SECTION 1

Elements

Imagine that you work for the Break-It-Down Company. Your job is to break down materials into simpler substances.

You haven't had any trouble breaking down materials so far. But one rainy Monday morning, you get a material that seems very hard to break down. First, you try physical changes, such as crushing and melting. But these do not change the material into something simpler. Next, you try some chemical changes, such as passing an electric current through the material. These do not change it either. What's going on?

READING WARM-UP

Objectives

- Describe pure substances.
- Describe the characteristics of elements, and give examples.
- Explain how elements can be identified.
- Classify elements according to their properties.

Terms to Learn

element
pure substance
metal
nonmetal
metalloid

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

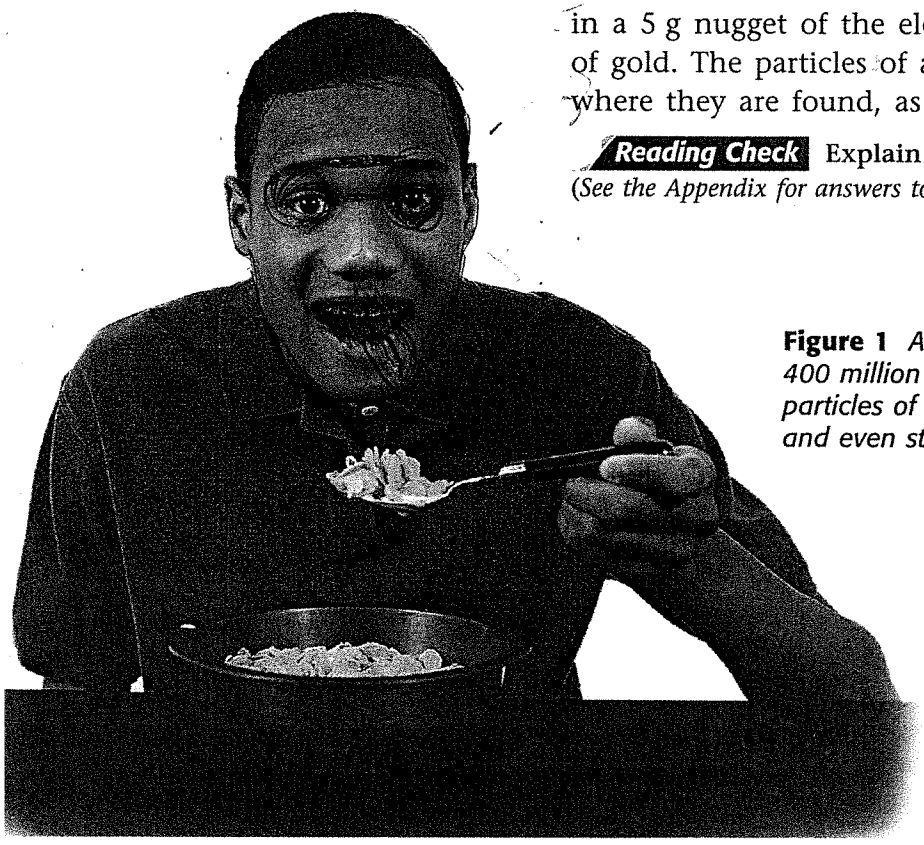
Elements, the Simplest Substances

You couldn't break down the material described above because it is an element. An **element** is a pure substance that cannot be separated into simpler substances by physical or chemical means. In this section, you'll learn about elements and the properties that help you classify them.

