After you read this section, you should be able to answer these questions:

- What is an element?
- How do elements differ from other materials?
- How are elements classified?

What Are Elements?

Many materials can be broken down into simpler materials. For example, some rocks contain copper. When they are heated in a large furnace, the copper separates from the rest of the rock. Another example is breaking down water by passing electricity through it. The electric current causes hydrogen gas and oxygen gas to form.

Some materials cannot be separated or broken down into other materials. An **element** is a pure substance that cannot be separated into simpler substances by chemical or physical methods. This is how elements are different from all other materials.

A **pure substance** is a material in which all the basic particles are the same. For example, table salt contains particles of sodium chloride. Table salt from anywhere is the same. All pure substances, except for elements, can be broken down into simpler substances. ☑

The basic particles of an element are called **atoms**. Copper is an example of an element. All of the atoms in a piece of pure copper are alike. As shown in the figure below, iron is also an element.

The iron atoms in the meteorite from space are the same as the iron atoms in a steel spoon. There are also iron atoms in the cereal, in the boy’s braces, and even in his blood.

**STUDY TIP**

**Graphic Organizer** In your notebook, make a Concept Map by using the terms element, substance, metal, nonmetal, and metalloid.

**READING CHECK**

1. Compare How does an element differ from other pure substances?

**TAKE A LOOK**

2. Identify Look at the illustration and identify one source of iron that comes to Earth from somewhere else.
How Can Elements Be Classified?

Elements can be classified based on their properties. There are two types of properties, chemical and physical. Physical properties include hardness, melting point, and density. Chemical properties include reactivity and flammability.

We can use properties to tell elements apart. For example, the elements helium and krypton are both colorless, odorless, unreactive gases. However, the elements have different densities (mass per unit volume). Helium is less dense than air, so a helium balloon floats upward. Krypton is denser than air. A krypton-filled balloon, on the other hand, will sink to the floor.

The Unique Properties of Elements

- **Cobalt**
  - Melting point: 1,495°C
  - Density: 8.9 g/cm³
  - Conducts electricity and heat
  - Reactivity: unreactive with oxygen in the air

- **Iron**
  - Melting point: 1,535°C
  - Density: 7.9 g/cm³
  - Conducts electricity and heat
  - Reactivity: reacts by combining with oxygen in the air to form rust.

- **Nickel**
  - Melting point: 1,455°C
  - Density: 8.9 g/cm³
  - Conducts electricity and heat
  - Reactivity: unreactive with oxygen in the air

The figure above shows some of the properties of three different elements. The physical properties shown are melting point, electrical and thermal conductivities, and density. Each element has other physical properties, including color, hardness, and texture. The figure also includes a chemical property: the reactivity of the element with oxygen in the air.

If you had a piece of metal, you could use these properties to determine which element it is. Iron has different physical and chemical properties than the other two elements. The density of iron is much less than cobalt or nickel, and it reacts with oxygen in the air.

We can also use properties to tell nickel and cobalt apart. They have the same density and reactivity, but the melting points of these two elements differ by 40°C. This property can be used to tell them apart.
How Can Elements Be Sorted?

Think about all the different types of dogs that you have seen. Dogs can be classified based on different properties. These include their size, the shape of the ears, or the length of their coat. You can often determine a dog’s breed just with a quick glance. The figure below shows three kinds of terriers. They are not exactly alike, but they share certain features.

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

The elements can be classified based on properties, just like the dogs in the image. There are three major categories of elements: metals, nonmetals, and metalloids. The elements iron, cobalt, and nickel are all metals. They are not exactly alike, but they have similar properties.

Metals tend to be shiny solids (except mercury, which is a shiny liquid). Metals conduct electric current and heat well. Nonmetals do not conduct heat or electric current very well. Many nonmetals are gases. The solid nonmetals have a dull appearance. Metalloids have some of the properties of metals and some of the properties of nonmetals. Metalloids are important in electronics because their electrical conductivity can vary with conditions.

<table>
<thead>
<tr>
<th>Property</th>
<th>Metals</th>
<th>Nonmetals</th>
<th>Metalloids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>shiny</td>
<td>dull</td>
<td>some are shiny</td>
</tr>
<tr>
<td>Conductivity of heat and electricity</td>
<td>good</td>
<td>poor</td>
<td>some do</td>
</tr>
<tr>
<td>Malleable—can be hammered into sheets</td>
<td>yes</td>
<td>no</td>
<td>some are somewhat malleable</td>
</tr>
<tr>
<td>Ductile—can be made into wires</td>
<td>yes</td>
<td>no</td>
<td>some are somewhat ductile</td>
</tr>
<tr>
<td>Brittle</td>
<td>no</td>
<td>yes</td>
<td>some are</td>
</tr>
</tbody>
</table>
Section 1 Review

