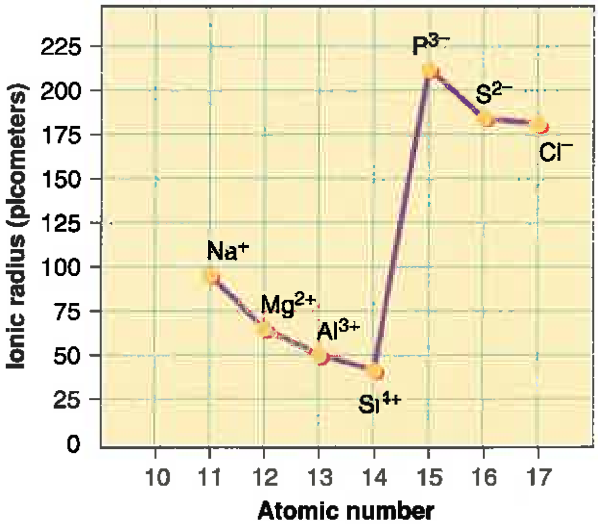
## Develop Your Skills

Use the skills you have developed in this chapter to complete each activity.

1. **Interpret Data** The graph below shows how the radius of different ions varies with their atomic number.
   a. What trend do you see among the sizes of the four positive ions shown?
   b. What happens to ionic radii as atomic number increases from 14 to 15? Why does this occur?

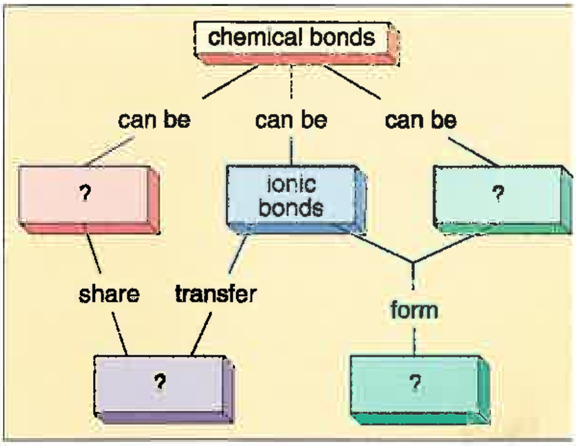



2. **Make a Model** Use plastic foam balls and toothpicks to make models of water ($H_2O$), diamond, and potassium chloride (KCl). Use a different color ball for each element.

3. **Data Bank** Use the information on page 637 to answer the following questions.
   a. What is the radius of a beryllium ion?
   b. How much smaller is a beryllium ion than a beryllium atom?
   c. Name an element with atoms that are the same size as the fluoride ion.

## Make Connections

1. **Link the Concepts** Below is a concept map that shows connections between some of the main concepts in this chapter. Only part of the map has been filled in. Copy the map and complete it, using words and ideas from the chapter.



