Activation Energy

Consider the reaction for the formation of water from the diatomic gases oxygen and hydrogen according to the following equation.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

The enthalpy of formation is quite high: $\Delta H_f^0 = -285.8$ kJ/mol at 298.15 K. The free-energy change is also large: $\Delta G^0 = -237.1$ kJ/mol. Why, then, don't oxygen and hydrogen combine spontaneously and immediately to form water when they are mixed at room temperature?

Hydrogen and oxygen gases exist as diatomic molecules. When the molecules approach each other, the electron clouds repel each other, so the molecules might not meet. For a reaction to occur, the colliding molecules must have enough kinetic energy to intermingle the valence electrons. In other words, the bonds of these molecular species must be broken in order for new bonds to be formed between oxygen and hydrogen atoms. Bond breaking is an endothermic process, and bond forming is exothermic. Even though the net process for forming water is exothermic, an initial input of energy is needed to overcome the repulsion forces that occur between reactant molecules when they are brought very close together. This initial energy input activates the reaction.

Once an exothermic reaction is started, the energy released is enough to sustain the reaction by activating other molecules. Thus, the reaction rate keeps increasing. It is limited only by the time required for reactant particles to acquire the energy and make contact. Energy from an outside source may start exothermic reactants along the pathway of reaction. A generalized reaction pathway for an exothermic reaction is shown as the forward reaction in **Figure 4.** The minimum amount of energy needed to activate this reaction is the activation energy represented by E_a. **Activation energy** *is the minimum energy required to transform the reactants into an activated complex.*

The reverse reaction, decomposition of water molecules, is endothermic because the water molecules lie at an energy level lower than that of the hydrogen and oxygen molecules. The water molecules require a larger activation energy before they can decompose to re-form oxygen and hydrogen. The energy needed to activate an endothermic reaction is greater than that required for the original exothermic change and is represented by E_a' in **Figure 4.** The difference between E_a' and E_a is equal to the energy change in the reaction, ΔE. This energy change has the same numerical value for the forward reaction as it has for the reverse reaction but with the opposite sign.

Reaction Pathways for Forward and Reverse Reactions

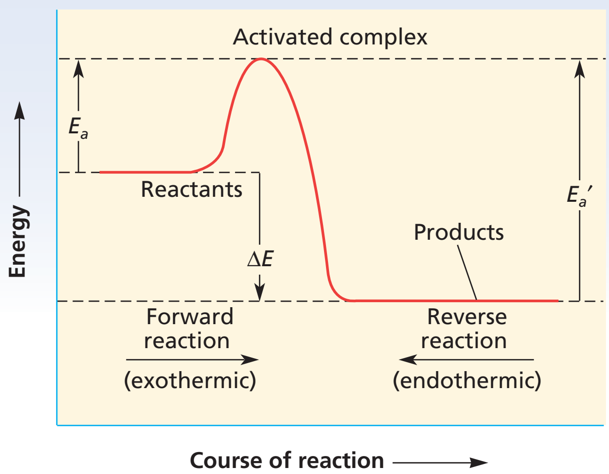

FIGURE 4 The difference between the activation energies for the reverse and forward reactions of a reversible reaction equals the energy change in the reaction, ΔE. The quantity for ΔE is the same for both directions, but is negative for the exothermic direction and positive for the endothermic direction.