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

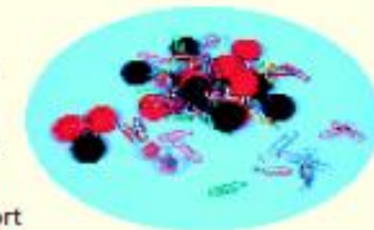
### Target Reading Skill

**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. You will learn more about the structure of atoms in Chapter 3.

**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.

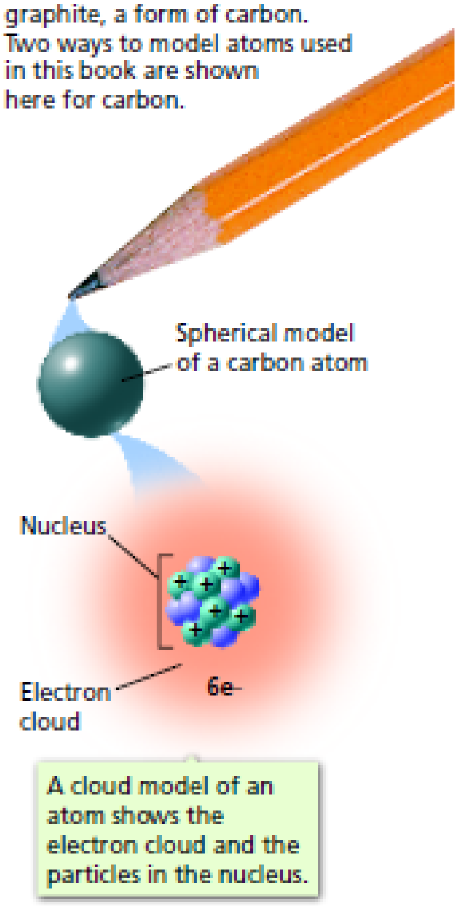
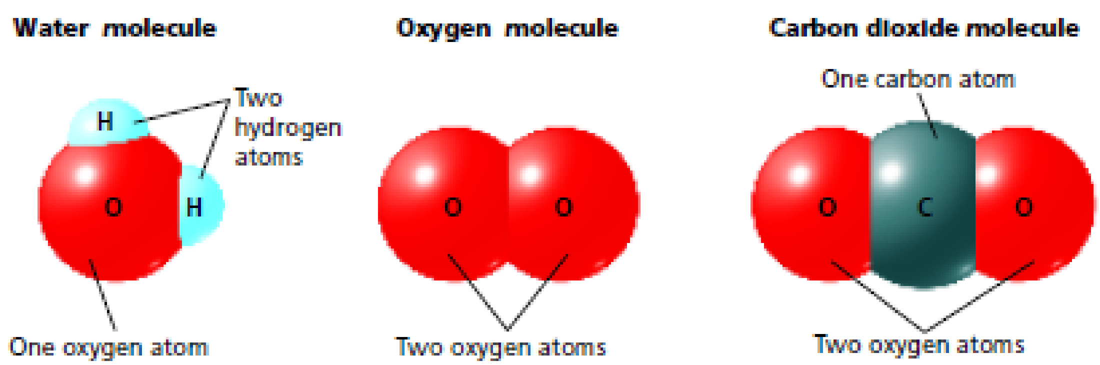



**FIGURE 6**
**Modeling Molecules**
Models of molecules often consist of colored spheres that stand for different kinds of atoms.
Observing *How many atoms are in a molecule of carbon dioxide?*



