2.3

1 FOCUS

Objectives

2.3.1 Explain the difference between an element and a compound.

2.3.2 Distinguish between a substance and a mixture.

2.3.3 Identify the chemical symbols of elements, and **name** elements, given their symbols.

Guide for Reading

Build Vocabulary L2

Word Forms Compare the common meanings of *element, elemental,* and *elementary* in relation to the specific use of *element* in chemistry. In their broadest sense, the terms refer to fundamentals, first principles, or basics.

Reading Strategy L2

Preview Before students read the section, have them preview the headings to get an overall sense or the content.

2 INSTRUCT

Connecting to Your World

Ask students if they have ever eaten cotton candy. Ask those who have to describe its properties. Explain that its sweet taste is due to a sugar called sucrose, which is a compound.

Distinguishing Elements and Compounds

Use Visuals L1

Compare the chemical change of sugar shown on R29 with the one shown in Figure 2.9. Ask, **What is similar about the changes?** *(Sugar breaks down into solid carbon and water vapor.)* **What is different?** *(In one case, heating causes the change; in the other, the addition of an acid.)* You can also compare the electrolysis of water to the distillation of water (Section 2.2).

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?

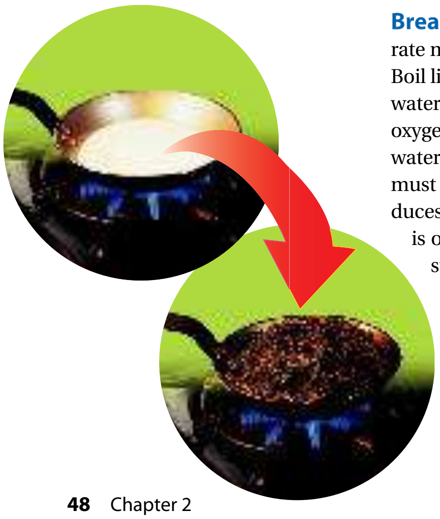


Figure 2.9 When table sugar is heated, it goes through a series of chemical changes. The final products of these changes are solid carbon and water vapor.

Section Resources

Print

- **Guided Reading and Study Workbook,** Section 2.3
- **Core Teaching Resources,** Section 2.3 Review, Interpreting Graphics
- **Transparencies,** T15–T17

Technology

- **Interactive Textbook with ChemASAP,** Problem-Solving 2.19, Assessment 2.3
- **Go Online,** Section 2.3

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.

Chemical change

Sugar (Compound) $\xrightarrow{\text{heat}}$ Carbon (Element) + Water (Compound)

