SECTION

1 What Is Chemistry?

KEY TERMS

- chemical
- chemical reaction
- states of matter
- reactant
- product

OBJECTIVES

1. **Describe** ways in which chemistry is a part of your daily life.
2. **Describe** the characteristics of three common states of matter.
3. **Describe** physical and chemical changes, and give examples of each.
4. **Identify** the reactants and products in a chemical reaction.
5. **List** four observations that suggest a chemical change has occurred.

Working with the Properties and Changes of Matter

Do you think of chemistry as just another subject to be studied in school? Or maybe you feel it is important only to people working in labs? The effects of chemistry reach far beyond schools and labs. It plays a vital role in your daily life and in the complex workings of your world.

Look at **Figure 1.** Everything you see, including the clothes the students are wearing and the food the students are eating, is made of chemicals. The students themselves are made of chemicals! Even things you cannot see, such as air, are made up of chemicals.

Chemistry is concerned with the properties of chemicals and with the changes chemicals can undergo. A **chemical** is any substance that has a definite composition—it's always made of the same stuff no matter where the chemical comes from. Some chemicals, such as water and carbon dioxide, exist naturally. Others, such as polyethylene, are manufactured. Still others, such as aluminum, are taken from natural materials.

chemical

any substance that has a defined composition

Figure 1
Chemicals make up everything you see every day.

You Depend on Chemicals Every Day

Many people think of chemicals in negative terms—as the cause of pollution, explosions, and cancer. Some even believe that chemicals and chemical additives should be banned. But just think what such a ban would mean—after all, everything around you is composed of chemicals. Imagine going to buy fruits and vegetables grown without the use of any chemicals at all. Because water is a chemical, the produce section would be completely empty! In fact, the entire supermarket would be empty because all foods are made of chemicals.

The next time you are getting ready for school, look at the list of ingredients in your shampoo or toothpaste. You'll see an impressive list of chemicals. Without chemicals, you would have nothing to wear. The fibers of your clothing are made of chemicals that are either natural, such as cotton or wool, or synthetic, such as polyester. The air you breathe, the food you eat, and the water you drink are made up of chemicals. The paper, inks, and glue used to make the book you are now reading are chemicals, too. You yourself are an incredibly complex mixture of chemicals.

Chemical Reactions Happen All Around You

You will learn in this course that changes in chemicals—or **chemical reactions**—are taking place around you and inside you. Chemical reactions are necessary for living things to grow and for dead things to decay. When you cook food, you are carrying out a chemical reaction. Taking a photograph, striking a match, switching on a flashlight, and starting a gasoline engine require chemical reactions.

Using reactions to manufacture chemicals is a big industry. **Table 1** lists the top eight chemicals made in the United States. Some of these chemicals may be familiar, and some you may have never heard of. By the end of this course, you will know a lot more about them. Chemicals produced on a small scale are important, too. Life-saving antibiotics, cancer-fighting drugs, and many other substances that affect the quality of your life are also products of the chemical industry.

chemical reaction

the process by which one or more substances change to produce one or more different substances

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Table 1 Top Eight Chemicals Made in the United States (by Weight)

Rank	Name	Formula	Uses
1	sulfuric acid	H_2SO_4	production of fertilizer; metal processing; petroleum refining
2	ethene	C_2H_4	production of plastics; ripening of fruits
3	propylene	C_3H_6	production of plastics
4	ammonia	NH_3	production of fertilizer; refrigeration
5	chlorine	Cl_2	bleaching fabrics; purifying water; disinfectant
6	phosphoric acid (anhydrous)	P_2O_5	production of fertilizer; flavoring agent; rustproofing metals
7	sodium hydroxide	NaOH	petroleum refining; production of plastics
8	1,2-dichloroethene	$C_2H_2Cl_2$	solvent, particularly for rubber

