CHEMISTRY
The Central Science

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Antoine Lavoisier (Section 1.1) was among the first to draw conclu about chemical processes from careful, quantitative observations. work laid the basis for the law of conservation of mass, one of the fundamental laws of chemistry. In this chapter, we will consider n practical problems based on the law of conservation of mass. These p lems involve the quantitative relationships between substances und ing chemical changes. The study of these quantitative relationshi known as **stoichiometry** (pronounced stoy-key-AHM-uh-tree), a derived from the Greek words *stoicheion* ("element") and *m* ("measure").

3.1 LAW OF CONSERVATION OF MASS

Studies of countless chemical reactions have shown that the total ma all substances present after a chemical reaction is the same as the mass before the reaction. This observation is embodied in the **la conservation of mass:** There are no *detectable* changes in mass in chemical reaction.* More precisely, *atoms are neither created nor des during a chemical reaction;* instead, they merely exchange partners o come otherwise rearranged. The simplicity with which this law ca stated should not mask its significance. As with many other scie laws, this law has implications far beyond the walls of the scie laboratory.

The law of conservation of mass reminds us that we really can't t anything away. If we discharge wastes into a lake to get rid of them, are diluted and seem to disappear. However, they are part of the

*In Chapter 19, we will discuss the relationship between mass and energy summarized equation $E = mc^2$ (E is energy, m is mass, and c is the speed of light). We will find that whene object loses energy it loses mass, and whenever it gains energy it gains mass. These changes i are too small to detect in chemical reactions. However, for nuclear reactions, such as those in in a nuclear reactor or in a hydrogen bomb, the energy changes are enormously larger; ir reactions there are detectable changes in mass.

choose. We have learned in recent years, however, that energy itself is a limited resource. Whether we like it or not, we must learn to conserve all our energy and material resources.

3.2 CHEMICAL EQUATIONS

We have seen (in Sections 2.2 and 2.6) that chemical substances can be represented by symbols and formulas. These chemical symbols and formulas can be combined to form a kind of statement, called a **chemical equation,** that represents or describes a chemical reaction. For example the combustion of carbon involves a reaction with oxygen (O_2) in the air to form gaseous carbon dioxide (CO_2). This reaction is represented as

$$C + O_2 \longrightarrow CO_2 \qquad [3.1]$$

We read the + sign to mean "reacts with" and the arrow as "produces." Carbon and oxygen are referred to as **reactants** and carbon dioxide as the **product** of the reaction.

It is important to keep in mind that a chemical equation is a description of a chemical process. Before you can write a complete equation you must know what happens in the reaction or be prepared to predict the products. In this sense, a chemical equation has qualitative significance; it identifies the reactants and products in a chemical process. In addition, a chemical equation is a quantitative statement; it must be consistent with the law of conservation of mass. This means that the equation must contain equal numbers of each type of atom on each side of the equation. When this condition is met the equation is said to be **balanced**. For example, Equation 3.1 is balanced because there are equal numbers of carbon and oxygen atoms on each side.

A slightly more complicated situation is encountered when methane (CH_4), the principal component of natural gas, burns and produces carbon dioxide (CO_2) and water (H_2O). The combustion is "supported by" oxygen (O_2), meaning that oxygen is involved as a reactant. The unbalanced equation is

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O \qquad [3.2]$$

The reactants are shown to the left of the arrow, the products to the right. Notice that the reactants and products both contain one carbon atom. However, the reactants contain more hydrogen atoms (four) than the products (two). If we place a coefficient 2 in front of H_2O, indicating peroxide, is quite different from water. *The subscripts in the chemical 'las should never be changed in balancing an equation.* On the other hand ing a coefficient in front of a formula merely changes the amount ar the identity of the substance; $2H_2O$ means two molecules of $3H_2O$ means three molecules of water, and so forth. Now let's co balancing Equation 3.3. There are equal numbers of carbon and h gen atoms on both sides of this equation; however, there are more o atoms among the products (four) than among the reactants (two). place a coefficient 2 in front of O_2 there will be equal numbers of o atoms on both sides of the equation:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

The equation is now balanced. There are four oxygen atoms, four h gen atoms, and one carbon atom on each side of the equation balanced equation is shown schematically in Figure 3.2.

Now, let's look at a slightly more complicated example, anal stepwise what we are doing as we balance the equation. Combust octane (C_8H_{18}), a component of gasoline, produces CO_2 and H_2O balanced chemical equation for this reaction can be determined by the following four steps.

First, the reactants and products are written in the unbalanced tion

$$C_8H_{18} + O_2 \longrightarrow CO_2 + H_2O$$

Before a chemical equation can be written the identities of the rea and products must be determined. In the present example this inf tion was given to us in the verbal description of the reaction.

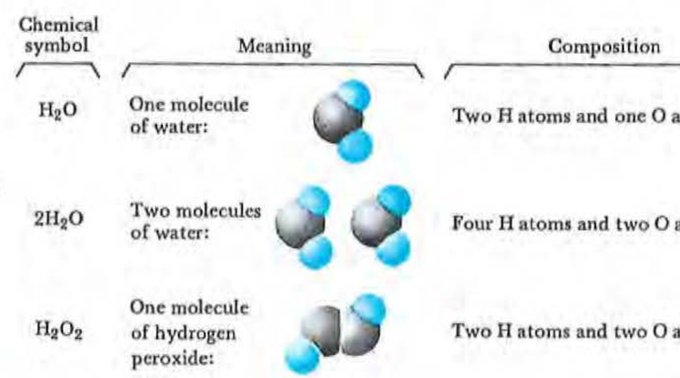

FIGURE 3.1 Illustration of the difference in meaning between a subscript in a chemical formula and a coefficient in front of the formula. Notice that the number of atoms of each type (listed under composition) is obtained by multiplying the coefficient and the subscript associated with each element in the formula.

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