Enzymes

Catalysts and enzymes, how enzymes work with their substrates (the lock and key hypothesis), and the effects of temperature and pH on enzyme activity.

5.1 Enzyme action

A catalyst is a substance that increases the rate of a chemical reaction and is not changed by the reaction.

Enzymes are proteins that function as biological catalysts. They are involved in all metabolic reactions (the chemical reactions in living things).

Enzymes work at the normal temperatures inside living things, which a chemical catalyst could not do. Because an enzyme is not used up, a small amount can be used again and again.

How an enzyme works

- The **substrate** is the substance that the enzyme acts on.
- The enzyme has a region called the **active site**, which has a specific shape.
- The substrate fits the active site to form an **enzyme–substrate complex**.
- The reaction takes place and the **products** are released. The enzyme is unchanged and can work again.

Specificity: the lock and key hypothesis

Each enzyme is specific: it only works on one type of substrate, because the shape of the active site is complementary to the shape of the substrate, like a key that fits only one lock.

This is the **lock and key hypothesis**. A substrate with a different shape does not fit the active site, so the enzyme cannot act on it.

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5.1 Effects of temperature and pH

The progress of an enzyme-catalysed reaction can be followed by measuring how the **concentration of the substrate falls** or how the **concentration of the product rises** over time. The reaction is fastest at the start and slows as the substrate is used up.

Examples of measurements: the time for starch to disappear (tested with iodine every 30 seconds), the volume of oxygen given off when catalase breaks down hydrogen peroxide, or the time for milk protein to clear.

Temperature

- At **low temperatures** the reaction is slow, because the enzyme and substrate molecules have little **kinetic energy**, so they collide less often and fewer collisions are effective.
- As the temperature rises, the molecules move faster, so there are more **frequent, effective collisions** and the rate increases.
- At the **optimum temperature** the rate is at its highest (about $37\ ^\circ\mathrm{C}$ for human enzymes).
- Above the optimum, the enzyme's shape starts to change. The active site no longer fits the substrate: the enzyme is **denatured**, and the reaction stops. Denaturation by high temperature is **permanent**.

pH

- Each enzyme has an **optimum pH**. Away from it, the rate falls.
- A pH that is too high or too low changes the shape of the enzyme and its active site, so the substrate no longer fits: the enzyme is **denatured**.
- Different enzymes have different optimum pH values. For example, **pepsin** (a protease in the stomach) works best in acid conditions at about **pH 2**, while **trypsin** (a protease in the small intestine) works best in alkaline conditions at about **pH 8**, and amylase in the mouth works best at about pH 7.

> **NOTE**
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> Do not say that enzymes are "killed" at high temperatures. Enzymes are not alive. Say that they are **denatured**: their shape changes, so the active site no longer fits the substrate.

Investigating the effect of temperature or pH. Mix the enzyme and substrate (for example amylase and starch) in a water bath at a chosen temperature, or in a buffer solution at a chosen pH, and measure the time taken for the starch to disappear (tested every 30 s with iodine). Keep the volumes, concentrations and other variables the same, and repeat. A shorter time means a higher rate.

> **TRY IT**

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> Explain why the rate of an enzyme reaction falls above the optimum temperature.

The high temperature changes the **shape of the enzyme**, including its active site. The substrate no longer fits (it is **denatured**), so fewer enzyme–substrate complexes form, and the rate falls to zero.

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