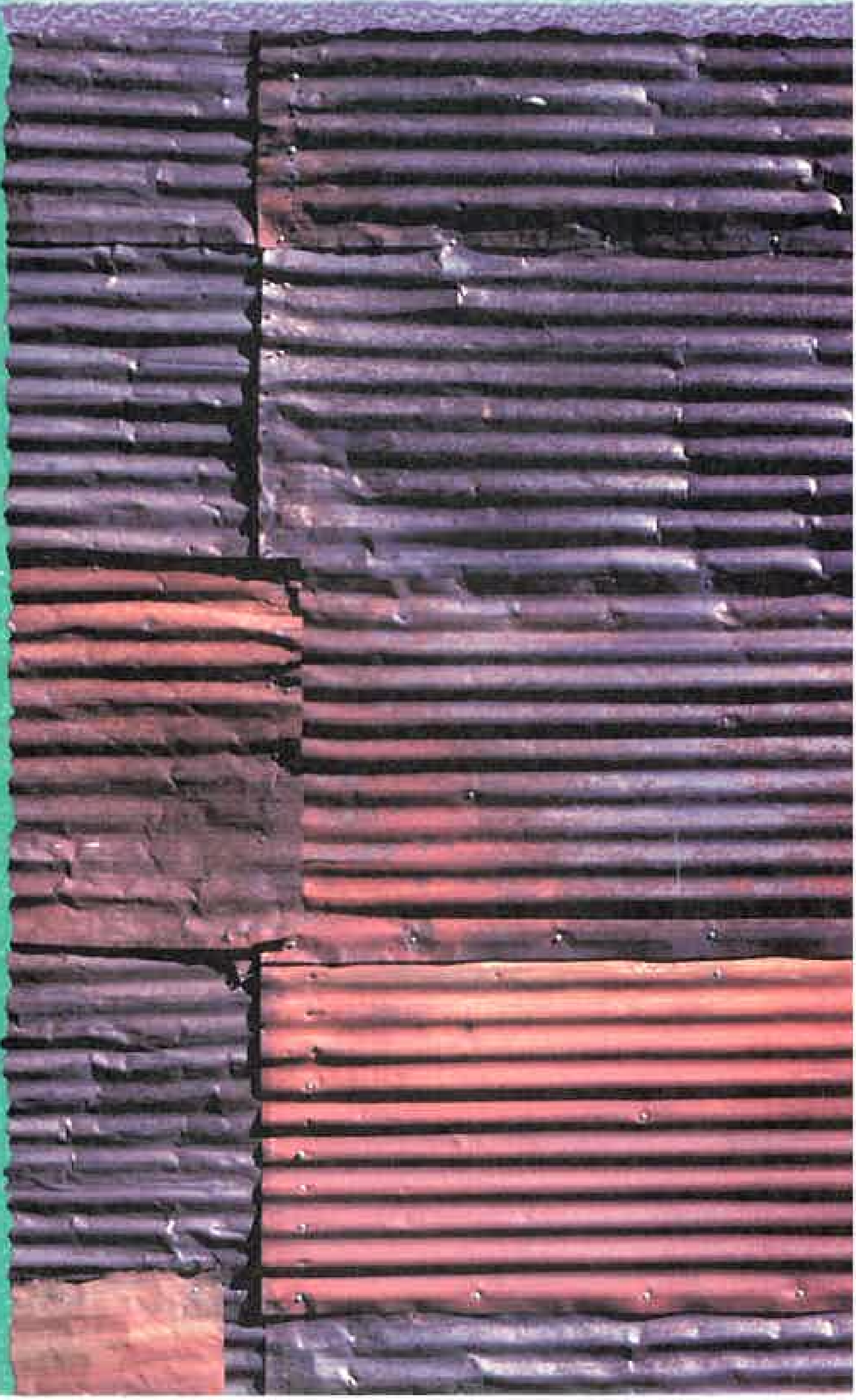

2. **Science and Art** Cut disks out of heavy paper to represent the outer electron shells of hydrogen, magnesium, oxygen, and chlorine atoms. Make the disks different sizes to account for the different numbers of electron shells in the elements. Draw inner circles to represent inner shells. Then, place pennies on the disks to represent the electrons in each atom. Decide which atoms will form an ionic bond and use the pennies to show how the bond forms. Do the same for atoms that will form covalent bonds.

3. **Science and You** Find out what dissolved ions your drinking water contains. The utility company or government agency that supplies your water will have this information. Determine if your water is hard, and if any of the ions are present in unusually high amounts.

# hapter 20 Chemical Reactions

## hapter Sections





## 'hat do you see?

I see what looks like small eets of metal overlapping form one large piece of etal with ridges. The metal covered with an orangish-own substance. I think the angish-brown substance is st, and it formed by the etal being exposed to oxy-n. Rust is composed of n and oxygen. ”

*Bridget Dunne*
*Swanson Middle School*
*Arlington, Virginia*

find out more about the otograph, look on page 2. As you read this chap-, you will learn about emical reactions.

# 20.1 Characteristics of Chemical Reactions

## Objectives

- **Identify** everyday chemical reactions.
- **Describe** four kinds of evidence for chemical reactions.
- **Distinguish** between exothermic and endothermic chemical reactions.
- **Make a model** that shows bonding changes in a chemical reaction.

What ingredients do you need to bake a cake? Include flour, eggs, sugar, water—and don't forget the baking powder! The person who baked the cake in the top of Figure 20.1 forgot to add baking powder, and look what happened. The cake didn't rise. What is it about baking powder that makes a cake rise?

Baking powder contains substances that begin to undergo a chemical change when they are mixed with water. The substances combine to produce bubbles of carbon dioxide gas. When these gas bubbles are trapped in the cake batter, they cause a cake to rise.