Source: ***Chemical and Engineering News.***

Physical States of Matter

states of matter

the physical forms of matter, which are solid, liquid, gas, and plasma

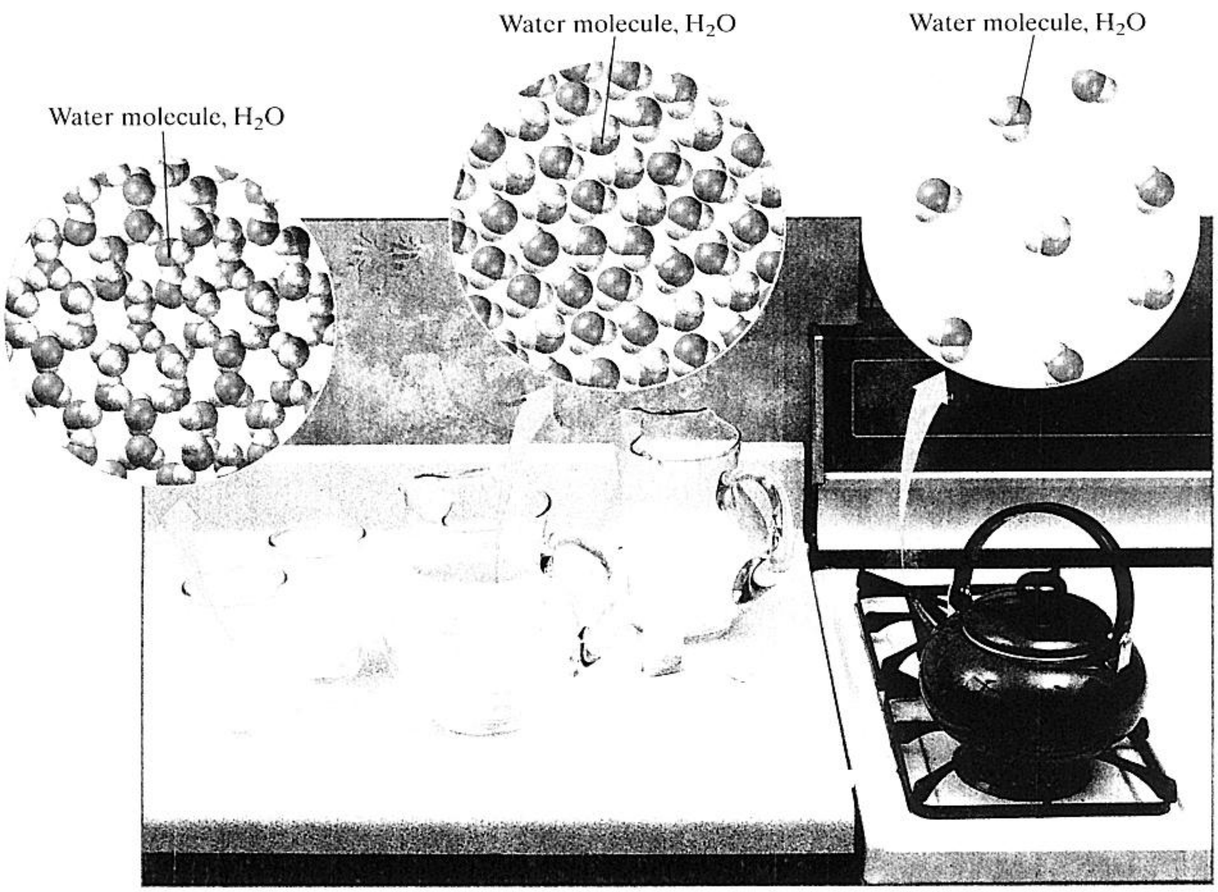
All matter is made of particles. The type and arrangement of the particles in a sample of matter determine the properties of the matter. Most of the matter you encounter is in one of three **states of matter:** solid, liquid, or gas. **Figure 2** illustrates water in each of these three states at the macroscopic and microscopic levels. *Macroscopic* refers to what you see with the unaided eye. In this text, *microscopic* refers to what you would see if you could see individual atoms.

