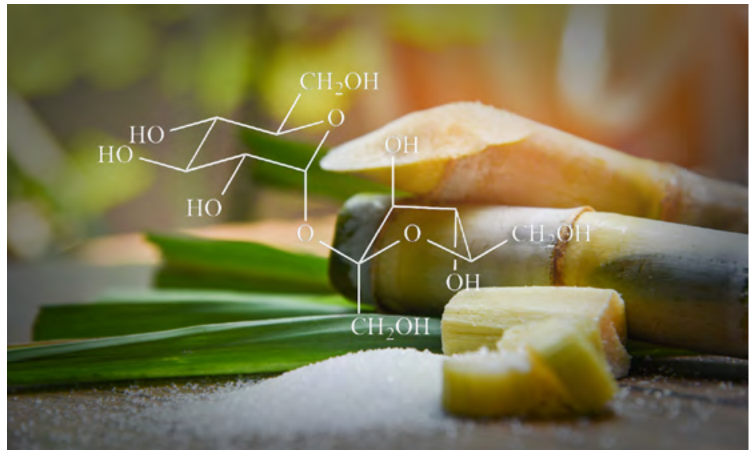
Chapter 2

The Chemistry of Life



2.4 Chemical Reactions

A mixture consists of chemicals that can be fairly stable with each other. Some chemicals when combined, however, are not so stable with each other. A good example is hydrogen gas, H_2, and oxygen gas, O_2. These two chemicals have a tendency to *react* with one another, which means that their atoms change partners and new types of molecules are formed.

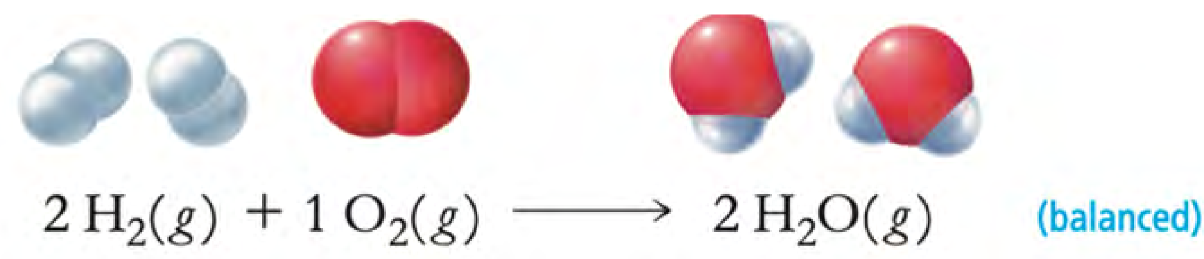


Figure 2.19

In hydrogen gas, H2, hydrogen atoms are connected to hydrogen atoms. In oxygen gas, O2, oxygen atoms are connected to oxygen atoms. These two chemicals can react to form water, H2O, in which two hydrogen atoms are connected to a single oxygen atom. Shown below the molecules is the chemical equation that represents this chemical change.

This is analogous to a dance floor where people dancing in couples suddenly step back from their partner to find a new partner or multiple partners. After such a change, you'll find the people are configured differently. Similarly, after a **chemical reaction**, the atoms will be bonded to different atoms in new arrangements. For example, every two hydrogen molecules, H_2, will react with one oxygen molecule, O_2, to form two water molecules, H_2O, as shown in Figure 2.19.

The result of any chemical reaction is that new materials are formed. Water, H_2O, is uniquely different from the hydrogen, H_2, and oxygen, O_2, from which it was formed. So how do chemists make new materials? Answer: through chemical reactions. And how are new materials made in nature? Same answer: through chemical reactions, as shown in Figure 2.20 on the next page.

Figure 2.20

The heat of a lightning bolt causes atmospheric nitrogen and oxygen to react, leading to the formation of nitric acid, HNO3, and nitrous acid, HNO2. As part of the nitrogen cycle, these acids are carried by rain into the ground, where they are transformed by microorganisms into nitrate ions that plants use for growing. We, in turn, eat the plants, or plant-eating animals, to support life-sustaining chemical reactions within ourselves.

Chemical reactions also involve energy. Reactions in which there is a net release of energy are called **exothermic**. Rocket ships lift off into space and campfires glow red hot as a result of exothermic reactions. Reactions in which there is a net absorption of energy are called **endothermic**. Photosynthesis, for example, involves a series of endothermic reactions that are driven by the energy of sunlight, as shown in Figure 2.21.

FIGURE 2.21

Chemical reactions that occur when wood is burning have a net release of energy. These are exothermic reactions. Chemical reactions that occur in a photosynthetic plant have a net absorption of energy. These are endothermic reactions.

