2.3 Elements and Compounds

Guide for Reading

Key Concepts

- How are elements and compounds different?
- How can substances and mixtures be distinguished?
- What do chemists use to represent elements and compounds?

Vocabulary

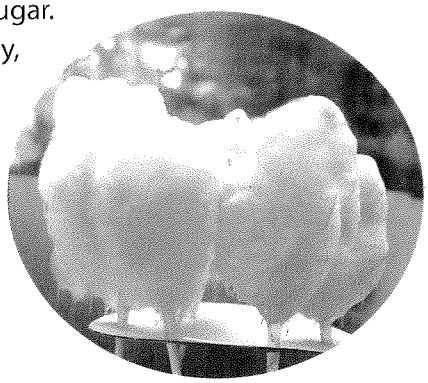
element
compound
chemical change
chemical symbol

Reading Strategy

Relating Text and Visuals As you read, look at Figure 2.10. Explain how this illustration helps you understand the relationship between different kinds of matter.

Connecting to Your World

Take two pounds of sugar, two cups of boiling water, and one-quarter teaspoon of cream of tartar. You have the ingredients to make spun sugar. Add food coloring and you have the sticky, sweet concoction sold at baseball games and amusement parks as cotton candy. Sugar is a substance that contains three other substances—carbon, hydrogen, and oxygen. In this section, you will learn how substances are classified as elements or compounds.



Distinguishing Elements and Compounds

Substances can be classified as elements or compounds. An **element** is the simplest form of matter that has a unique set of properties. Oxygen and hydrogen are two of the more than 100 known elements. A **compound** is a substance that contains two or more elements chemically combined in a fixed proportion. For example, carbon, oxygen, and hydrogen are chemically combined in the compound sucrose, the sugar in spun sugar. (Sometimes sucrose is referred to as table sugar to distinguish it from other sugar compounds.) In every sample of sucrose there are twice as many hydrogen particles as oxygen particles. The proportion of hydrogen particles to oxygen particles in sucrose is fixed. There is a key difference between elements and compounds. **Compounds can be broken down into simpler substances by chemical means, but elements cannot.**

Breaking Down Compounds Physical methods that are used to separate mixtures cannot be used to break a compound into simpler substances. Boil liquid water and you get water vapor, not the oxygen and hydrogen that water contains. Dissolve a sugar cube in water and you still have sucrose, not oxygen, carbon, and hydrogen. This result does not mean that sucrose or water cannot be broken down into simpler substances. But the methods must involve a chemical change. A **chemical change** is a change that produces matter with a different composition than the original matter. Heating is one of the processes used to break down compounds into simpler substances. The layer of sugar in Figure 2.9 is heated in a skillet until it breaks down into solid carbon and water vapor. Can the substances that are produced also be broken down?

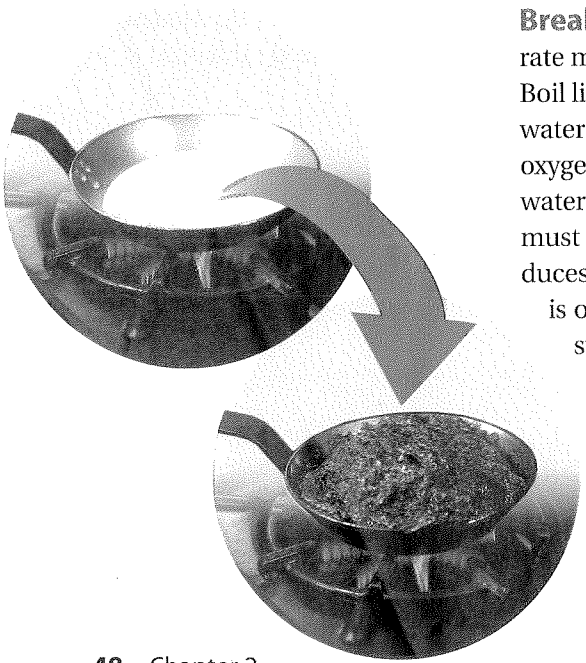
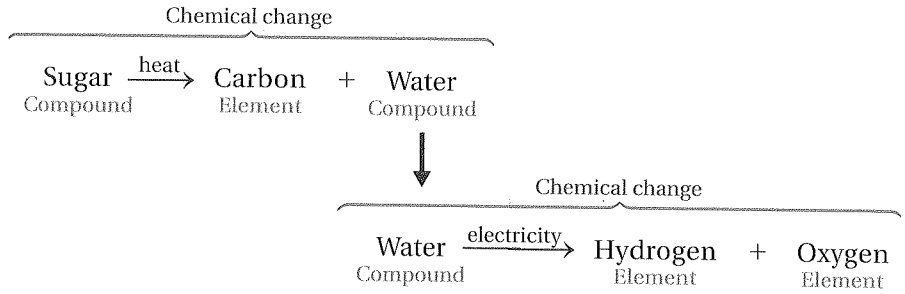


Figure 2.9 When table sugar is heated, it goes through a series of chemical changes. The final products of these changes are solid carbon and water vapor.