The microscopic views in this book are models that are designed to show you the differences in the arrangement of particles in different states of matter. They also show you the differences in size, shape, and makeup of particles of chemicals. But don't take these models too literally. Think of them as cartoons. Atoms are not really different colors. And groups of connected atoms, or molecules, do not look lumpy. The microscopic views are also limited in that they often show only a single layer of particles whereas the particles are really arranged in three dimensions. Finally, the models cannot show you that particles are in constant motion.

Figure 2
a Below 0°C, water exists as ice. Particles in a solid are in a rigid structure and vibrate in place.

b Between 0°C and 100°C, water exists as a liquid. Particles in a liquid are close together and slide past one another.

c Above 100°C, water is a gas. Particles in a gas move randomly over large distances.



Properties of the Physical States

Solids have fixed volume and shape that result from the way their particles are arranged. Particles that make up matter in the solid state are held tightly in a rigid structure. They vibrate only slightly.

Liquids have fixed volume but not a fixed shape. The particles in a liquid are not held together as strongly as those in a solid. Like grains of sand, the particles of a liquid slip past one another. Thus, a liquid can flow and take the shape of its container.

Gases have neither fixed volume nor fixed shape. Gas particles weakly attract one another and move independently at high speed. Gases will fill any container they occupy as their particles move apart.

There are other states that are beyond the scope of this book. For example, most visible matter in the universe is plasma—a gas whose particles have broken apart and are charged. Bose-Einstein condensates have been described at very low temperatures. A neutron star is also considered by some to be a state of matter.

Changes of Matter

Many changes of matter happen. An ice cube melts. Your bicycle's spokes rust. A red shirt fades. Water fogs a mirror. Milk sours. Scientists who study these and many other events classify them by two broad categories: *physical changes* and *chemical changes.*

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Physical Changes

Physical changes are changes in which the identity of a substance doesn't change. However, the arrangement, location, and speed of the particles that make up the substance may change. Changes of state are physical changes. The models in **Figure 2** show that when water changes state, the arrangement of particles changes, but the particles stay water particles. As sugar dissolves in the tea in **Figure 3,** the sugar molecules mix with the tea, but they don't change what they are. The particles are still sugar. Crushing a rock is a physical change because particles separate but do not change identity.