Only One Type of Particle

Elements are pure substances. A **pure substance** is a substance in which there is only one type of particle. So, each element contains only one type of particle. These particles, called *atoms*, are much too small for us to see. For example, every atom in a 5 g nugget of the element gold is like every other atom of gold. The particles of a pure substance are alike no matter where they are found, as shown in **Figure 1.**

Reading Check Explain why an element is a pure substance. (*See the Appendix for answers to Reading Checks.*)



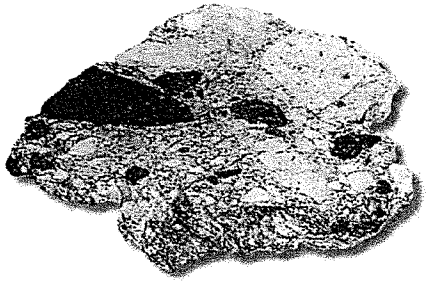


Figure 1 *A meteorite might travel more than 400 million kilometers to reach Earth. But the particles of iron in a meteorite, a steel spoon, and even steel braces are alike.*

Properties of Elements

Each element can be identified by its unique set of properties. For example, each element has its own *characteristic properties*. These properties do not depend on the amount of the element present. Characteristic properties include some physical properties, such as boiling point, melting point, and density. Chemical properties, such as reactivity with acid, are also characteristic properties.

An element may share a property with another element, but other properties can help you tell the elements apart. For example, the elements helium and krypton are both unreactive gases. However, the densities (mass per unit volume) of these elements are different. Helium is less dense than air. A helium-filled balloon will float up if it is released. Krypton is denser than air. A krypton-filled balloon will sink to the ground if it is released.

Identifying Elements by Their Properties

Look at the elements shown in **Figure 2.** These three elements have some similar properties. But each element can be identified by its unique set of properties.

Notice that the physical properties shown in **Figure 2** include melting point and density. Other physical properties, such as color, hardness, and texture, could be added to the list. Chemical properties might also be useful. For example, some elements, such as hydrogen and carbon, are flammable. Other elements, such as sodium, react with oxygen at room temperature. Still other elements, including zinc, are reactive with acid.

QUICK LAB

Separating Elements

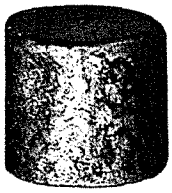
1. Examine a sample of nails provided by your teacher.
2. Your sample has **aluminum nails** and **iron nails.** Try to separate the two kinds of nails. Group similar nails into piles.
3. Pass a **bar magnet** over each pile of nails. Record your results.
4. Were you successful in completely separating the two types of nails? Explain.
5. Based on your observations, explain how the properties of aluminum and iron could be used to separate cans in a recycling plant.

element a substance that cannot be separated or broken down into simpler substances by chemical means

pure substance a sample of matter, either a single element or a single compound, that has definite chemical and physical properties

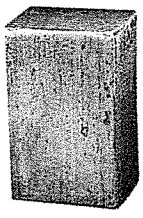
Figure 2 The Unique Properties of Elements

Cobalt



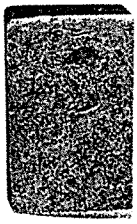
- Melting point: 1,495°C
- Density: 8.9 g/cm^3
- Conducts electric current and heat energy
- Unreactive with oxygen in the air

Iron



- Melting point: 1,535°C
- Density: 7.9 g/cm^3
- Conducts electric current and heat energy
- Combines slowly with oxygen in the air to form rust

Nickel



- Melting point: 1,455°C
- Density: 8.9 g/cm^3
- Conducts electric current and heat energy
- Unreactive with oxygen in the air