## Chemical Changes and Chemical Reactions

If you think about it, chemical changes similar to what happens to baking powder occur all the time. Recall that a chemical change in matter results in a new substance being formed. New substances are produced when you fry an egg, eat a piece of pizza, operate a power mower, snap a photograph, or light a candle. Even as you read these words, the cells in your body are creating new substances that you need to survive.

What is actually happening to atoms and molecules when a chemical change occurs? Every chemical change involves a **chemical reaction.** When a chemical reaction occurs, chemical bonds between atoms or ions break, and new bonds form between different atoms or ions. A chemical reaction creates one or more new substances. The new substance has properties that are different from the properties of the original substances.

**ACTIVITY**

**Inferring**

***New Substances***

Make a list of substances created from other substances. What evidence do you have that each is a new substance or that a chemical change took place when the substance was produced?

**SKILLS WARMUP**

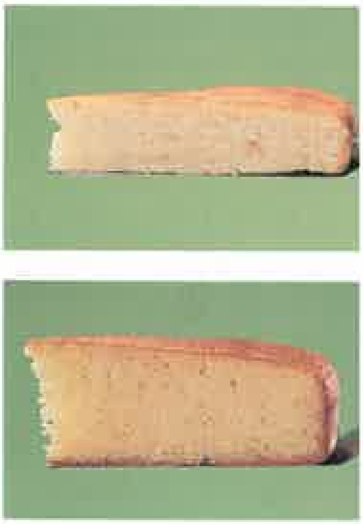


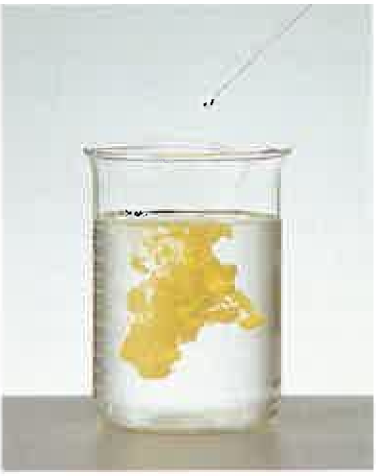
**Figure 20.1 ▲**
Which of these cakes was bake without baking powder?

## Evidence for Chemical Reactions

You can't see chemical bonds breaking or forming. So how do you know when a chemical change is happening? If you have a window in your oven, you can watch a cake bake and see little bubbles break the surface. These bubbles are evidence that a chemical reaction is taking place in the cake batter. Most chemical reactions give you very good clues that a new substance is being produced. Here are four of the most important kinds of clues.

**'ecipitate**

A white substance forms hen household ammonia is ıdded to a solution of alum. ıe white substance is called *precipitate* (pree SIHP uh ΛYT). The appearance of a :ecipitate is a sign of a ıemical reaction.

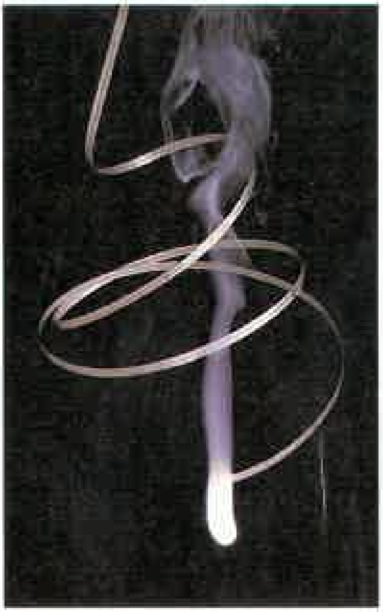


**Color Change**

The colorful substance is a clue that a chemical reaction occurred. Here a colorless solution is added to another colorless solution to form a bright yellow product.

**Release of Energy**

Many chemical reactions give off some form of energy. Here you can see light energy given off by burning magnesium. Other reactions release heat energy alone.



**Gas Formation**

The release of gas indicates that a chemical reaction is taking place. Hydrogen gas bubbles form as zinc reacts with hydrochloric acid.

## Mechanics of Chemical Reactions

During a chemical reaction, at least one new substance with different properties is produced. Look at Figure 20.2 below. It shows a chemical reaction. The original substances are on the left. What are they? What elements make them up? How are the atoms bonded? The new substance produced in the reaction is on the right. What has changed during the reaction? How did these changes occur?