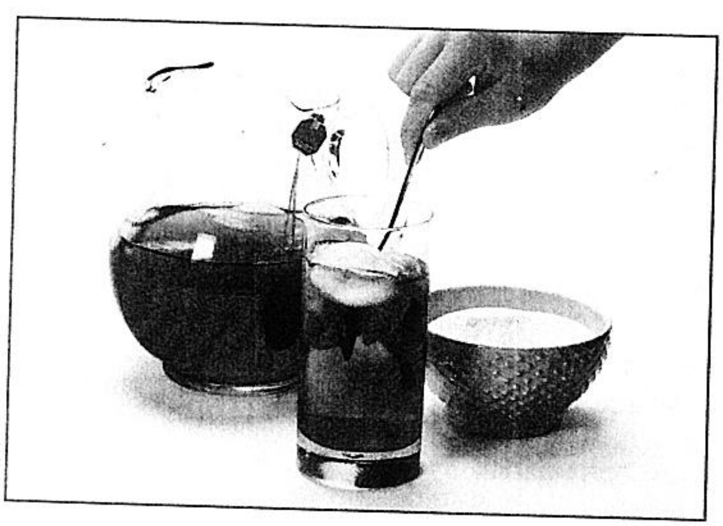
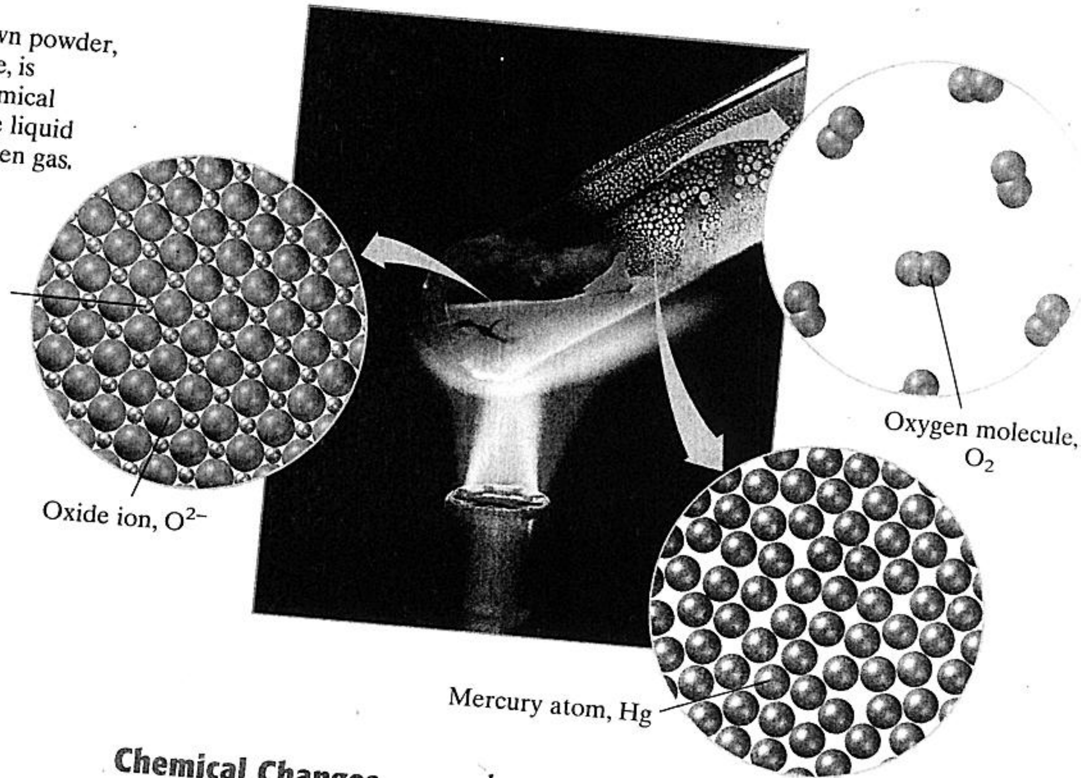


Figure 3
Dissolving sugar in tea is a physical change.

Figure 4
The reddish-brown powder, mercury(II) oxide, is undergoing a chemical change to become liquid mercury and oxygen gas.



Chemical Changes

In a chemical change, the identities of substances change and new substances form. In **Figure 4**, mercury(II) oxide changes into mercury and oxygen as represented by the following word equation:

$$\text{mercury(II) oxide} \longrightarrow \text{mercury} + \text{oxygen}$$

In an equation, the substances on the left-hand side of the arrow are the **reactants.** They are used up in the reaction. Substances on the right-hand side of the arrow are the **products.** They are made by the reaction.

A chemical reaction is a rearrangement of the atoms that make up the reactant or reactants. After rearrangement, those same atoms are present in the product or products. Atoms are not destroyed or created, so mass does not change during a chemical reaction.

reactant
a substance or molecule that participates in a chemical reaction

product
a substance that forms in a chemical reaction

Evidence of Chemical Change

Evidence that a chemical change may be happening generally falls into one of the categories described below and shown in **Figure 5.** The more of these signs you observe, the more likely a chemical change is taking place. But be careful! Some physical changes also have one or more of these signs.

