer.

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.



22. Interpreting Diagrams Which diagrams represent a single element? Explain.
23. Classifying Which diagrams represent pure substances? Explain.
24. Interpreting Data How do the molecules in diagram A differ from those in diagram D?
25. Interpreting Diagrams Which diagram represents a mixture? Explain.

Lab zone Chapter Project

Performance Assessment Present a brief summary of your experience with building your density-calculating system. Describe the most difficult part of construction. What steps were easiest? Defend the accuracy and reliability of your system, and describe its limitations.

Standardized Test Prep

Test-Taking Tip

Anticipating the Answer

You may be able to figure out the answer to a question before looking at the answer choices. After thinking of your own answer, compare it with the choices provided. Select the answer that most closely matches your own. This strategy can be especially useful for questions that test vocabulary. Try to answer the question below before looking at the answer choices.

Sample Question

Which two pieces of laboratory equipment would be most useful for measuring the mass and volume of a rectangular aluminum block?

- **A** metric ruler and stopwatch
- **B** balance and metric ruler
- **C** thermometer and graduated cylinder
- **D** balance and stopwatch

Answer

The correct answer is **B**. Mass is measured with a balance. The volume of a rectangular solid is found by multiplying length × width × height, which are measured with a metric ruler. Choices **A** and **D** each contain only one of the necessary pieces of equipment. A stopwatch measures time. In Choice **C**, the graduated cylinder measures volume, but a thermometer measures temperature, not mass.

Choose the letter of the best answer.

A scientist did an experiment, described by the words and symbols below, to demonstrate the law of conservation of mass. Use the information and your knowledge of science to answer Questions 1 to 2.

hydrogen + oxygen → water + energy

1. 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

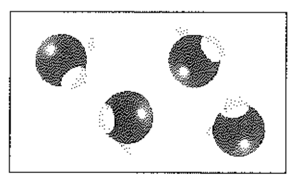
2. Which pair of terms best describes the type of change that occurred in the reaction?
   - **F** chemical and exothermic
   - **G** chemical and endothermic
   - **H** physical and exothermic
   - **J** physical and endothermic

3. What is the best title for the chart below?

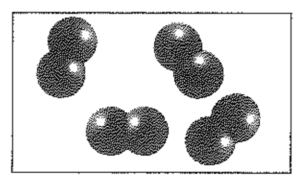
?	
Helium	Colorless; less dense than air
Iron	Attracted to a magnet; melting point of 1,535°C
Oxygen	Odorless; gas at room temperature

   - **A** The Periodic Table of the Elements
   - **B** Gases Found in Air
   - **C** Chemical Properties of Some Compounds
   - **D** Physical Properties of Some Elements

4. Which diagram best represents a mixture of two kinds of gas molecules?



F



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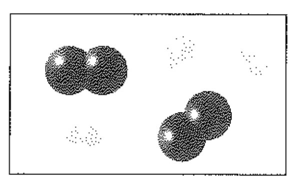

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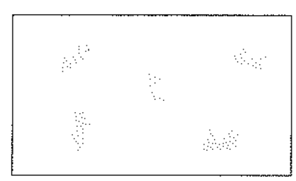

J

5. The density of a substance equals its mass divided by its volume. The density of sulfur is 2.0 g/cm^3. What is the mass of a sample of sulfur that has a volume of 6.0 cm^3?
   - **A** 3.0 g
   - **B** 4.0 g
   - **C** 8.0 g
   - **D** 12 g

Constructed Response

6. Describe three forms of energy related to changes in matter and provide an example of each.