## 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.

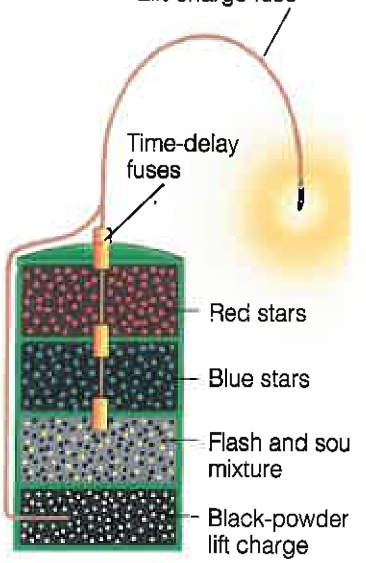



**Figure 20.5** ▲
Which of the compartments in a fireworks shell ignites first?

## 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).

**Reactants**

Compounds or elements on the left side of the equation are the starting materials, or reactants. When more than one reactant is present, a plus sign separates them.

**Yield Sign**

As its name implies, the yield sign means "yield" or "produce." It is similar to the equal sign in a mathematical equation.

**Products**

New substances forme in a reaction are its products. They are placed to th right of the yield sign. A plus sign separates differer products when there is more than one.


**Figure 20.6** ▲
**Parts of a Chemical Equation**

The reactants are the substances that undergo a chemical change. When combined, the reactants begin the chemical equation. Look at the chemical equation shown in Figure 20.6. In this equation, the reactants are sodium hydroxide (NaOH) and hydrochloric acid (HCl).

An arrow, called a yield sign, connects the two sides of the equation. The yield sign acts like the verb of the sentence. When you read the chemical equation you read the arrow as "yield." The yield sign also shows the direction of the reaction. The sentence ends with the formulas for the new substances formed by the reaction. The substances formed are called the **products**. As Figure 20.6 shows, the products of this reaction are sodium chloride (NaCl) and water ($H_2O$).

To show whether a reaction is exothermic or endothermic, the word *energy* is sometimes added to the appropriate side of an equation. Energy, however, is neither a reactant nor a product. Can you explain why?

Chemical equations are always written to represent one set of reactants and one set of products. Thus, one equation describes equally well what happens to two molecules or to a beaker full of those molecules. But, as you will see, equations must sometimes be written to include more than one molecule or unit of the same substance.

**ACTIVITY**

**Communicating**

*The Right Equation*

Write a chemical equatic for the following reaction: Silicon (Si) reacts with oxygen ($O_2$) to form silicon dio ide ($SiO_2$).

**SKILLS WORKOU**

**Life Science**

**L I N K**

Photosynthesis is the pro-
:ess by which plants use the
:nergy of the sun to make
ood. A chemical equation
:hows how this works.

$CO_2 + H_2O$ + light -> $C_6H_{12}O_6 + O_2$

Rewrite the photosynthe-
:is equation and balance it.

**A C T I V I T Y**

## Balanced Chemical Equations

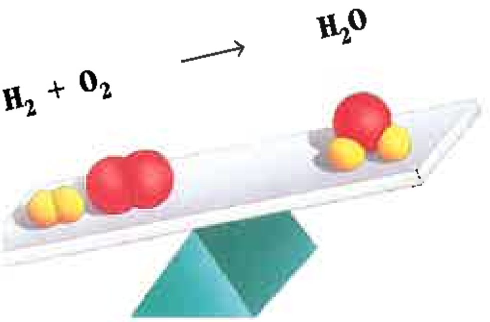
Look again at Figure 20.6. How many atoms of sodium are on the left side of the equation? How many are on the right side? Also, count the numbers of hydrogen, oxygen, and chlorine atoms. You should come up with an equal number of atoms for each element on each side of the equation. Why?

The law of conservation of mass and energy states that mass can't be lost or gained in a chemical reaction. The atoms present in the reactants must also be present in the products. Chemical equations, therefore, are often written so that the numbers of each kind of atom on one side equal the numbers of each kind of atom on the other side. A chemical equation written in this way is called a *balanced* chemical equation.

The equation in Figure 20.6 is already balanced. You will come across many chemical equations, however, in which you know the *kinds* of substances involved but not *how many* molecules or atoms of each are present. These equations must be balanced.

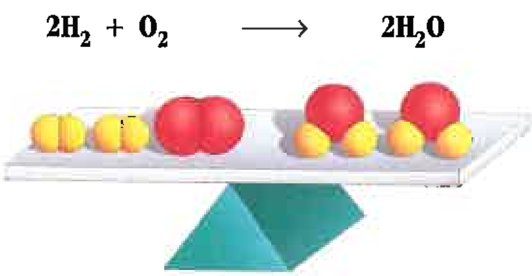
When you balance an equation, you write numbers in front of the formulas where they are needed. These numbers, called **coefficients** (KOH eh FIHSH uhnts),

**jure 20.7 ▼**
**ılancing a Chemical Equation**




**ıbalanced Chemical Equation ▲**
Why is this equation unbalanced? Count
e number of hydrogen atoms. You'll find
ere are two on each side. The number of
ygen atoms, however, are not equal on
ch side. There are two oxygen atoms on
e left and only one on the right.

