

Effect of Temperature on the Rate of Reaction

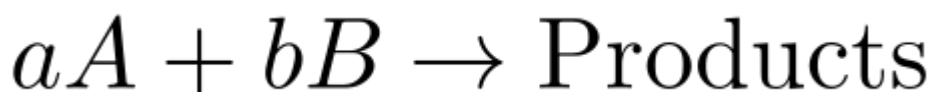
Among all the factors that influence the speed of a chemical reaction, temperature has the most pronounced effect. A reaction that proceeds very slowly at room temperature may become rapid when the reaction mixture is heated, whereas cooling often reduces the reaction rate significantly. This behaviour is observed in almost every branch of chemistry, from laboratory experiments to large-scale industrial processes. The influence of temperature is so remarkable that even a small increase of 10 °C is sufficient to accelerate the rate of many reactions by nearly two to three times. Understanding why this occurs is one of the central objectives of chemical kinetics.

At the molecular level, chemical reactions occur only when reacting particles collide with one another. However, not every collision results in the formation of products. For a collision to be effective, the colliding molecules must possess sufficient energy to overcome the energy barrier associated with bond breaking and bond formation, and they must also approach each other with a favourable orientation. Molecules that fail to satisfy these conditions simply rebound after collision without undergoing any chemical change.

Temperature directly influences the kinetic energy of molecules. As the temperature increases, molecules move more rapidly and collide more frequently. More importantly, the distribution of molecular energies shifts towards higher values. Consequently, a much larger fraction of the reacting molecules acquires enough energy to cross the activation energy barrier. Although the increase in the total number of collisions is relatively small, the increase in the number of *effective collisions* is substantial. It is this increase in effective collisions that is primarily responsible for the rapid increase in the reaction rate with temperature.

The relationship between temperature and molecular energy is explained by the Maxwell-Boltzmann distribution law. At a lower temperature, only a small fraction of molecules possesses energy greater than the activation energy. When the temperature is raised, the distribution curve becomes broader and shifts towards higher energies, increasing the number of molecules capable of reacting successfully. Therefore, the probability of product formation increases dramatically even for a modest rise in temperature.

The effect of temperature is reflected mainly in the value of the **rate constant**. For a reaction represented by



the rate law is

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

where k is the rate constant and m and n are the orders of the reaction. Increasing the temperature does not alter the order of the reaction because the reaction mechanism generally remains unchanged. Instead, the value of the rate constant increases, causing the reaction to proceed at a faster rate. Thus, the observed increase in reaction rate is essentially a consequence of the increase in the rate constant with temperature.

| Temperature Coefficient

Before the development of the Arrhenius theory, chemists used an empirical quantity known as the **temperature coefficient** to describe the effect of temperature on reaction rate. The temperature coefficient is defined as the ratio of the rate constant at a temperature 10 °C higher to the rate constant at the original temperature.

$$\mu = \frac{k_{T+10}}{k_T}$$

where k_T is the rate constant at temperature T and k_{T+10} is the rate constant at $T + 10$ °C.

For many ordinary chemical reactions, the temperature coefficient lies between 2 and 3. This means that increasing the temperature by 10 °C approximately doubles or triples the reaction rate. However, this relationship is only an experimental observation and cannot accurately predict the behaviour of every reaction. Some reactions show a much greater increase, whereas others exhibit only a slight change with temperature.

Although the temperature coefficient provides a convenient estimate of the effect of temperature, it does not explain why the rate constant changes or how the change depends on activation energy. These limitations led Svante Arrhenius to establish a quantitative relationship between the rate constant and temperature. The resulting Arrhenius equation remains one of the most important equations in chemical kinetics and provides the theoretical basis for understanding the temperature dependence of chemical reactions.