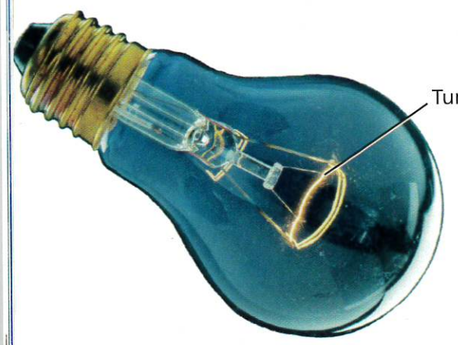
FIGURE 4
Examples of Elements
Some elements have familiar uses. Many elements are solids at room temperature, but some are gases or liquids.



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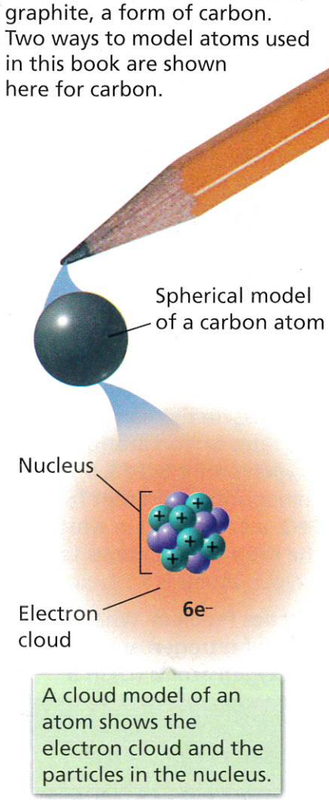
Particles of Elements—Atoms What is the smallest possible piece of matter? Suppose you could keep tearing a piece of aluminum foil in half over and over again. Would you reach a point where you have the smallest possible piece of aluminum? The answer is yes. Since the early 1800s, scientists have known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

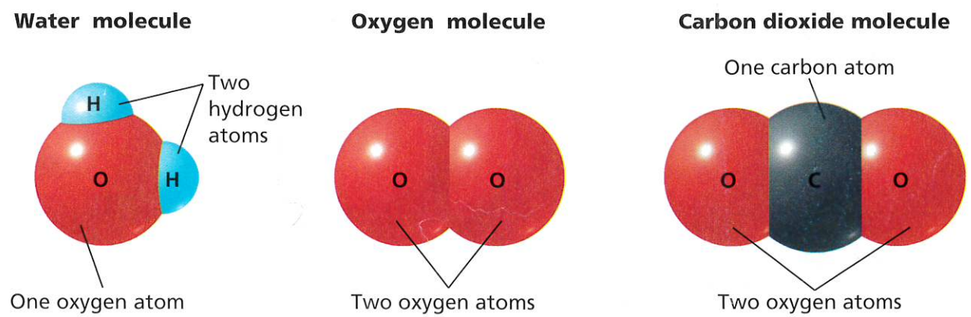
Reading Checkpoint **What is a molecule?**

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.