**Balanced Chemical Equation**
The equation is balanced when the coefficient *2* is placed in front of the formula for water on the right and the formula for hydrogen on the left. You can see that there are now two oxygen atoms on the left and two on the right. There are four hydrogen atoms on the left and four on the right. ▼



indicate how many atoms or molecules of a substance are involved in a reaction. For example, $2H_2O$ means there are two molecules of water. Be careful not to confuse coefficients and subscripts. A subscript, which shows how many *atoms* of an element are present in a molecule, can't be changed to balance an equation. Only the coefficient can be changed.

Look at Figure 20.7. The equation on the left needs balancing. Count the number of atoms of hydrogen and oxygen on each side of the equation. As you can see, the hydrogens balance, but the oxygens don't.

How can you make the number of oxygen atoms on the right side equal the number on the left side while keeping the hydrogens balanced? You can put a 2 in front of the formula for hydrogen and a 2 in front of the formula for water. With these coefficients, the equation says that two molecules of hydrogen and one molecule of oxygen react to form two molecules of water.

## SkillBuilder *Calculating*

ACTIVITY

### *Writing Chemical Equations*

Writing chemical equations is an important skill that you learn through practice. Write chemical equations for the word equations that follow. Each problem includes the formulas you need to write the equation.

**1.** Calcium and hydrochloric acid yield calcium chloride and hydrogen.

hydrochloric acid: $HCl$
calcium chloride: $CaCl_2$ hydrogen: $H_2$

**2.** Magnesium and oxygen yield magnesium oxide.

oxygen: $O_2$
magnesium oxide: $MgO$

**3.** Sodium and water yield sodium hydroxide and hydrogen.

sodium hydroxide: $NaOH$

Remember that an equation is not finished until it is balanced. Go back and balance each of the equations you've just written by following these steps.

a. Count the number of atoms of each element on each side of the equation.
b. Use coefficients to balance the numbers of atoms.
c. Check your work by repeating step a.

Are you getting better at balancing equations? Sharpen your skill even more by balancing the equations below.

**4.** $Br_2 + KI \longrightarrow KBr + I_2$

**5.** $Zn + HCl \longrightarrow ZnCl_2 + H_2$

**6.** $Fe + Cl_2 \longrightarrow FeCl_3$

**7.** $HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O$

## Science and Society
### *Chain Reactions in the Ozone Layer*

High above the earth's surface, a thin layer of ozone molecules protects all life on earth from the sun's harmful ultraviolet radiation. Ozone is a form of oxygen with the formula $O_3$. In 1974, scientists discovered that substances called chlorofluorocarbons (CLOR oh FLOR oh KAR buhns), or CFCs, were destroying the ozone layer. CFCs are synthetic gases used in some spray cans and in refrigerators and air conditioners. Look at Figure 20.8 to see how the ozone layer over the South Pole has thinned.

As CFCs rise in the atmosphere, ultraviolet radiation breaks the bonds between their carbon and chlorine atoms.

$$2CF_2Cl_2 \longrightarrow 2CF_2Cl + Cl_2$$

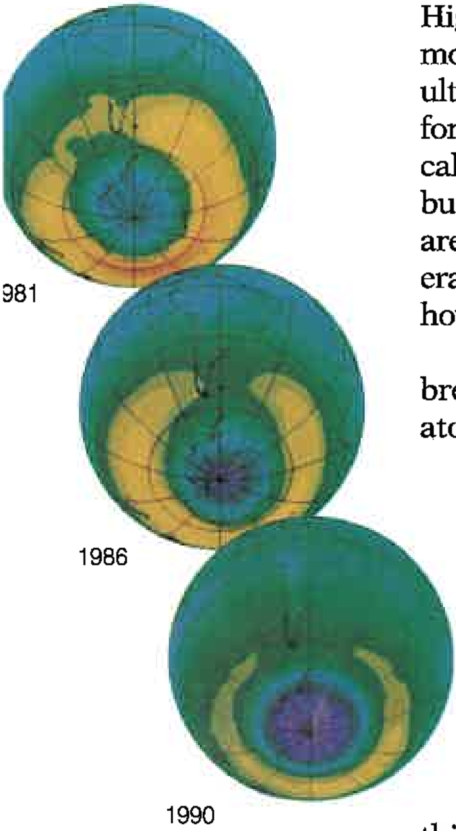
The chlorine molecules produced in this reaction are split apart by ultraviolet radiation to form chlorine atoms.

$$Cl_2 \longrightarrow 2Cl$$

The chlorine atoms then attack ozone molecules.

$$Cl + O_3 \longrightarrow ClO + O_2$$

The ordinary oxygen molecules that result from this chain of reactions don't prevent ultraviolet radiation from reaching the earth's surface. Many people are worried because too much ultraviolet radiation can cause skin cancer and damage food crops. In 1990, 93 nations agreed to stop using CFCs by the year 2000. This action, however, may not be enough to stop the gradual destruction of ozone.




**igure 20.8** ▲
ı these computer images, yellɔw shows areas where the zone layer is thick. Blue and urple areas have a very thin ıyer of ozone.

## Check and Explain

1. Identify the reactants and the products in this equation: $Ca + 2HCl \longrightarrow CaCl_2 + H_2$.
2. Balance this equation: $NaCl + H_2SO_4 \longrightarrow Na_2SO_4 + HCl$.
3. **Compare and Contrast** How are coefficients and subscripts alike? How are they different?
4. **Communicate** Write a balanced equation for this reaction: iron + oxygen yields iron oxide. The formula for iron oxide is $Fe_2O_3$.