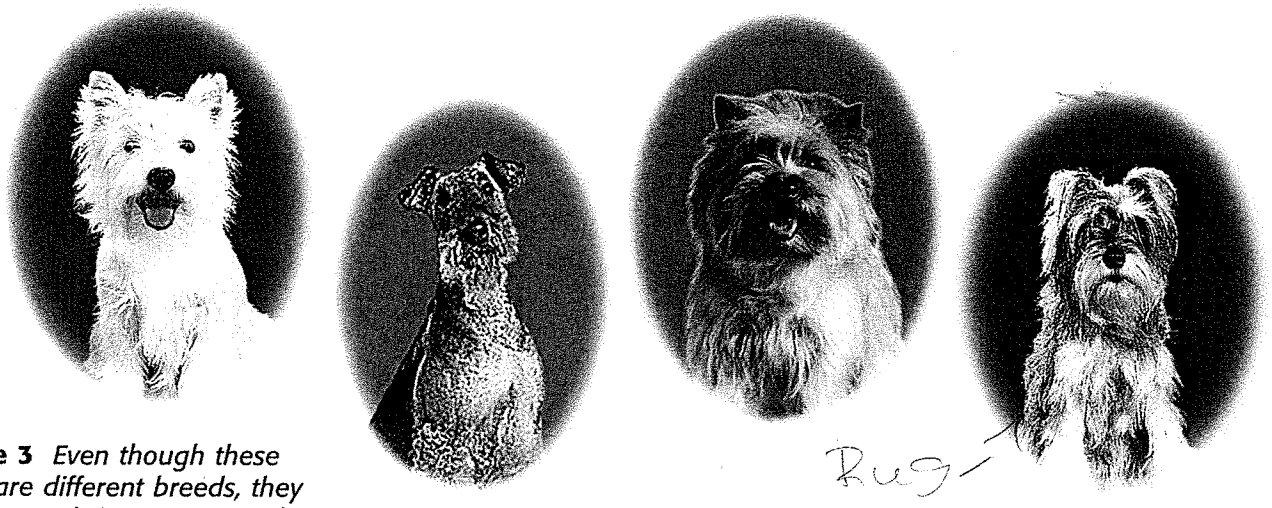


Figure 3 *Even though these dogs are different breeds, they have enough in common to be classified as terriers.*

Classifying Elements by Their Properties

Think about how many different breeds of dogs there are. Now, think about how you tell one breed from another. Most often, you can tell just by their appearance, or the physical properties, of the dogs. **Figure 3** shows several breeds of terriers. Many terriers are fairly small in size and have short hair. Not all terriers are alike, but they share enough properties to be classified in the same group.

Categories of Elements

Elements are also grouped into categories by the properties they share. There are three major categories of elements: metals, nonmetals, and metalloids. The elements iron, nickel, and cobalt are all metals. Not all metals are exactly alike, but they do have some properties in common. **Metals** are shiny, and they conduct heat energy and electric current. **Nonmetals** make up the second category of elements. They do not conduct heat or electric current, and solid nonmetals are dull in appearance. **Metalloids,** which have properties of both metals and nonmetals, make up the last category.

metal an element that is shiny and that conducts heat and electricity well

nonmetal an element that conducts heat and electricity poorly

metalloid an element that has properties of both metals and nonmetals

Reading Check **What are three characteristics of metals?**

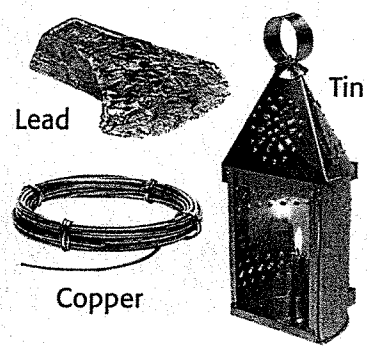
Categories Are Similar

Imagine being in a music store. The CDs are categorized by type of music. If you like rock-and-roll, you would go to the rock-and-roll section. You might not know every CD, but you know that a CD has the characteristics of rock-and-roll for it to be in this section.

By knowing the category to which an unfamiliar element belongs, you can predict some of its properties. **Figure 4** shows examples of each category and describes the properties that identify elements in each category.

