14.1: Preview to Chemical Equilibria

In Chapter 14, we discussed the principles of chemical kinetics, which deal with the rate of change, or how quickly a given chemical reaction occurs. We now turn our attention to the extent to which a reaction occurs and how reaction conditions affect the final concentrations of reactants and products. For most of the reactions that we have discussed so far, you may have assumed that once reactants are converted to products, they are likely to remain that way. In fact, however, virtually all chemical reactions are reversible to some extent. That is, an opposing reaction occurs in which the products react, to a greater or lesser degree, to re-form the reactants. Eventually, the forward and reverse reaction rates become the same, and the system reaches chemical equilibrium, the point at which the composition of the system no longer changes with time.

A smoggy sunset in Shenzhen, China. The reaction of O_2 with N_2 at high temperature in an internal combustion engine produces small amounts of NO, which reacts with atmospheric O_2 to form NO_2, an important component of smog. The reddish-brown color of NO_2 is responsible for the characteristic color of smog, as shown in this true-color photo.

We introduced the concept of equilibrium in Chapter 11, where you learned that a liquid and a vapor are in equilibrium when the number of molecules evaporating from the surface of the liquid per unit time is the same as the number of molecules condensing from the vapor phase. Vapor pressure is an example of a physical equilibrium because only the physical form of the substance changes. Similarly, in Chapter 13, we discussed saturated solutions, another example of a physical equilibrium, in which the rate of dissolution of a solute is the same as the rate at which it crystallizes from solution.

In this chapter, we describe the methods chemists use to quantitatively describe the composition of chemical systems at equilibrium, and we discuss how factors such as temperature and pressure influence the equilibrium composition. As you study these concepts, you will also learn how urban smog forms and how reaction conditions can be altered to produce H_2 rather than the combustion products CO_2 and H_2O from the methane in natural gas. You will discover how to control the composition of the gases emitted in automobile exhaust and how synthetic polymers such as the polyacrylonitrile used in sweaters and carpets are produced on an industrial scale.