What Are Elements?

Many materials can be broken down into different components. 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 the breakdown of water when electricity is passed through it. The electric current causes hydrogen and oxygen gases 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 of the basic particles are identical. All of the particles of a pure substance are alike, no matter where the substance is found. Pure substances that are not 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.
How Can Elements Be Classified?

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

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

Unique Properties of Elements

Cobalt
- Melting point: 1,495°C
- Density: 8.9 g/cm³
- Conducts electricity and heat.
- Reactivity: Does not react 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: does not react 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, as well, 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, could you determine which of the elements it was, based on these properties? Iron can be distinguished from both other elements by physical and chemical properties. The density of iron is much less than that of either cobalt or nickel, and it reacts with oxygen in the air.

You can’t use those properties to tell nickel and cobalt apart. However, their melting points differ by 40°C. So, you can use melting points to tell them apart.

3. List What are three physical properties that are characteristics of an element?

4. Make Inferences Compare the properties of iron with those of cobalt and nickel. How do you think cobalt and nickel are used in manufactured products?

5. Explain Why can't you use the density or reactivity with air to determine whether a sample is cobalt or nickel?
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 size, ear shape, and length of 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 some properties.

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

The elements can be sorted based on properties, just as the dogs in the illustration can. 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 heat and electric current 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.

### Take a Look

6. Describe What are some of the physical properties that describe terriers?

7. Identify What are the three main categories of elements?

### Reading Check

Explore Applications The properties of metals make them very useful in everyday things. In groups of three or four, make a list of things that you use for cooking that are made of metal. Make another list of things used for cooking that are never made of metal. Discuss why the properties of metals determine which things are in which group.
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 the blanks 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, tell whether or not this statement is true. Explain your answer.

4. Apply Concepts Several elements are used between the panes of glass in double windows designed to block heat flow. From what category are these elements chosen. How do you know?

5. Make Calculations 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 in the universe is neither hydrogen nor helium? Show your work.
After you read this section, you should be able to answer these questions:

• What are compounds made of?
• What happens during a chemical reaction?
• Are the properties of compounds like the properties of the elements used to make them?

What Are Compounds?

Most elements take part in chemical changes fairly easily, so they are rarely found in pure form in nature. Instead, they are found combined with other elements in compounds. A compound is a pure substance composed of two or more elements that are chemically combined. The figure below shows some compounds that you might find in your kitchen and what elements make up those compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Elements combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table salt</td>
<td>sodium and chlorine</td>
</tr>
<tr>
<td>Water</td>
<td>hydrogen and oxygen</td>
</tr>
<tr>
<td>Sugar</td>
<td>hydrogen, carbon, and oxygen</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>carbon and oxygen</td>
</tr>
<tr>
<td>Baking soda</td>
<td>sodium, hydrogen, carbon, and oxygen</td>
</tr>
</tbody>
</table>

A chemical change, or reaction, happens when one or more substances are changed into one or more other substances. During a chemical reaction, new substances form because atoms are rearranged. The properties of a compound can be very different from those of its elements. For example, water is made of hydrogen and oxygen. Both are gases at room temperature. Water is a liquid at room temperature.

In some chemical reactions, two or more elements combine to form a compound. In other chemical reactions, a compound can be separated into elements or simpler compounds. Still other reactions involve changing compounds into other compounds. In all cases, though, different materials exist after the reaction occurs.
What Properties Do Compounds Have?

Just as each element has physical and chemical properties, each compound has characteristic properties. Physical properties of compounds include melting point, boiling point, density, and color. The table below shows some of the physical properties of three colorless liquids. These properties can be used to tell them apart, even though the three compounds look alike in a container.

### Physical Properties

<table>
<thead>
<tr>
<th></th>
<th>Melting point (°C)</th>
<th>Boiling point (°C)</th>
<th>Odor</th>
<th>Density (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroform</td>
<td>−64</td>
<td>61</td>
<td>strong</td>
<td>1.48</td>
</tr>
<tr>
<td>Ethanol</td>
<td>−114</td>
<td>75</td>
<td>mild</td>
<td>0.79</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
<td>100</td>
<td>none</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Chemical properties can be used to identify compounds, too. Chemical properties include changes that occur when compounds are exposed to other chemicals or to heat or light. The figure below shows how the chemical properties of three common white solids differ.

### Chemical Properties

<table>
<thead>
<tr>
<th></th>
<th>Reacts with acid</th>
<th>Flammable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium chloride (salt)</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Sucrose (sugar)</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Sodium bicarbonate (baking soda)</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

The properties of a compound differ, not only from those of other compounds, but also from those of its elements. Sodium chloride is made of two very reactive and toxic elements—sodium and chlorine. Sodium is a metal that reacts violently with water and can cause damage if it touches skin. Chlorine is a poisonous gas. The combination of the two elements results in sodium chloride. Sodium chloride, or table salt, is safe to eat.
SECTION 2 Compounds continued

How Can I Tell Two Compounds Apart?

You can tell one compound from another because every compound has a unique set of properties. This means that a compound can be identified by measuring or observing some of its properties. These properties are different for different compounds. 

Suppose you are given two white powders and told that one is powdered sugar and the other is baking soda. You must identify which is sugar without tasting it. How can you do this? Knowing that baking soda will fizz in an acid like vinegar, but sugar will not, gives you a way to identify the sugar.

You can put each powder into a beaker. Then, add some vinegar to each beaker. The powder that fizzes is the baking soda.

Do Elements Always Combine in the Same Way to Make Compounds?

You may have heard that carbon monoxide is a poisonous gas and that plants use carbon dioxide to make oxygen. How are these compounds different? Carbon monoxide has one carbon atom combined with one oxygen atom. Carbon dioxide has one carbon atom combined with two oxygen atoms.

The properties of a compound depend on which elements combine and how much of each element is in the compound. It is similar to making words from letters. The same letters can be combined to make the words “hose” and “shoe,” but the words are different.

Can Compounds Be Broken Down?

Some compounds can be broken down into their elements by applying heat or using electricity. In the figure below, mercury oxide forms mercury and oxygen.

When mercury oxide is heated, it undergoes a chemical change in which it separates into the elements mercury and oxygen.

READING CHECK
6. Identify How can a compound be identified?

7. Describe What chemical property of baking soda can be used to identify it from sugar?

Say It
Discuss The paragraph to the left compares elements to letters of the alphabet. In small groups, discuss other comparisons that can help you better understand how compounds differ from one another.

TAKE A LOOK
8. Identify What is used to break down the mercury oxide into mercury and oxygen?
Section 2 Review

SECTION VOCABULARY

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

1. Explain How do the basic particles of a compound differ from the basic particles of an element?

__________________________________________________________________________

2. Organize Fill in the Knowledge Web below with words from this section.

   **Compounds**
   - have
   - are made of
   - can be broken down by

   **unique properties**
   - types of properties

3. Draw Conclusions A plant label made of copper is bright and shiny when it is placed in the garden. After a few months, the label has a dull, greenish color. When you rub your finger over the surface, some soft material rubs off. What has happened to the copper?

__________________________________________________________________________

4. Analyze Ideas If a piece of pure iron is placed in pure nitrogen, nothing happens. If the iron is exposed to air, it begins to rust. What conclusion can you make about air, based on this observation?

__________________________________________________________________________

__________________________________________________________________________