**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?*

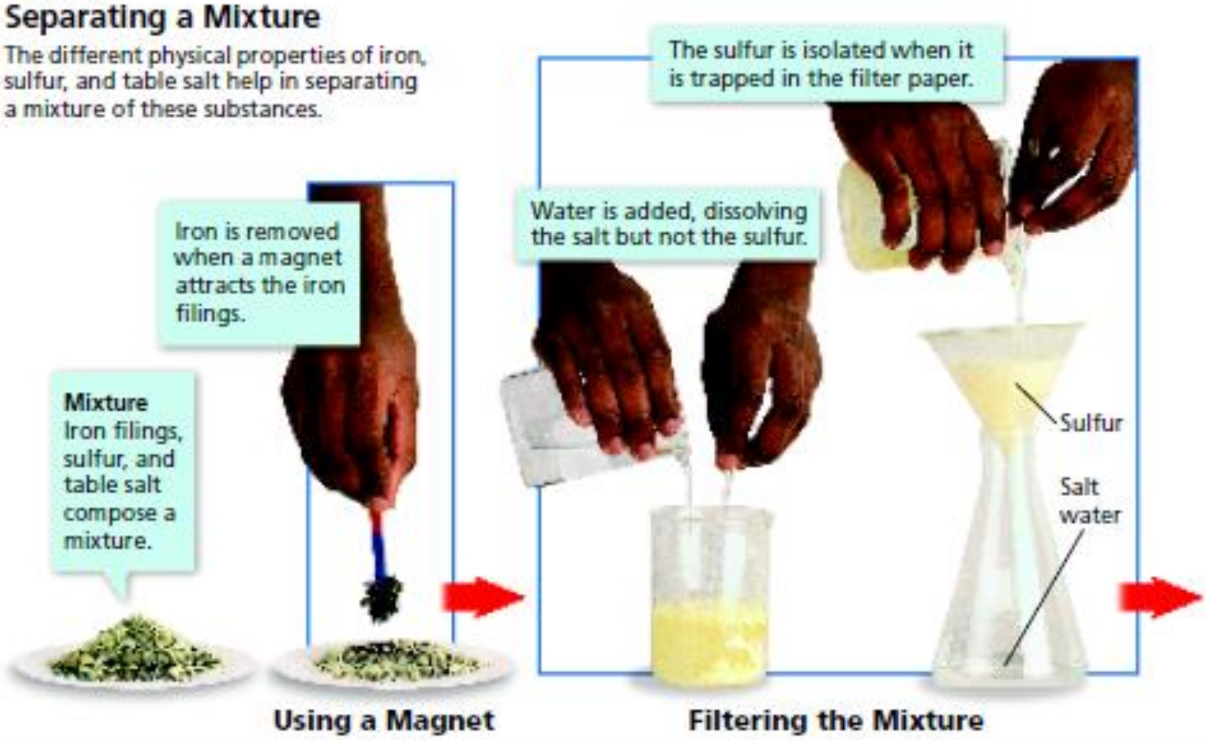
**Heterogeneous Mixtures** A mixture can be heterogeneous or homogeneous. In a **heterogeneous mixture** (het ur uh JEE nee us), you can see the different parts. The damp soil described above is one example of a heterogeneous mixture. So is a salad. Just think of how easy it is to see the pieces of lettuce, 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.




**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.

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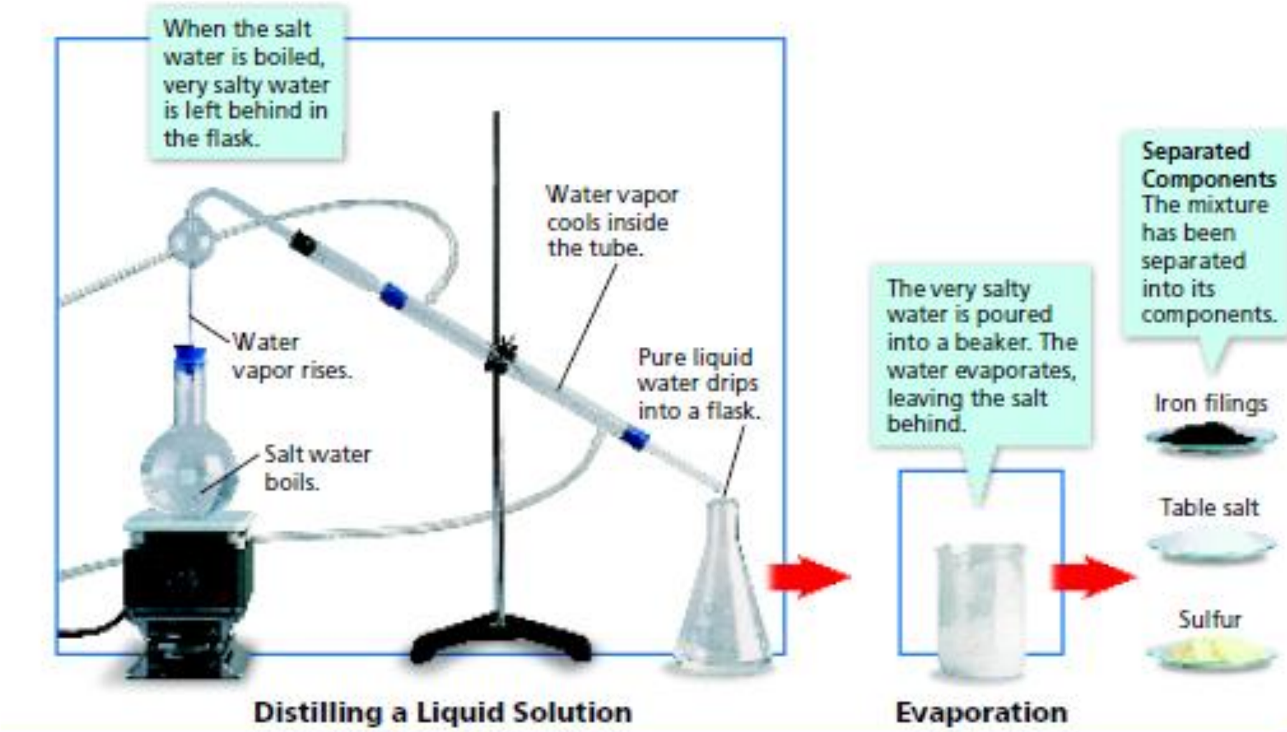


## Section 1 Assessment

**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.