There is no chemical process that will break down carbon into simpler substances because carbon is an element. Heating will not cause water to break down, but electricity will. When an electric current passes through water, oxygen gas and hydrogen gas are produced. The following diagram summarizes the overall process.



Properties of Compounds In general, the properties of compounds are quite different from those of their component elements. Sugar is a sweet-tasting, white solid, but carbon is a black, tasteless solid. Hydrogen is a gas that burns in the presence of oxygen—a colorless gas that supports burning. The product of this chemical change is water, a liquid that can stop materials from burning. Figure 2.10 shows samples of table salt (sodium chloride), sodium, and chlorine. When the elements sodium and chlorine combine chemically to form sodium chloride, there is a change in composition and a change in properties. Sodium is a soft, gray metal. Chlorine is a pale yellow-green poisonous gas. Sodium chloride is a white solid.

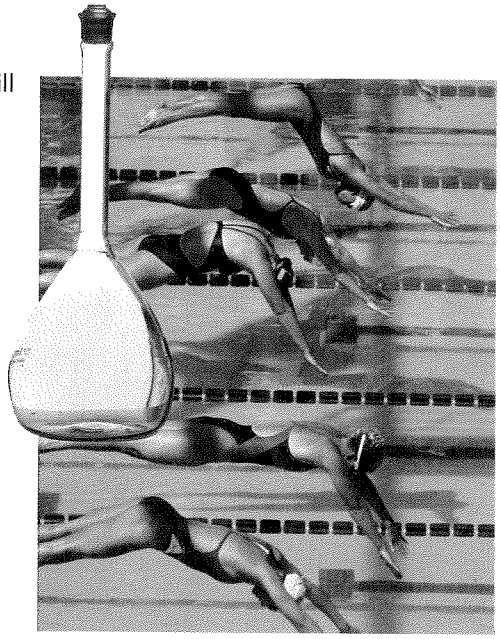
Checkpoint ***What process can be used to break down water?***

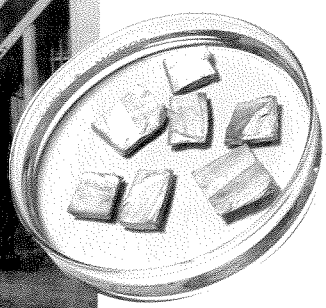
Word *Origins*

Compound comes from a Latin word *componere*, meaning "to put together." Elements are put together, or chemically combined, in compounds. **What items are put together in a compound sentence?**

Figure 2.10 Compounds and the elements from which they form have different properties. **Observing** ***Based on the photographs, describe two physical properties of sodium and two of chlorine.***

Chlorine is used to kill harmful organisms in swimming pools.





Sodium is stored under oil to keep it from reacting with oxygen or water vapor in air. Sodium vapor produces the light in some street lamps.

Sodium chloride (commonly known as table salt) is used to season or preserve food.

Distinguishing Substances and Mixtures

Deciding whether a sample of matter is a substance or a mixture based solely on appearance can be difficult. After all, homogeneous mixtures and substances will both appear to contain only one kind of matter. Sometimes you can decide by considering whether there is more than one version of the material in question. For example, you can buy whole milk, low-fat milk, no-fat milk, light cream, and heavy cream. From this information, you can conclude that milk and cream are mixtures. You might infer that these mixtures differ in the amount of fat they contain. Most gas stations offer at least two blends of gasoline. The blends have different octane ratings and different costs per gallon, with premium blends costing more than regular blends. So gasoline must be a mixture.

You can use their general characteristics to distinguish substances from mixtures. **If the composition of a material is fixed, the material is a substance. If the composition of a material may vary, the material is a mixture.** Figure 2.11 summarizes the general characteristics of elements, compounds, and mixtures.

