2.13: The process of making and breaking chemical bonds- chemical reactions

The preceding section has discussed chemical compounds and the two major kinds of bonds— covalent bonds and ionic bonds — that hold them together. Next is discussed the process of making and taking apart chemical compounds, **chemical reactions**. A chemical reaction occurs when chemical bonds are broken and formed and atoms are exchanged to produce chemically different species.

First consider two very simple chemical reactions involving only one element, oxygen. In the very thin air high in the stratosphere more than 10 kilometers above Earth's surface (above the altitudes where jet airliners normally cruise), high-energy ultraviolet radiation from the sun, represented by the symbol $h\nu$, splits apart molecules of elemental oxygen, O_2,

$$O_2 + h\nu \rightarrow 2O \tag{2.13.1}$$

to produce oxygen atoms. As with most single atoms, the O atoms are reactive and combine with oxygen molecules to produce ozone, O_3:

$$O + O_2 \rightarrow O_3 \tag{2.13.2}$$

Both of these processes are chemical reactions. In a chemical reaction, the substances on the left of the arrow (read as "yields") are the **reactants** and those on the right of the arrow are **products**. The first of these reactions states that the chemical bond holding together a molecule of O_2 *reactant* is split apart by the high energy of the ultraviolet radiation to produce two oxygen atom *products*. In the second reaction, an oxygen atom reactant, O, and an oxygen molecule reactant, O_2, form a chemical bond to yield an ozone product, O3. Are these very simple chemical reactions important to us? Emphatically yes. They produce a shield of ozone molecules in the stratosphere which in turn absorb ultraviolet radiation that otherwise would reach Earth's surface, destroying life, causing skin cancer and other maladies that would make our existence on Earth impossible. As discussed in Chapter 10, the use of chlorofluorocarbon refrigerants (Freons) has seriously threatened the stratospheric ozone layer. It is a triumph of environmental chemistry that this threat was realized in time to do something about it and an accomplishment of green chemistry to develop relatively safe substitutes for ozone-threatening chemicals.

Many chemical reactions are discussed in this book. At this point a very common chemical reaction can be considered, that of elemental hydrogen with elemental oxygen to produce water. A first approach to writing this reaction is

$$H_2 + O_2 \rightarrow H_2O \tag{2.13.3}$$

stating that elemental hydrogen and elemental oxygen react together to produce water. This is not yet a proper *chemical equation* because it is not balanced. A **balanced chemical equation** has the same number of each kind of atom on both sides of the equation. As shown above, there are 2 H atoms in the single H_2 molecule on the left and 2 H atoms in the single molecule H_2O product. That balances hydrogen, but leaves 2 O atoms in the O_2 molecule on the left with only 1 O atom in the single H_2O molecule product. But, writing the reaction a

$$2H_2 + O_2 \rightarrow 2H_2O \tag{2.13.4}$$

gives a balanced chemical equation with a total of 4 H atoms in 2 H_2 molecules on the left, 4 H atoms in 2 H_2O molecules on the right, and a total of 2 O atoms in the 2 H_2O molecules on the right, which balances the 2 O atoms in the O_2 molecule on the left. So the equation as now written is *balanced*. A **balanced** chemical equation always has the same number of each kind of atom on both sides of the equation.