Notice that in the original substances on the left, chemical bonds join atoms of the same element. When the two different molecules come together with enough energy, the bonds that hold the atoms together begin to break. At the same time, new bonds form. Take a look at Figure 20.2. Each chlorine atom begins to form a bond with a hydrogen atom. New hydrogen chloride molecules are produced when the old bonds break. Now the chemical bonds are between atoms of different elements. Hydrogen chloride molecules have been formed. All this takes place in a very short, almost immeasurable, period of time.

As you will see, there are many kinds of chemical reactions. Compounds can break down into elements, and elements can join to form compounds. Compounds can react with elements or other compounds to form one, two, or more new substances. The substances involved in a chemical reaction can be pure metals, ionic solids, or covalently bonded molecules. They can be solids, liquids, or gases.

In all chemical reactions, however, old bonds break and new bonds form. The same elements present in the original substances are also present in the new substances. The atoms or ions are simply rearranged during the reaction. Why do you think the atoms remain as either an element or in a compound?

### ACTIVITY

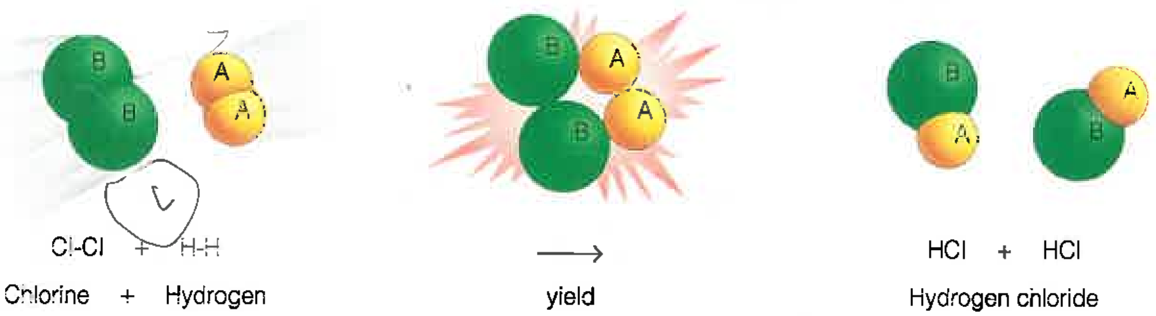
**Making a Model**

***Reaction Model***

Using Figure 20.2 as an example, draw a model that shows how atoms are rearranged in the following reaction. A molecule of $CH_4$ reacts with two molecules of $O_2$ to form a molecule of $CO_2$ and two molecules of $H_2O$.

**SKILLS WORKOUT**

**Figure 20.2**
In a chemical reaction, bonds between atoms break and reform between different atoms.



## Energy and Chemical Reactions

Energy changes occur whenever chemical bonds break or form. Some chemical reactions release energy; others absorb energy. The law of conservation of mass and energy, however, applies to chemical reactions.

In other words, chemical reactions do not create or destroy energy. Any energy released in a reaction was present in the chemical bonds of the original substances. Any energy absorbed in a reaction becomes part of the chemical bonds of the new substances.

gure 20.3 ▲
ı explosion is a very exother-
ic chemical reaction.

**Exothermic Reactions** You probably can think of several chemical reactions that release energy. Such reactions heat your home, cook your food, and run your family's car. The explosion in Figure 20.3 is a chemical reaction that released a large amount of energy.

A reaction that releases energy is called an **exothermic** (EHK soh THER mihk) **reaction**. All exothermic reactions fit this chemical description.

$$\textbf{original substances} \longrightarrow \textbf{new substances} + \textbf{energy}$$

Exothermic reactions most often produce energy in the form of heat, light, or electricity.

**Endothermic Reactions** Chemical reactions that absorb energy, called **endothermic** (EHN doh THER mihk) **reactions**, are probably less familiar to you. Here is the chemical description for an endothermic reaction.

$$\textbf{original substances} + \textbf{energy} \longrightarrow \textbf{new substances}$$

gure 20.4 ▲
'hat kind of energy is absorbed
this endothermic reaction?

Look at Figure 20.4. If you could feel the glass, you would notice the water becomes colder as the antacid tablet disappears. The chemical reaction that is taking place absorbs heat energy from the water.

Some reactions absorb energy in the form of light or electricity. For example, when you take a photograph, light energy enters the camera. The light energy is absorbed by the film and molecules in the film undergo a chemical change. When electric energy is added to water, the water molecules absorb the electricity. The water molecules undergo a chemical change, breaking apart into hydrogen and oxygen.