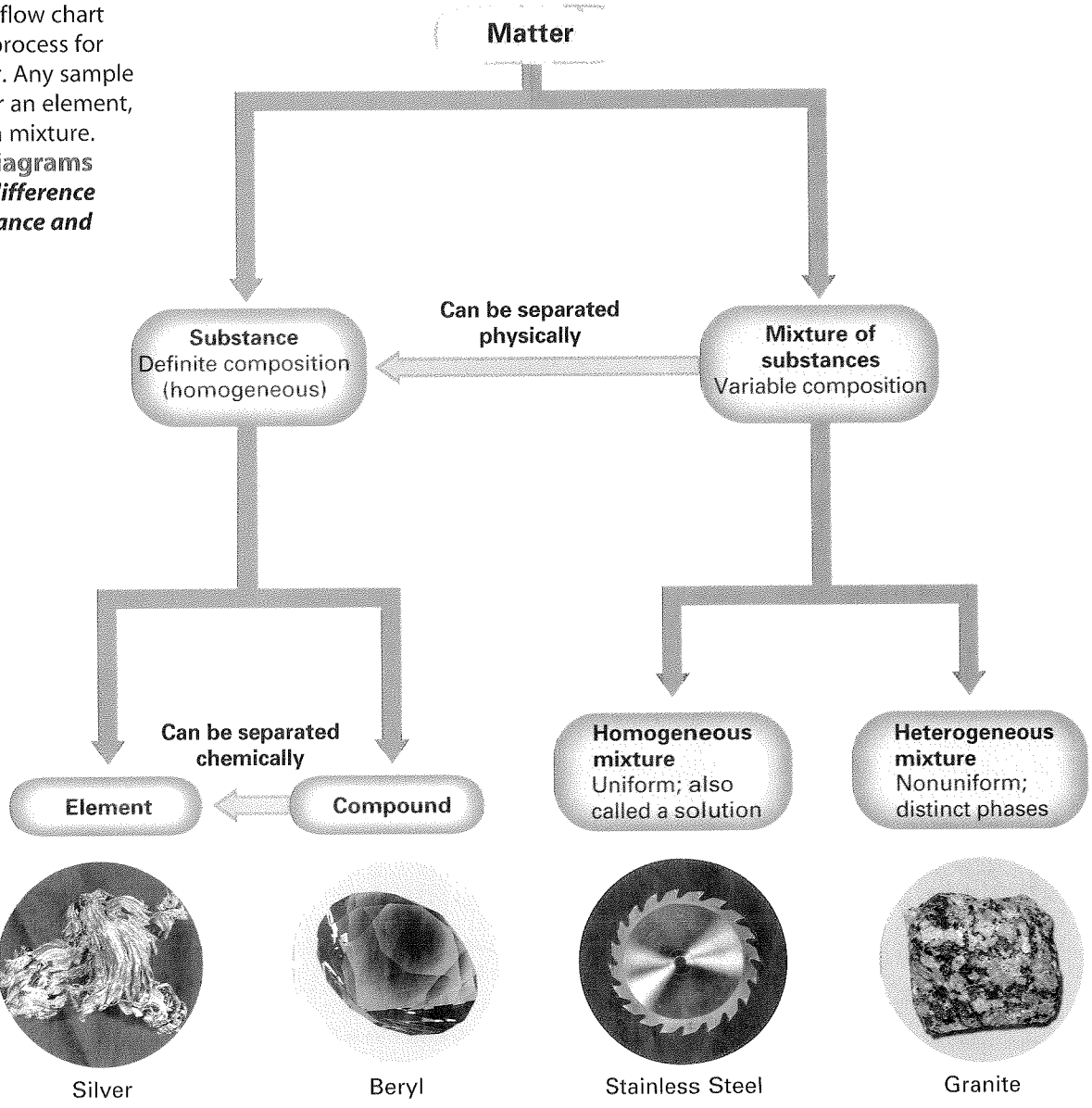
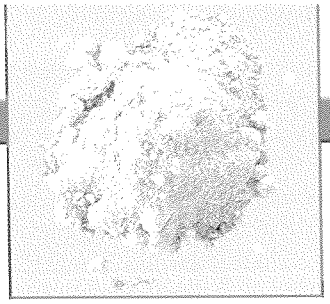


Figure 2.11 The flow chart summarizes the process for classifying matter. Any sample of matter is either an element, a compound, or a mixture.
Interpreting Diagrams ***What is the key difference between a substance and a solution?***

CONCEPTUAL PROBLEM 2.2



Classifying Materials

When the blue-green solid in the photograph is heated, a colorless gas and a black solid form. All three materials are substances. Is it possible to classify these substances as elements or compounds?

1 Analyze ***Identify the relevant concepts.***

List the known facts and relevant concepts.

- A blue-green solid is heated.
- A colorless gas and a black solid appear.
- A compound can be broken down into simpler substances by a chemical change, but an element cannot.
- Heating can cause a chemical change.

2 Solve ***Apply concepts to this situation.***

Determine if the substances are elements or compounds. Before heating, there was one substance. After heating there were two substances. The blue-green solid must be a compound. Based on the information given, it isn't possible to know if the colorless gas or black solid are elements or compounds.