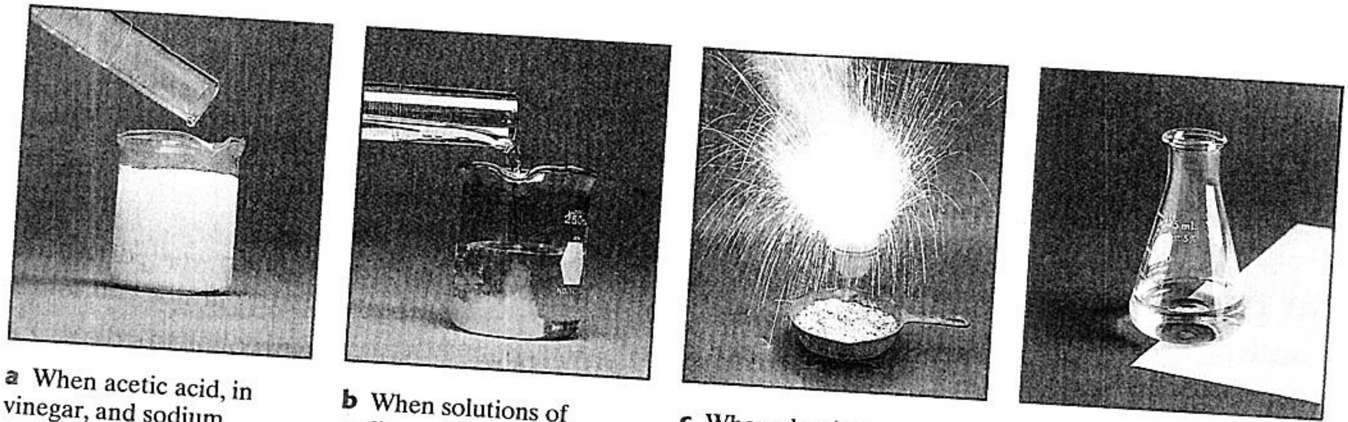
a. **The Evolution of a Gas** The production of a gas is often observed by bubbling, as shown in **Figure 5a,** or by a change in odor.

b. **The Formation of a Precipitate** When two clear solutions are mixed and become cloudy, a precipitate has formed, as shown in **Figure 5b.**

c. **The Release or Absorption of Energy** A change in temperature or the giving off of light energy, as shown in **Figure 5c,** are signs of an energy transfer.

d. **A Color Change in the Reaction System** Look for a different color when two chemicals react, as shown in **Figure 5d.**

Figure 5



a When acetic acid, in vinegar, and sodium hydrogen carbonate, or baking soda, are mixed, the solution bubbles as carbon dioxide forms.

b When solutions of sodium sulfide and cadmium nitrate are mixed, cadmium sulfide, a solid precipitate, forms.

c When aluminum reacts with iron(III) oxide in the clay pot, energy is released as heat and light.

d When phenolphthalein is added to ammonia dissolved in water, a color change from colorless to pink occurs.

1 Section Review

UNDERSTANDING KEY IDEAS

1. Name three natural chemicals and three artificial chemicals that are part of your daily life.

2. Describe how chemistry is a part of your morning routine.

3. Classify the following materials as solid, liquid, or gas at room temperature: milk, helium, granite, oxygen, steel, and gasoline.

4. Describe the motions of particles in the three common states of matter.

5. How does a physical change differ from a chemical change?

6. Give three examples of physical changes.

7. Give three examples of chemical changes.

8. Identify each substance in the following word equation as a reactant or a product.

limestone $\xrightarrow{heat}$ lime + carbon dioxide

9. Sodium salicylate is made from carbon dioxide and sodium phenoxide. Identify each of these substances as a reactant or a product.

10. List four observations that suggest a chemical change is occurring.

CRITICAL THINKING

11. Explain why neither liquids nor gases have permanent shapes.

12. Steam is sometimes used to melt ice. Is this change physical or chemical?

13. Mass does not change during a chemical change. Is the same true for a physical change? Explain your answer, and give an example.

14. In beaker A, water is heated, bubbles of gas form throughout the water, and the water level in the beaker slowly decreases. In beaker B, electrical energy is added to water, bubbles of gas appear on the ends of the wires in the water, and the water level in the beaker slowly decreases.

a. What signs of a change are visible in each situation?

b. What type of change is happening in each beaker? Explain your answer.