## Science and You
### *Chemistry Celebration: The Fourth of July*

You probably see fireworks every Fourth of July. Have you ever wondered how the dazzling colors and thunderous sounds of fireworks are made? They are carefully controlled exothermic reactions. Safety is a major concern in making fireworks.

Modern fireworks are shells launched from tubes on the ground. A fast-burning fuse ignites a charge of black powder that propels the shell skyward. When the shell is high in the air, a slower-burning fuse ignites other compartments filled with flash powder. Pellets inside these charges produce colors. Usually, another charge explodes in a final big bang.

Making fireworks is both a science and an art. It requires a great deal of knowledge of chemistry. Each color, for example, is the result of a certain mixture of elements or compounds in the pellets. Green stars come from barium compounds, red from strontium, and blue from copper. Because the color-producing compounds aren't very stable, they must be created during the explosion of the charge. Making the right chemical reactions occur in the correct way is one of the biggest challenges of building fireworks.

Each pattern you see when a fireworks shell explodes is the result of a different arrangement of the color-producing pellets inside the flash-powder charges. A fireworks company carefully guards its secret "recipes" for packing its fireworks shells.

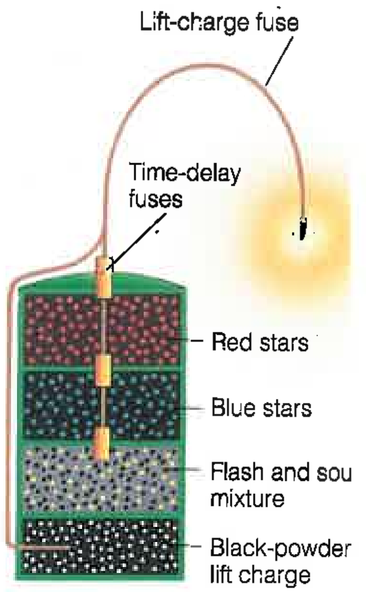



**Figure 20.5** ▲
Which of the compartments in a fireworks shell ignites first?

## Check and Explain

1. Describe three everyday chemical reactions.
2. What kinds of evidence can tell you that a chemical reaction is taking place in a beaker?
3. **Compare and Contrast** What is the difference between exothermic and endothermic reactions? How can you identify a reaction as one or the other?
4. **Make a Model** On paper, draw a model that shows how you think the chemical bonds change when an atom of sulfur (S) and a molecule of oxygen ($O_2$) react to form a molecule of sulfur dioxide ($SO_2$).

**ACTIVITY**

**Communicating**

*Secret Code*

Write two or three messages to a friend using different pictures as symbols for words.

**SKILLS WARMUP**

# 20.2 Chemical Equations

## Objectives

- **Identify** the reactants and products of a chemical reaction.
- **Distinguish** between subscripts and coefficients.
- **Communicate** what happens during a chemical change by writing a balanced chemical equation.

Have you ever written a message in a secret code? In one example of a simple number code, 1 represents *A*, 2 represents *B*, and so on. The words *secret code* are written in this code as 19-5-3-18-5-20 3-15-4-5. Pictures can also represent words. What does the picture message 👁 ❤ U mean?

Numbers and pictures are symbols. You use symbols every day because they are very useful. In math, for example, you substitute symbols for words when you solve word problems. What other kinds of symbols do you use regularly?

Chemists use symbols to show what happens during a chemical reaction. Many of these symbols you already know. As you will see, describing a chemical reaction with symbols is much like writing a word puzzle.

## Equations in Chemistry

Suppose you want to describe the chemical reaction that occurs when baking soda and vinegar are mixed together. You could say, "Sodium bicarbonate reacts with a solution of acetic acid to produce carbon dioxide gas, sodium acetate, and water." This statement says exactly what you mean, but it takes up a lot of space.

You need a short, precise way to state what happens in a chemical reaction. The way to do this is to write a **chemical equation**. A chemical equation is an expression that uses symbols to describe a chemical reaction. Because the same chemical symbols are used worldwide, a chemical equation can be understood in any country in the world.

An equation is like a sentence in chemical terms. The sentence begins at the left with the formulas for the starting materials, called **reactants** (ree AK tuhnts).