Concentration Dependence of Reaction Rate

The rate of a chemical reaction depends on the concentration of the reactants because chemical reactions occur through collisions between reacting particles. According to the collision theory, an increase in the concentration of reactants increases the number of particles present in a given volume, leading to a higher frequency of effective collisions per unit time. As a result, the reaction rate increases. Conversely, when the concentration of reactants decreases, the number of effective collisions decreases, causing the reaction rate to slow down. Therefore, the concentration of reactants is one of the most important factors controlling the speed of a chemical reaction.

The quantitative relationship between the reaction rate and the concentration of reactants is expressed by the **rate law** or **rate equation**. For a general reaction,

$$aA + bB \rightarrow \text{Products}$$

the experimentally determined rate law is given by

$$\text{Rate} = k[A]^m[B]^n$$

where k is the rate constant, $[A]$ and $[B]$ are the molar concentrations of reactants A and B, and m and n are the orders of reaction with respect to A and B, respectively. The overall order of the reaction is the sum of these exponents.

$$\text{Overall Order} = m + n$$

Effect of Concentration on Reaction Rate

The dependence of the reaction rate on concentration can be understood from the rate law. If the concentration of a reactant is increased while all other conditions remain constant, the reaction rate changes according to the power of that concentration in the rate equation.

- If $m = 0$, the reaction rate is independent of the concentration of A.
- If $m = 1$, doubling the concentration of A doubles the reaction rate.
- If $m = 2$, doubling the concentration of A increases the reaction rate by four times.
- If $m = 3$, doubling the concentration of A increases the reaction rate by eight times.

Illustration

Consider the rate law

$$\text{Rate} = k[A]^2[B]$$

For this reaction:

- Doubling the concentration of A increases the reaction rate by $2^2 = 4$ times.
- Doubling the concentration of B increases the reaction rate by $2^1 = 2$ times.
- Doubling the concentrations of both A and B simultaneously increases the reaction rate by $2^2 \times 2 = 8$ times.

Thus, the concentration dependence of the reaction rate is governed by the experimentally determined rate law rather than by the stoichiometric coefficients of the balanced chemical equation. This concept forms the basis for understanding reaction kinetics and for determining the order of a chemical reaction experimentally.