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?**

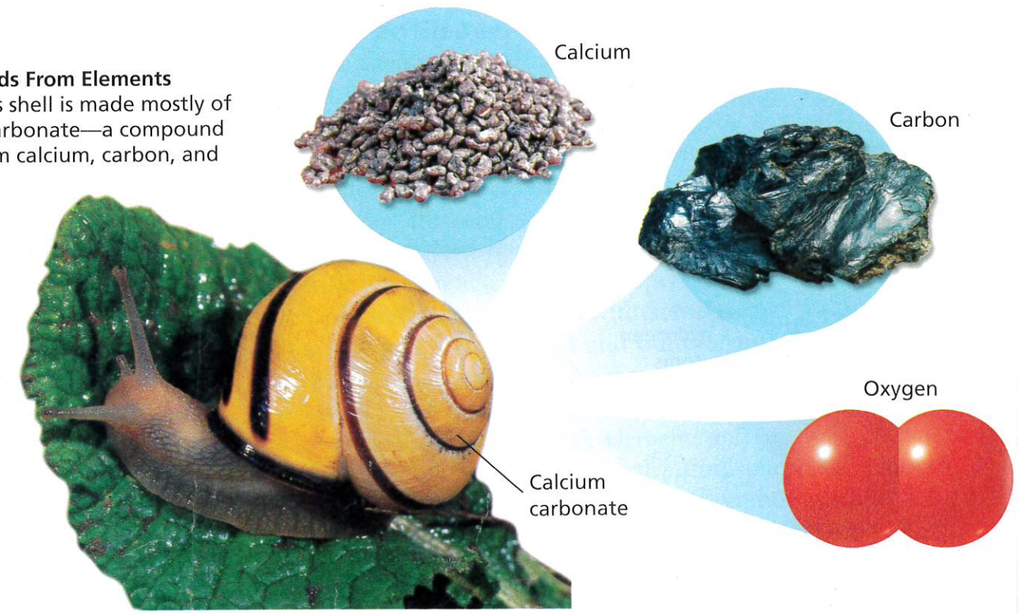


FIGURE 7
Compounds From Elements
This snail's shell is made mostly of calcium carbonate—a compound made from calcium, carbon, and oxygen.

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.

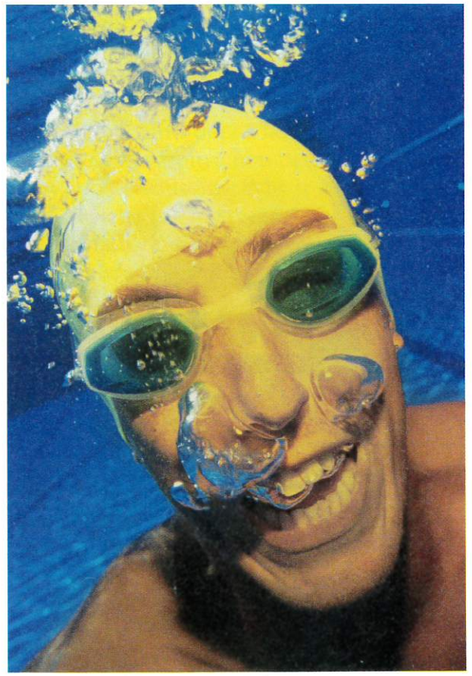
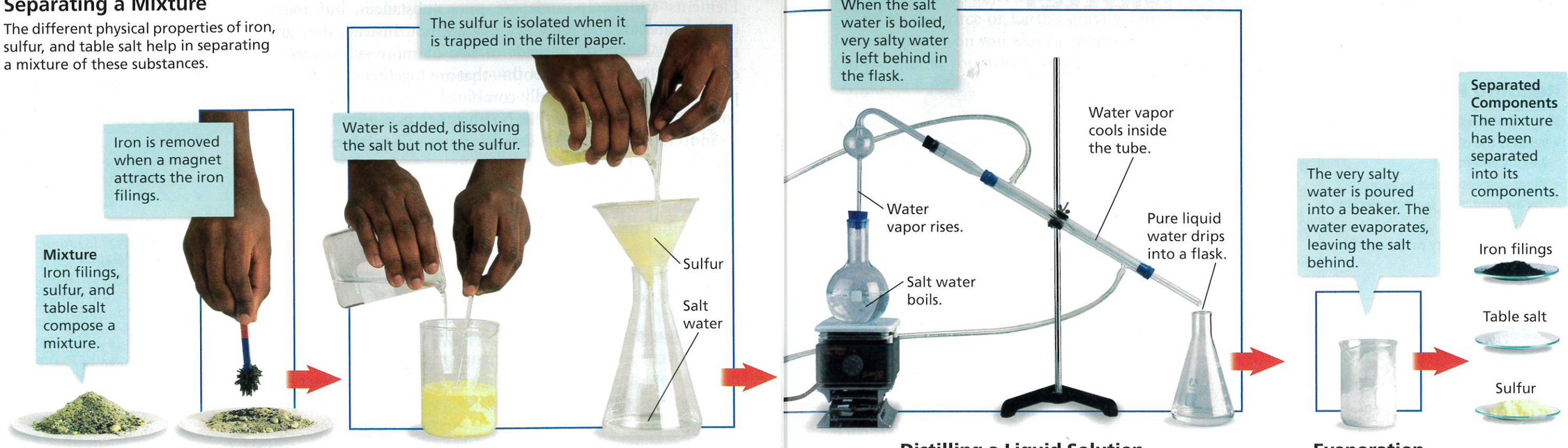


FIGURE 9
Homogeneous Mixture
A swimmer blows bubbles of air—a homogeneous mixture of gases.

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.

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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.