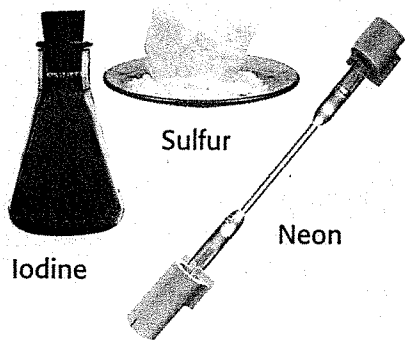
Figure 4 The Three Major Categories of Elements

Metals



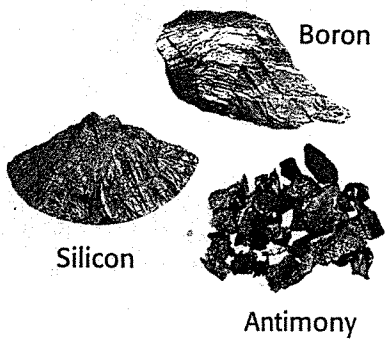
Metals are elements that are shiny and are good conductors of heat and electric current. They are *malleable.* (They can be hammered into thin sheets.) They are also *ductile.* (They can be drawn into thin wires.)

Nonmetals



Nonmetals are elements that are dull (not shiny) and that are poor conductors of heat and electric current. Solids tend to be brittle and unmalleable. Few familiar objects are made of only nonmetals.

Metalloids



Metalloids are also called semiconductors. They have properties of both metals and nonmetals. Some metalloids are shiny. Some are dull. Metalloids are somewhat malleable and ductile. Some metalloids conduct heat and electric current as well.

SECTION Review

Summary

- A substance in which all of the particles are alike is a pure substance.
- An element is a pure substance that cannot be broken down into anything simpler by physical or chemical means.
- Each element has a unique set of physical and chemical properties.
- Elements are classified as metals, nonmetals, or metalloids, based on their properties.

Using Key Terms

1. Use the following terms in the same sentence: *element* and *pure substance.*

Understanding Key Ideas

2. A metalloid
   - **a.** may conduct electric current.
   - **b.** can be ductile.
   - **c.** is also called a semiconductor.
   - **d.** All of the above
3. What is a pure substance?

Math Skills

4. There are eight elements that make up 98.5% of the Earth's crust: 46.6% oxygen, 8.1% aluminum, 5.0% iron, 3.6% calcium, 2.8% sodium, 2.6% potassium, and 2.1% magnesium. The rest is silicon. What percentage of the Earth's crust is silicon?

Critical Thinking

5. **Applying Concepts** From which category of elements would you choose to make a container that wouldn't shatter if dropped? Explain your answer.
6. **Making Comparisons** Compare the properties of metals, nonmetals, and metalloids.
7. **Evaluating Assumptions** Your friend tells you that a shiny element has to be a metal. Do you agree? Explain.

SECTION 2

Compounds

What do salt, sugar, baking soda, and water have in common? You might use all of these to bake bread. Is there anything else similar about them?

Salt, sugar, baking soda, and water are all compounds. Because most elements take part in chemical changes fairly easily, they are rarely found alone in nature. Instead, they are found combined with other elements as compounds.

READING WARM-UP

Objectives

- Explain how elements make up compounds.
- Describe the properties of compounds.
- Explain how a compound can be broken down into its elements.
- Give examples of common compounds.

Terms to Learn

compound

READING STRATEGY

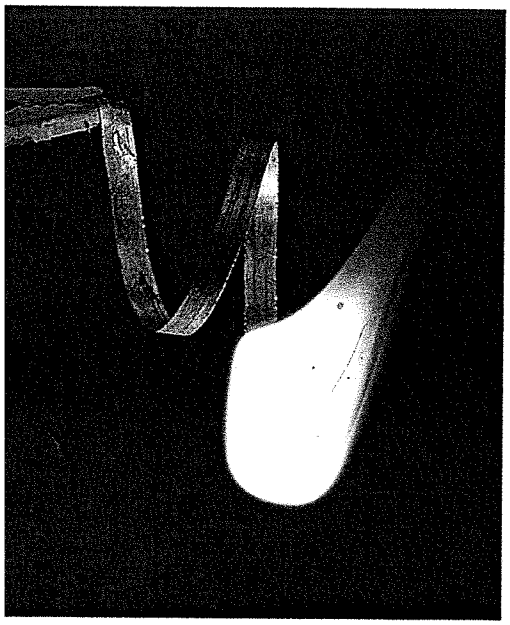
Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Compounds: Made of Elements

A **compound** is a pure substance composed of two or more elements that are chemically combined. Elements combine by reacting, or undergoing a chemical change, with one another. A particle of a compound is a molecule. Molecules of compounds are formed when atoms of two or more elements join together.

