

Physico-chemical influences affecting the activity of enzymes

Effect of the temperature

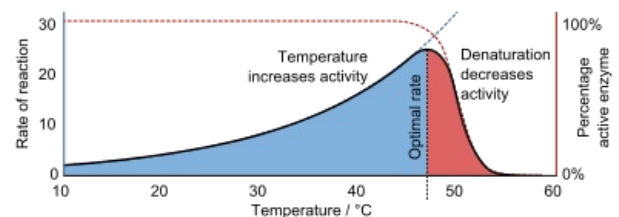
Most chemical reactions depend on the **temperature**, and reactions catalyzed by enzymes are no exception.

- According to the kinetic theory, we interpret the increase in the reaction rate with temperature until the optimum temperature is reached by the increased kinetic energy of the reacting molecules, which also contributes to the formation of the enzyme-substrate complex.
- **The temperature coefficient Q₁₀** is the ratio of how many times the rate of a chemical reaction changes with a 10°C increase in temperature. For most chemical reactions, this ratio is about 2, but for some physiological processes, catalyzed by enzymes, it is higher.
- For most enzymes, the **optimum temperature** is roughly the same as the temperature that exists in the cell's environment, and for warm-blooded (homoiothermic) organisms, including **humans**, it is **37 °C**.
- For some bacteria living in extreme conditions, the optimal temperature (but also the optimal pH and the optimal ionic composition) can reach quite extreme values. E.g. some microorganisms living in hot natural springs have an optimum temperature for their enzymes close to the boiling point of water. For mammalian enzymes, however, such temperatures are already much higher than the optimal temperature. In such conditions, the kinetic energy of enzyme molecules is so great that it exceeds the energy barrier for breaking secondary bonds and interactions, keeping the enzyme molecule in the conformation (secondary and tertiary structure) necessary for enzyme catalysis. This causes denaturation accompanied by a decrease or even loss of enzyme activity.

Test of the heat lability

(but also lability to pH) belongs to the simple criteria of whether a given reaction is catalyzed by enzymes.

- For most mammalian enzymes, enzymes are thermally denatured as early as **60 to 80 °C**. Enzymes are usually denatured very quickly by cooking.
- The dependence of enzyme activity on increasing temperature can be expressed graphically by a bell-shaped curve, which has a peak at the optimal temperature.



Enzyme activity initially increases with the temperature until reaching its optimum. Subsequently, it starts to denature and quickly loses its catalytic ability.

Dependence of the enzyme activity on pH

Dependence of the enzyme activity on pH is another important factor affecting enzyme activity. This dependence can also be expressed graphically by a bell-shaped curve with a peak at the **optimal pH**, which for most enzymes lies in the range of **5.0 to 9.0**.

- However, some enzymes are exceptions, e.g. pepsin, acting in the strongly acidic environment of gastric juice, has an optimal pH between **1.5 and 2.0**.
- The effect of pH on the increase in enzyme activity until reaching the optimum pH can be explained by affecting the dissociation of ionizable functional groups of the substrate and enzyme, which are responsible for the interaction of the enzyme with the substrate during the formation of the enzyme-substrate complex, but also for maintaining the conformation of the enzyme. In addition, some ionizable functional groups in the active center participate in acid-base catalysis. Since enzymes are proteinaceous in nature, they are stable as ampholytes only in a certain range of pH values close to neutrality.
- **Extremely acidic or alkaline solutions denature** the enzymes again by changing their conformation. This is conditioned by the disruption of secondary bonds and interactions, sometimes even by the disintegration of the quaternary structure into subunits or the dissociation of the non-protein component of the enzyme.

The effect of ions on enzymes

The effect of ions on enzymes is best seen with some **divalent cations** (e.g. Ca²⁺, Mg²⁺, Zn²⁺) as **activators**. These ions can form a complex with the substrate to form a *metallosubstrate complex*, or a complex with an enzyme, which then binds the substrate in the form of an *enzyme-metallo-substrate complex*.

- **Metal ions** can also change the equilibrium states, either by *removing products* in the form of a complex with the reaction product, or by *increasing the supply of the substrate*, if the effective form is a metallo-substrate complex.
 - At other times, metals can **affect the conformation of the enzyme protein**, maintain the quaternary structure of the enzyme, or act as inhibitors by binding to the effective groups of the active site (eg -SH groups are blocked by Hg²⁺ ions).
 - Some metal ions can participate in the mechanism of the **enzyme-catalytic reaction** by interacting with the substrate as so-called Lewis acids (acceptors of electron pairs).
- **Fluoride ions** can in turn have an inhibitory effect by binding cations as *activators*, e.g. by binding Ca²⁺ or

Mg²⁺.

- **The presence of salts** can also non-specifically affect the activity of the enzyme by changing the ionic strength (e.g. Cl⁻ ions), thereby affecting the hydration of the enzyme protein or the electrokinetic potential, which changes the strength of the ionic (electrostatic) bonds in the enzyme molecule.