↓

Chemical change

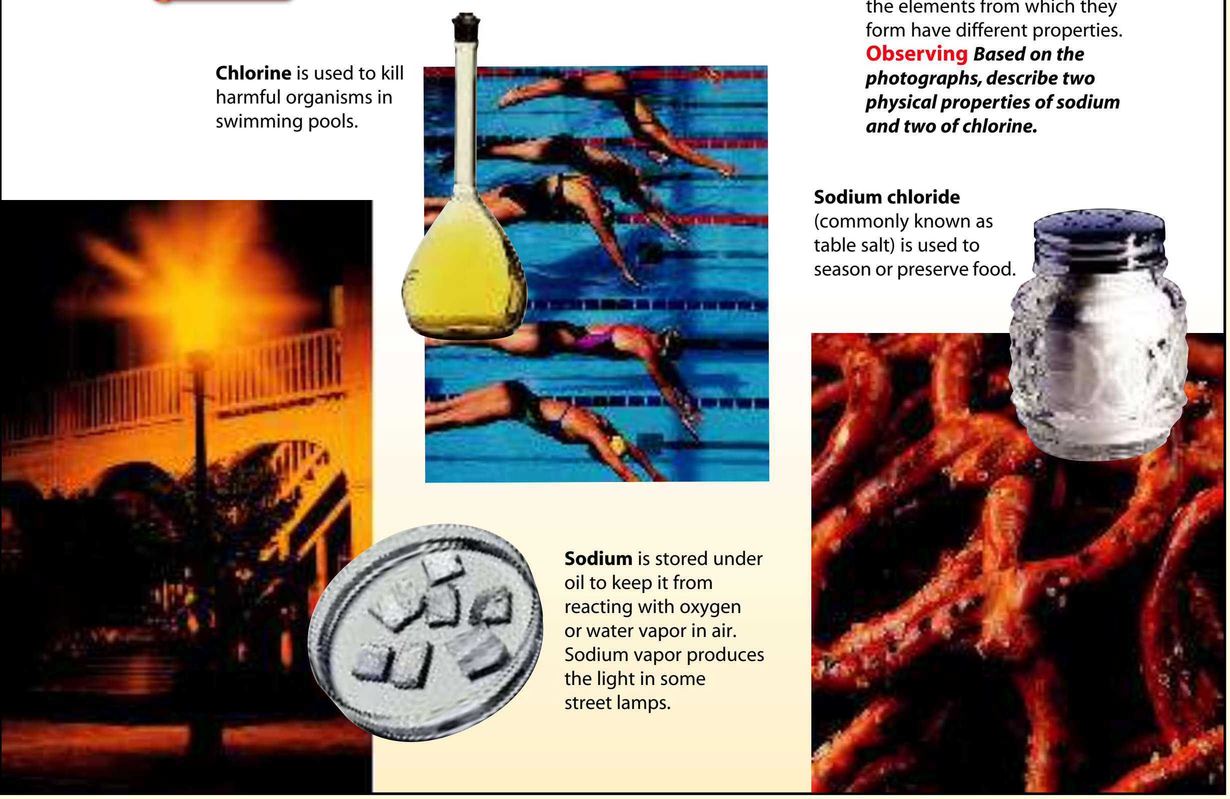
Water (Compound) $\xrightarrow{\text{electricity}}$ Hydrogen (Element) + Oxygen (Element)

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?**



Chlorine is used to kill harmful organisms in swimming pools.

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

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.

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.***

TEACHER Demo

Decomposition of Sugar L2

Purpose Students will observe the decomposition of sugar by acid.

Materials 100-mL beaker, powdered sugar, 18*M* sulfuric acid, glass stirring rod

Safety Perform the demo in a fume hood or in a well-ventilated area and be sure to wear safety goggles. **CAUTION** *This is an extremely exothermic reaction.*

Procedure Place about 25 g of powdered sugar in a 100-mL beaker. Carefully add about 10–15 mL of 18*M* sulfuric acid, and stir rapidly with a glass rod.

Disposal Place the cooled beaker and its contents in a large beaker and add water. Neutralize with NaOH and pour the liquid down the drain, flushing with excess water. Throw the solid residue in the trash.

Expected Outcome The mixture turns dark and a column of carbon rises out of the beaker.

Word *Origins* L2

A compound sentence contains two independent clauses, each with a subject and a verb. The two clauses are joined by a conjunction.

Relate L2

Refer students to *Salt of the Earth* on page R9 of the Elements Handbook for a discussion of the historic importance of table salt.

FYI

In the Small-Scale lab in Chapter 21, students will learn that the electrolysis of water doesn't work with pure water.

Differentiated Instruction

Gifted and Talented L3

Other forms of energy besides electricity can be used to bring about the decomposition of water into hydrogen and oxygen. Ask students to consider whether heat could be used for this purpose. Tell them that early chemists considered water to be an element because it would not decompose when heated. Have students do research on the conditions necessary to decompose water using heat. What hazards, if any, might preclude the routine use of this method?

Answers to...

Figure 2.10 sodium: gray color, shiny, solid at room temperature; chlorine: yellow-green color, gas at room temperature.