In **Figure 1,** you see magnesium reacting with oxygen. A compound called *magnesium oxide* is forming. The compound is a new pure substance. It is different from the elements that make it up. Most of the substances that you see every day are compounds. **Table 1** lists some familiar examples.

Figure 1 *As magnesium burns, it reacts with oxygen and forms the compound magnesium oxide.*



The Ratio of Elements in a Compound

Elements do not randomly join to form compounds. Elements join in a specific ratio according to their masses to form a compound. For example, the ratio of the mass of hydrogen to the mass of oxygen in water is 1 to 8. This mass ratio can be written as 1:8. This ratio is always the same. Every sample of water has a 1:8 mass ratio of hydrogen to oxygen. What happens if a sample of a compound has a different mass ratio of hydrogen to oxygen? The compound cannot be water.

Table 1 **Familiar Compounds**

Compound	Elements combined
Table salt	sodium and chlorine
Water	hydrogen and oxygen
Vinegar	hydrogen, carbon, and oxygen
Carbon dioxide	carbon and oxygen
Baking soda	sodium, hydrogen, carbon, and oxygen

Quick Lab

Compound Confusion

1. Measure **4 g of compound A,** and place it in a **clear plastic cup.**
2. Measure **4 g of compound B**, and place it in a **second clear plastic cup.**
3. Observe the color and texture of each compound. Record your observations.
4. Add **5 mL of vinegar** to each cup. Record your observations.
5. Baking soda reacts with vinegar. Powdered sugar does not react with vinegar. Which compound is baking soda, and which compound is powdered sugar? Explain your answer.

Properties of Compounds

As an element does, each compound has its own physical properties. Physical properties include melting point, density, and color. Compounds can also be identified by their different chemical properties. Some compounds react with acid. For example, calcium carbonate, found in chalk, reacts with acid. Other compounds, such as hydrogen peroxide, react when exposed to light.

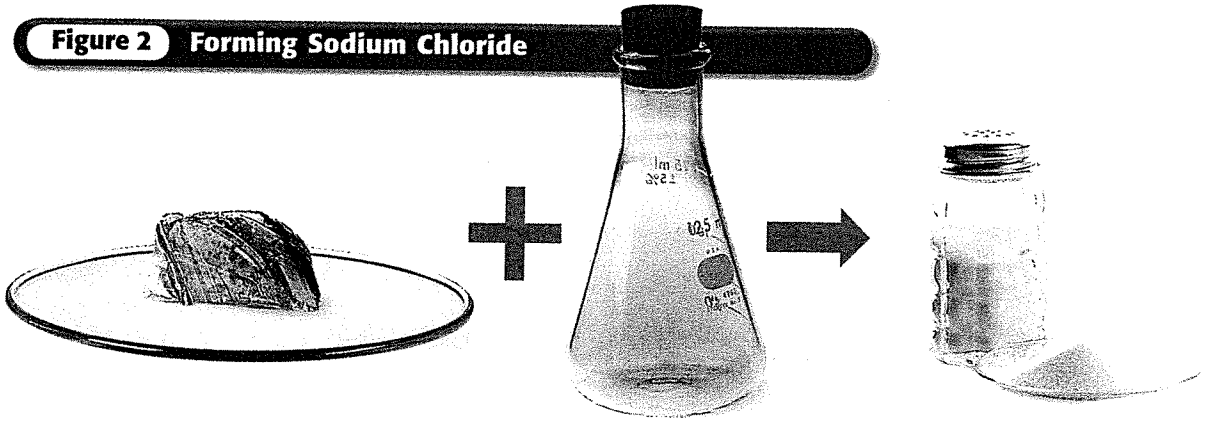
compound a substance made up of atoms of two or more different elements joined by chemical bonds