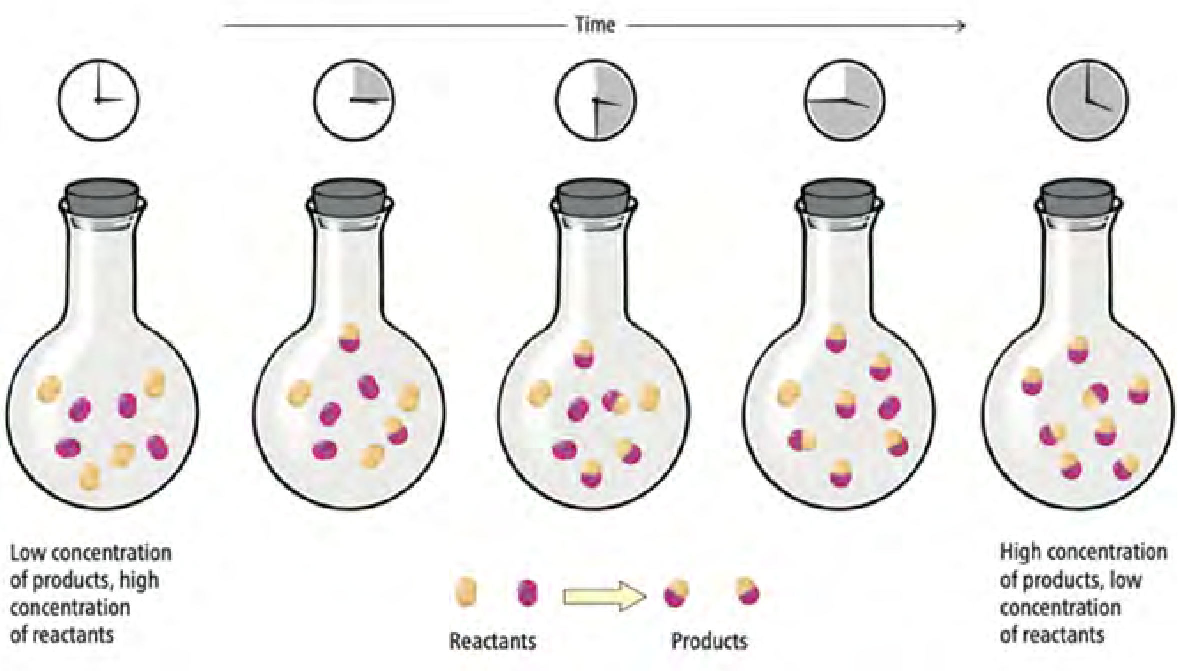


FIGURE 2.22

Over time, the reactants in this reaction flask may transform into products. If this happens quickly, the reaction rate is high. If this happens slowly, the reaction rate is low.

Some chemical reactions, such as the rusting of iron, are slow, whereas others, such as the burning of gasoline, are fast. The speed of any reaction is indicated by its *reaction rate*, which is an indicator of how quickly the reactants transform to products. As shown in Figure 2.22, initially a flask may contain only reactant molecules. Over time, these reactants form product molecules and, as a result, the concentration of product molecules increases. The **reaction rate**, therefore, can be defined either as how quickly the concentration of products increases or as how quickly the concentration of reactants decreases.

FIGURE 2.23

Why did the alligator cross the road on a chilly day? It was attracted to the daytime warmth of the pavement. All animals regulate their internal temperatures, just in different ways and with different amounts of tolerated variability.

The speed of most chemical reactions is influenced by temperature, including reactions that occur in living bodies. The body temperature of some animals, such as humans, is fairly constant. However, the body temperature of other animals, such as the alligator shown in Figure 2.23, may vary a bit depending on the temperature of the environment. On a warm day, the chemical reactions occurring in an alligator are "up to speed," and the animal may be more active. On a chilly day, however, the chemical reactions proceed at a lower rate and, as a consequence, the alligator's movements are more sluggish.

The rate of a chemical reaction can be sped up by using a **catalyst**, which is any substance that increases the rate of a chemical reaction but is not itself consumed by the chemical reaction. The chemical industry depends on catalysts because they lower manufacturing costs by lowering required temperatures and by providing greater product yields without being consumed (the catalysts can be recycled). Indeed, more than 90% of all manufactured goods are produced with the assistance of catalysts. Without catalysts,

the price of gasoline would be much higher, as would be the prices of such consumer goods as rubber, plastics, pharmaceuticals, automobile parts, clothing, and food grown with chemical fertilizers. Living organisms rely on special types of catalysts in their cells known as *enzymes*, which allow complex biochemical reactions to occur with ease. As we'll be exploring, this includes the digestion of food and the activity of DNA.

Reading Check

What happens to atoms during a chemical reaction?

Check Your Answer

During a chemical reaction there is no change in the number or types of atoms. Rather, the change involves how those atoms are connected. As those connections change, a new material is created.