Practice Problems

18. Liquid A and Liquid B are clear liquids. They are placed in open containers and allowed to evaporate. When evaporation is complete, there is a white solid in container B, but no solid in container A. From these results, what can you infer about the two liquids?

19. A clear liquid in an open container is allowed to evaporate. After three days, a solid is left in the container. Was the clear liquid an element, a compound, or a mixture? How do you know?

Interactive Textbook

Problem Solving 2.19 Solve Problem 19 with the help of an interactive guided tutorial.

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Symbols and Formulas

The common names water and table salt do not provide information about the chemical composition of these substances. Also, words are not ideal for showing what happens to the composition of matter during a chemical change. **Chemists use chemical symbols to represent elements, and chemical formulas to represent compounds.**

Using symbols to represent different kinds of matter is not a new idea. Figure 2.12 shows some symbols that were used in earlier centuries. The symbols used today for elements are based on a system developed by a Swedish chemist, Jöns Jacob Berzelius (1779–1848). He based his symbols on the Latin names of elements. Each element is represented by a one- or two-letter **chemical symbol.** The first letter of a chemical symbol is always capitalized. When a second letter is used, it is lowercase.

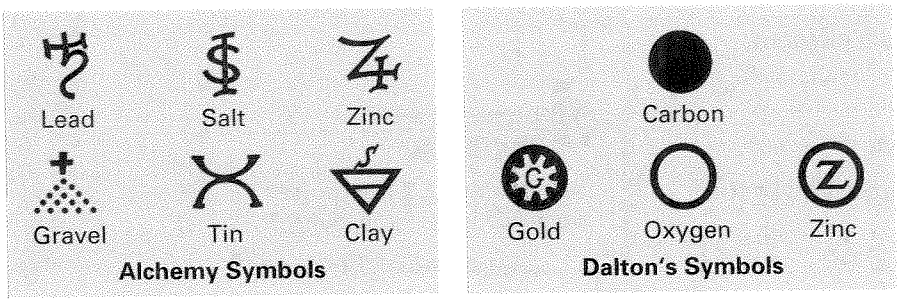

Figure 2.12 The symbols used to represent elements have changed over time. Alchemists and the English chemist John Dalton (1766–1844) both used drawings to represent chemical elements. Today, elements are represented by one- or two-letter symbols.

Table 2.2

Symbols and Latin Names for Some Elements

Name	Symbol	Latin name
Sodium	Na	*natrium*
Potassium	K	*kalium*
Antimony	Sb	*stibium*
Copper	Cu	*cuprum*
Gold	Au	*aurum*
Silver	Ag	*argentum*
Iron	Fe	*ferrum*
Lead	Pb	*plumbum*
Tin	Sn	*stannum*

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If the English name and the Latin name of an element are similar, the symbol will appear to have been derived from the English name. Examples include Ca for calcium, N for nitrogen, and S for sulfur. Table 2.2 shows examples of elements where the symbols do not match the English names.

Chemical symbols provide a shorthand way to write the chemical formulas of compounds. The symbols for hydrogen, oxygen, and carbon are H, O, and C. The formula for water is H_2O. The formula for sucrose, or table sugar, is $C_{12}H_{22}O_{11}$. Subscripts in chemical formulas are used to indicate the relative proportions of the elements in the compound. For example, the subscript 2 in H_2O indicates that there are always two parts of hydrogen for each part of oxygen in water. Because a compound has a fixed composition, the formula for a compound is always the same.

2.3 Section Assessment

20. **Key Concept** How is a compound different from an element?

21. **Key Concept** How can you distinguish a substance from a mixture?

22. **Key Concept** What are chemical symbols and chemical formulas used for?

23. Name two methods that can be used to break down compounds into simpler substances.

24. Classify each of these samples of matter as an element, a compound, or a mixture.

a. table sugar **b.** tap water
c. cough syrup **d.** nitrogen

25. Write the chemical symbol for each element.

a. lead **b.** oxygen
c. silver **d.** sodium
e. hydrogen **f.** aluminum

26. Name the chemical elements represented by the following symbols.

a. C **b.** Ca **c.** K **d.** Au **e.** Fe **f.** Cu

27. What elements make up the pain reliever acetaminophen, chemical formula $C_8H_9O_2N$? Which element is present in the greatest proportion by number of particles?

Writing Activity

Compare and Contrast Paragraph Compare and contrast elements and compounds. Compare them by saying how they are alike. Contrast them by describing how they are different.

Interactive Textbook

Assessment 2.3 Test yourself on the concepts in Section 2.3.

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