Checkpoint passing an electric current through water

Distinguishing Substances and Mixtures

Use Visuals L1

Figure 2.11 Have students study the figure. Then ask, **Can compounds be separated into their component elements by physical processes?** *(No, they must be separated by chemical processes.)*

CLASS Activity

Substances L2

Purpose To establish the definition of *substance*, using an inductive approach.

Materials 20 index cards, masking tape

Procedure Make signs with the names of each of these items: 1 oxygen, 2 neon, 3 apple, 4 sand, 5 iron, 6 water, 7 air, 8 paint, 9 sodium chloride, 10 sucrose, 11 carbon dioxide, 12 granite, 13 laundry detergent, 14 citric acid, 15 cereal, 16 salad, 17 salad dressing, 18 copper, 19 ocean water, 20 gold. Using masking tape and the board or wall, create two columns. Place items 1 and 2 under Column A and items 3 and 4 under Column B. Ask students to think about the criteria for each column. Then place item 5 in Column A. Students may have to change their criteria. Place item 6 in Column A. Ask students what they think the criteria are now. Continue placing one item up at a time in a column until students understand the criteria. Everything in Column A has a uniform and definite composition.

Expected Outcome Column A is for substances. Column A: 1, 2, 5, 6, 9, 10, 11, 14, 18, 20. Column B is for mixtures. Column B: 3, 4, 7, 8, 12, 13, 15, 16, 17, 19. Make sure students understand the difference between the uniform composition of a substance and of a solution. The composition of the substance is fixed. The composition of the mixture can vary.

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.

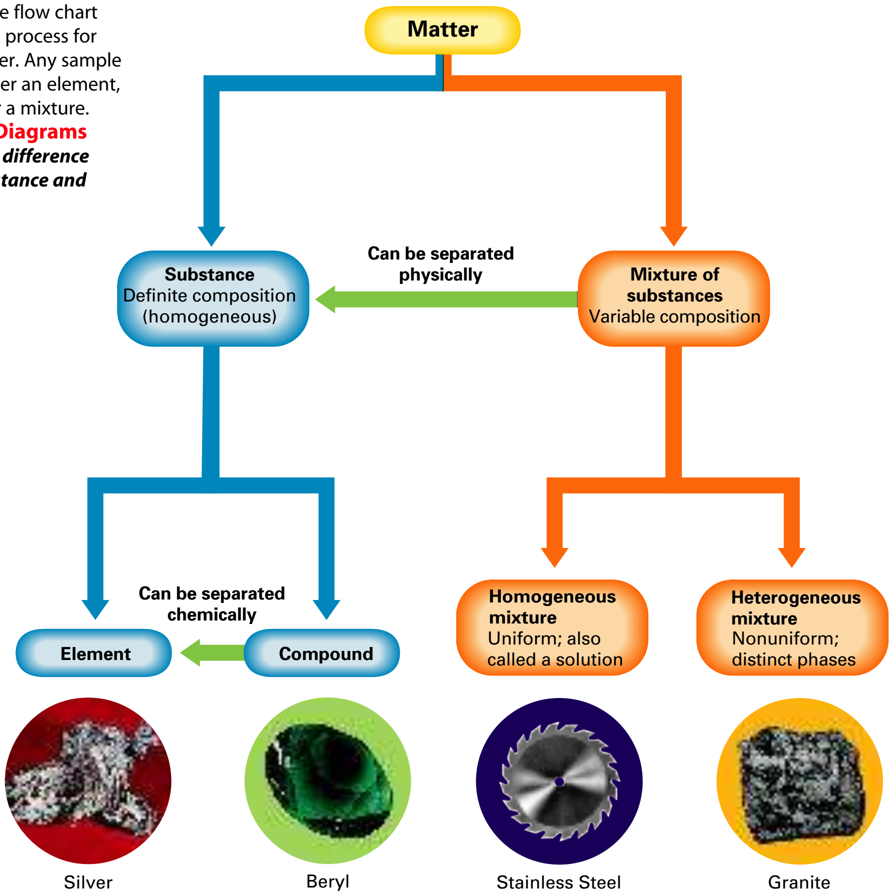


Figure 2.11 The flow chart summarizes the process for classifying matter. Any sample of matter is either an element, a compound, or a mixture. **Interpreting Diagrams** ***What is the key difference between a substance and a solution?***