SECTION VOCABULARY

<table>
<thead>
<tr>
<th>Element</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>element</td>
<td>a substance that cannot be separated or broken down into simpler substances by chemical means</td>
</tr>
<tr>
<td>metal</td>
<td>an element that is shiny and conducts heat and electricity well</td>
</tr>
<tr>
<td>metalloid</td>
<td>an element that has properties of both metals and nonmetals</td>
</tr>
<tr>
<td>nonmetal</td>
<td>an element that conducts heat and electricity poorly</td>
</tr>
<tr>
<td>pure substance</td>
<td>a sample of matter, either a single element or a single compound that has definite chemical and physical properties</td>
</tr>
</tbody>
</table>

1. **Compare**  How does the ability to conduct heat differ between metals and nonmetals?

2. **Classify**  Fill in each blank to complete the table.

<table>
<thead>
<tr>
<th>Element</th>
<th>Property</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>shiny solid</td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>gas</td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td>electrical conductivity varies depending on conditions</td>
<td></td>
</tr>
</tbody>
</table>

3. **Evaluate Assumptions**  Your friend tells you that all of the electric wires in your home are metals. From what you know about elements, explain whether or not this statement is true.

4. **Apply Concepts**  Several elements are placed between panes of glass in double windows to block heat flow. Should these elements be metals or nonmetals? Why?

5. **Calculate**  Two elements, hydrogen and helium, make up most of the atoms in the universe. 92.7% of atoms are hydrogen and 6.9% of atoms are helium. What percentage of atoms are neither hydrogen nor helium? Show your work.
Chapter 4 Elements, Compounds, and Mixtures

SECTION 1 ELEMENTS
1. Elements cannot be separated into simpler substances.
2. the meteorite
3. hardness, melting point, density, boiling point, solubility
4. Because their properties are so similar to iron’s, cobalt and nickel can be used where a strong metal is needed, such as in structures, tools, or vehicles.
5. These properties are too similar in the two elements to be used to tell them apart.
6. small size; short, curly hair; shape of face
7. metals, nonmetals, metalloids

Review
1. Metals are good heat conductors, and nonmetals are poor heat conductors.

<table>
<thead>
<tr>
<th>Element</th>
<th>Property</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>shiny solid</td>
<td>metal</td>
</tr>
<tr>
<td>Oxygen</td>
<td>gas</td>
<td>nonmetal</td>
</tr>
<tr>
<td>Silicon</td>
<td>electrical conductivity (varies depending on conditions)</td>
<td>metalloid</td>
</tr>
</tbody>
</table>

3. Possible answers: Yes, because metals conduct electric current and nonmetals don’t. Yes, because electric wires are made of copper or aluminum, which are metals. No, because some metalloids conduct electric current, so it may be possible to use metalloids as wires.
4. The elements are nonmetals because all of the elements that are gases are nonmetals and because metals conduct heat.
5. 100% – (92.7% + 6.9%) = 0.4%

SECTION 2 COMPOUNDS
1. a pure substance composed of two or more elements that are joined by chemical bonds
2. 1:4
3. Room temperature is about 25°C. This value falls between the melting point and the boiling point of each of the three compounds.
4. sodium
5. They are different.
6. heat
7. proteins and carbohydrates

Review
1. The particles of a compound contain atoms of more than one element. The particles of an element are the atoms of that element.
2. physical, chemical, elements, heat or electricity
3. There was a chemical reaction with something in the air. It formed a new compound that had properties different from those of copper.
4. heat and electricity
5. 1:2

SECTION 3 MIXTURES
1. a physical change
2. The components in the mixtures are not changed.
3. the flame or the burner
4. A pure substance has the same particles throughout, so it cannot separate into layers.
5. the water
6. The ratio of components in a mixture is not fixed, but a compound always has the same elements in the same ratio.
7. the solvent
8. water
9. It is not a solution, because the metals are not spread evenly throughout the coin.
10. Oxygen, carbon dioxide, alcohol, salt, and zinc should be circled.
11. amount of solute and amount of solution
12. You add more than the solubility of sugar in water.
13. 160 g/100 mL of water
14. \[ \text{concentration} = \frac{\text{grams of solute}}{\text{milliliters of solvent}} \]
\[ \text{concentration} = \frac{55 \text{ g}}{500 \text{ mL}} = 0.11 \text{ g/mL} \]
15. low temperatures
16. mixing by stirring, heating the solution, crushing the solid
17. a mixture in which the particles of a material are large enough to settle out
18. by passing it through a filter
19. a mixture in which the particles are spread throughout but are not large enough to settle out