Reading Check **What are three physical properties used to identify compounds?** *(See the Appendix for answers to Reading Checks.)*

Properties: Compounds Versus Elements

A compound has properties that differ from those of the elements that form it. Look at **Figure 2.** Sodium chloride, or table salt, is made of two very dangerous elements—sodium and chlorine. Sodium reacts violently with water. Chlorine is a poisonous gas. But when combined, these elements form a harmless compound with unique properties. Sodium chloride is safe to eat. It also dissolves (without exploding!) in water.

Figure 2 **Forming Sodium Chloride**



Sodium is a soft, silvery white metal that reacts violently with water.

Chlorine is a poisonous, greenish yellow gas.

Sodium chloride, or table salt, is a white solid. It dissolves easily in water and is safe to eat.

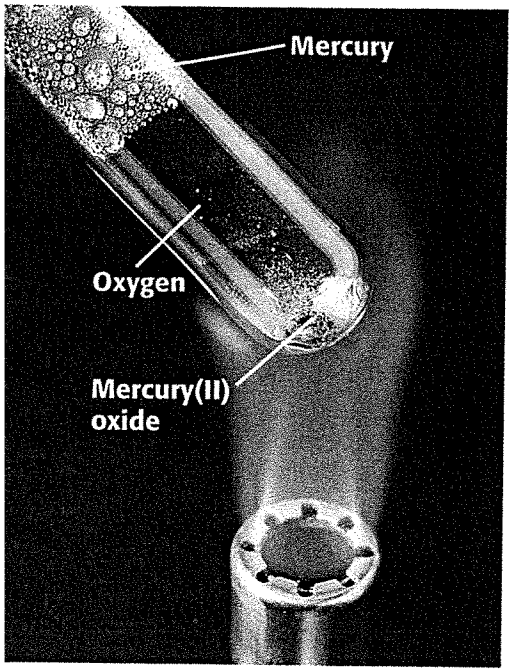


Figure 3 *Heating mercury(II) oxide causes a chemical change that separates it into the elements mercury and oxygen.*

Breaking Down Compounds

Some compounds can be broken down into their elements by chemical changes. Other compounds break down to form simpler compounds instead of elements. These simpler compounds can then be broken down into elements through more chemical changes. For example, carbonic acid is a compound that helps give carbonated beverages their "fizz." When you open a carbonated beverage, carbonic acid breaks down into carbon dioxide and water. Carbon dioxide and water can then be broken down into the elements carbon, oxygen, and hydrogen through chemical changes.

Reading Check **Compounds can be broken down into what two types of substances?**

Methods of Breaking Down Compounds

The only way to break down a compound is through a chemical change. Sometimes, energy is needed for a chemical change to happen. Two ways to add energy to break down a compound are to apply heat and to apply an electric current. For example, heating the compound mercury(II) oxide breaks it down into the elements mercury and oxygen, as shown in **Figure 3.**

Compounds in Your World

You are surrounded by compounds. Compounds make up the food you eat, the school supplies you use, and the clothes you wear—even you!

Compounds in Industry

The compounds found in nature are not usually the raw materials needed by industry. Often, these compounds must be broken down to provide elements or other compounds that can be used as raw material. For example, aluminum is used in cans and airplanes. But aluminum is not found alone in nature. Aluminum is produced by breaking down the compound aluminum oxide. Ammonia is another important compound used in industry. It is used to make fertilizers. Ammonia is made by combining the elements nitrogen and hydrogen.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5MIXW.**

CONNECTION TO Physics

Electrolysis The process of using electric current to break down compounds is known as *electrolysis*. For example, electrolysis can be used to separate water into hydrogen and oxygen. Research ways that electrolysis is used in industry. Make a poster of what you learn, and present a report to your class.