Facts and Figures

Origins of Element Names

Many elements were named for the people who discovered them or the places where they were discovered. Some elements were given descriptive names taken from classical Latin or Greek. Others were named for figures in mythology. Polonium is named for Poland, the native land of Marie Curie, who discovered radium. Californium was discovered at the University of California. The name chlorine comes from the Greek *chloros*, meaning greenish-yellow. Chlorine is a greenish-yellow gas. The name calcium is derived from the Latin *calx*, meaning lime. Calcium is a major component of limestone. Students can find the origins of element names by consulting a dictionary or encyclopedia.

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.

with ChemASAP

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.

CONCEPTUAL PROBLEM 2.2

Answers

18. Liquid A is probably a substance. Liquid B is a mixture.

19. The liquid was not an element because a solid was left when the liquid evaporated. A physical process, such as evaporation, cannot be used to break down a compound. Therefore, the liquid was a mixture.

Practice Problems Plus L2

Classify the following materials as an element, compound, or mixture. Give reasons for your answers.

a. table salt (NaCl) (*compound; its formula shows that it is composed of at least two elements)*

b. salt water *(mixture; its name suggests that it is composed of at least two substances)*

c. sodium (Na) *(element; its symbol shows that it is composed of only one kind of matter)*

Symbols and Formulas

Discuss L2

Point out that the use of chemical symbols is an example of the "international language of chemistry." Discuss why people all over the world use the same set of chemical symbols. Show how symbols are used in chemical formulas. Emphasize that a compound is always made up of the same elements in the same proportions.

CLASS Activity

Timeline of Discovery L2

To help students explore the history of science, have the class work as a group to make a timeline for the discovery of elements. Refer them to the data on dates of discovery in the Elements Handbook. Students could use the timeline to detect shifts in naming conventions.

Answers to...

Figure 2.11 *The composition of a substance is fixed; the composition of a solution may vary.*

Differentiated Instruction

Less Proficient Readers/ English Learners L1

Have students make flash cards to help learn the names and symbols of at least 30 elements. If an element has a different common name in the student's native country, have the student include that information on the flash card.

Go Online NSTA SCI LINKS

Download a worksheet on **Element Names** for students to complete, and find additional teacher support from NSTA SciLinks.

3 ASSESS

Evaluate Understanding L2

Ask students to explain in their own words the difference between an element and a compound.

Reteach L1

Set up a display of elements in the classroom to help students relate abstract chemical symbols to actual samples. Have students present oral reports about the physical properties of elements and refer to the display.

Writing Activity

Elements and compounds are alike in that they both are substances of fixed composition. They are different in that elements cannot be separated into simpler substances through chemical changes.

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 2.3.

with ChemASAP

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*

Go Online NSTA SCI LINKS

For: Links on Element Names
Visit: www.SciLinks.org
Web Code: cdn-1023

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.

with ChemASAP

52 Chapter 2

Section 2.3 Assessment

20. Compounds can be broken down into simpler substances by chemical means, but elements cannot.
21. A substance has a fixed composition. The composition of a mixture may vary.
22. Chemical symbols are used to represent elements. Chemical formulas are used to represent compounds.
23. heating or an electric current
24. a. compound **b.** mixture **c.** mixture **d.** element
25. a. Pb **b.** O **c.** Ag **d.** Na **e.** H **f.** Al
26. a. carbon **b.** calcium **c.** potassium **d.** gold **e.** iron **f.** copper
27. Carbon, hydrogen, oxygen, and nitrogen; hydrogen is present in the greatest proportion by number of atoms.