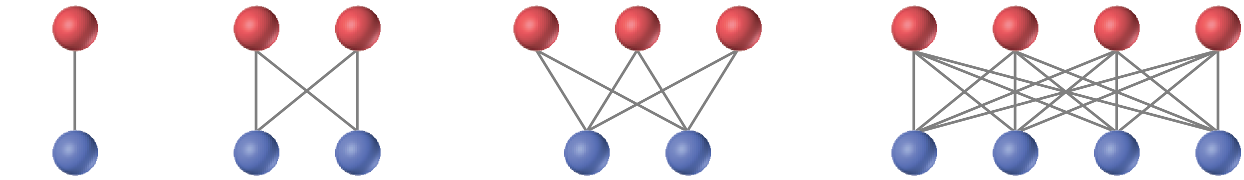

FIGURE 7 The number of molecules of reacting species affects the number of possible collisions and therefore the reaction rate.

increases as well. In general, an increase in rate is expected if the concentration of one or more of the reactants is increased, as depicted by the model in **Figure 7.** In the system with only two molecules, shown in **Figure 7a,** only one collision can possibly occur. When there are four molecules in the system, as in **Figure 7b,** there can be four possible collisions. Under constant conditions, as the number of molecules in the system increases, so does the total number of possible collisions between them. **Figure 7c** and **d** show a five- and eight-molecule system, allowing six and sixteen possible collisions, respectively. Lowering the concentration should have the opposite effect. The actual effect of concentration changes on reaction rate, however, must be determined experimentally.

FIGURE 8 The reaction rate of the decomposition of hydrogen peroxide, H_2O_2, can be increased by using a catalyst. The catalyst used here is manganese dioxide, MnO_2, a black solid. A 30% H_2O_2 solution is added dropwise onto the MnO_2 in the beaker and rapidly decomposes to O_2 and H_2O. Both the oxygen and water appear as gases because the energy released by the reaction causes much of the water to vaporize.

Presence of Catalysts

Some chemical reactions proceed quite slowly. Sometimes their reaction rates can be increased dramatically by the presence of a catalyst. *A* **catalyst** *is a substance that changes the rate of a chemical reaction without itself being permanently consumed. The action of a catalyst is called* **catalysis.** The catalysis of the decomposition reaction of hydrogen peroxide by manganese dioxide is shown in **Figure 8.** A catalyst provides an alternative energy pathway or reaction mechanism in which the potential-energy barrier between reactants and products is lowered. The catalyst may be effective in forming an alternative activated complex that requires a lower activation energy—as suggested in the energy profiles of the decomposition of hydrogen peroxide, H_2O_2, shown in **Figure 9**—according to the following equation.

$$2H_2O_2(l) \longrightarrow O_2(g) + 2H_2O(l)$$

Catalysts do not appear among the final products of reactions they accelerate. They may participate in one step along a reaction pathway and be regenerated in a later step. In large-scale and cost-sensitive reaction systems, catalysts are recovered and reused. *A catalyst that is in the same phase as all the reactants and products in a reaction system is called a* **homogeneous catalyst.** *When its phase is different from that of the reactants, it is called a* **heterogeneous catalyst.** Metals are often used as heterogeneous catalysts. The catalysis of many reactions is promoted by adsorption of reactants on the metal surfaces, which has the effect of increasing the concentration of the reactants.