ACTIVITY

Compounds in Nature

Proteins are compounds found in all living things. The element nitrogen is one of the elements needed to make proteins. **Figure 4** shows how some plants get the nitrogen they need. Other plants use nitrogen compounds that are in the soil. Animals get the nitrogen they need by eating plants or by eating animals that have eaten plants. The proteins in the food are broken down as an animal digests the food. The simpler compounds that form are used by the animal's cells to make new proteins.

Another compound that plays an important role in life is carbon dioxide. You exhale carbon dioxide that was made in your body. Plants take in carbon dioxide, which is used in photosynthesis. Plants use photosynthesis to make compounds called carbohydrates. These carbohydrates can then be broken down for energy through other chemical changes by plants or animals.

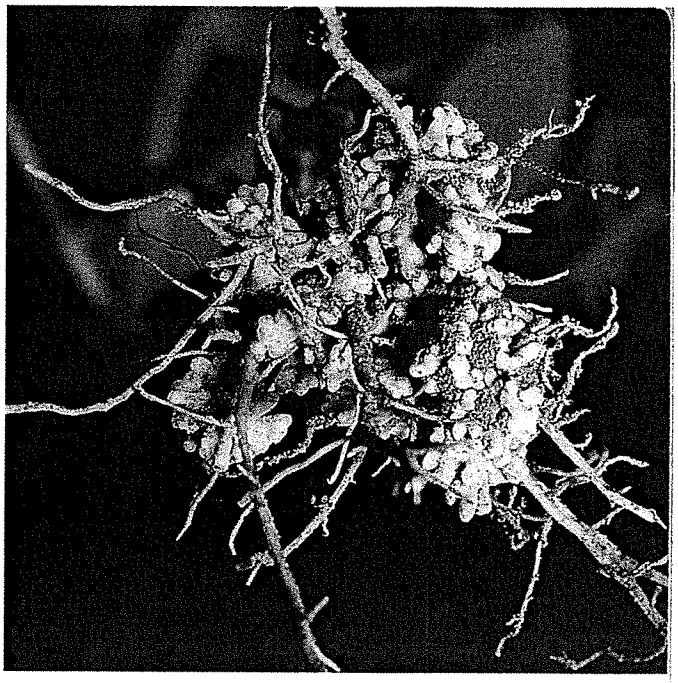


Figure 4 *The bumps on the roots of this pea plant are home to bacteria that form compounds from nitrogen in the air. The pea plant makes proteins from these compounds.*

SECTION Review

Summary

- A compound is a pure substance composed of two or more elements.
- The elements that form a compound always combine in a specific ratio according to their masses.
- Each compound has a unique set of physical and chemical properties that differ from those of the elements that make up the compound.
- Compounds can be broken down into simpler substances only by chemical changes.

Using Key Terms

1. In your own words, write a definition for the term *compound*.

Understanding Key Ideas

2. The elements in a compound
   - **a.** join in a specific ratio according to their masses.
   - **b.** combine by reacting with one another.
   - **c.** can be separated by chemical changes.
   - **d.** All of the above
3. What type of change is needed to break down a compound?

Math Skills

4. Table sugar is a compound made of carbon, hydrogen, and oxygen. If sugar contains 41.86% carbon and 6.98% hydrogen, what percentage of sugar is oxygen?

Critical Thinking

5. **Applying Concepts** Iron is a solid, gray metal. Oxygen is a colorless gas. When they chemically combine, rust is made. Rust has a reddish brown color. Why is rust different from the iron and oxygen that it is made of?
6. **Analyzing Ideas** A jar contains samples of the elements carbon and oxygen. Does the jar contain a compound? Explain your answer.