Enzymes

A-Level Biology

What enzymes are

Enzymes 酶 are **globular proteins** 球状蛋白质—a type of **protein** 蛋白质 with a rounded, soluble shape. They are biological catalysts: they **catalyse** 催化 (speed up) the chemical reactions in living things, and they are not used up, so each enzyme works again and again.

Enzymes work in two places:

- **intracellular** 细胞内 enzymes work inside the **cell** 细胞 that made them. An example is **catalase** 过氧化氢酶, which breaks down harmful hydrogen peroxide.
- **extracellular** 细胞外 enzymes are **secreted** 分泌 (sent out) to work outside the cell. An example is **amylase** 淀粉酶, which is released into the gut to **digest** 消化 **starch** 淀粉.

Yeast enzymes ferment sugar, giving off bubbles of carbon dioxide

How enzymes work

Each enzyme has a special pocket called the **active site** 活性位点. The molecule it acts on is its **substrate** 底物. The substrate fits into the active site to form an **enzyme–substrate complex** 酶底物复合物. The reaction then happens, and the **products** 产物 leave, freeing the active site for the next substrate.

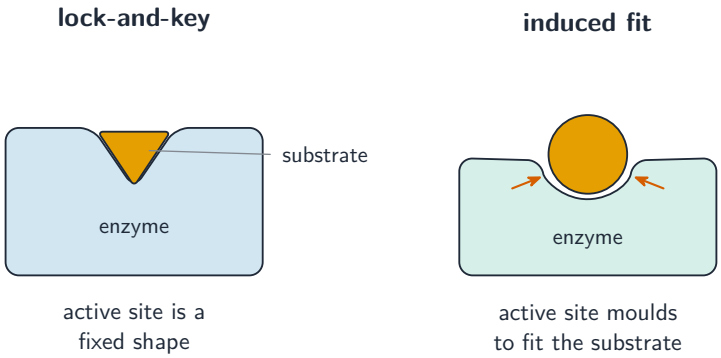
Specificity

An enzyme is **specific**: it usually works on only one substrate. This is because the shape of the active site is **complementary** 互补 to (fits) the shape of that substrate and no

other. We call this **specificity** 专一性.

Two ideas explain how the substrate fits:

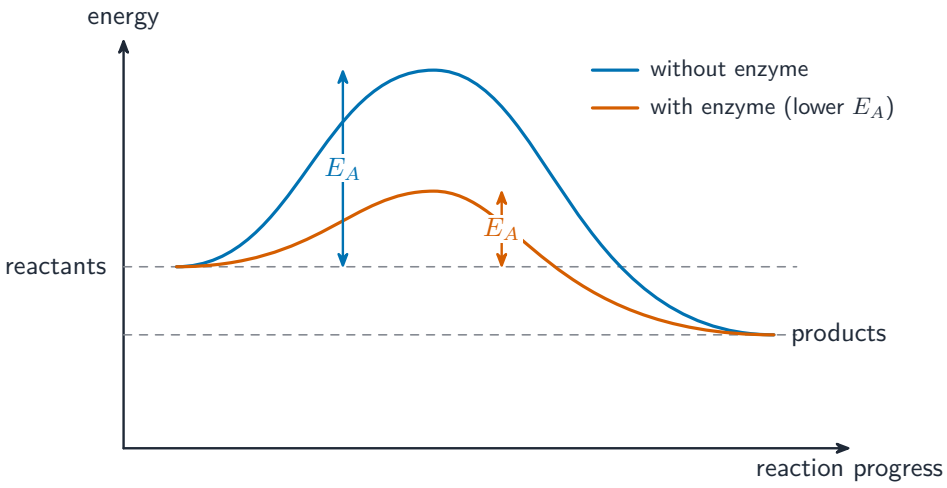
- the **lock-and-key hypothesis** 锁钥学说—the active site is a fixed shape, and only a substrate with the matching shape fits, like a key in a lock.
- the **induced-fit hypothesis** 诱导契合学说—the active site is not quite the right shape at first. When the substrate binds, the active site changes shape a little to wrap around it tightly. This idea fits the evidence better.



Lock-and-key 锁钥*: a fixed active site. Induced fit* 诱导契合*: the active site changes shape to grip the substrate*

Lowering activation energy

Every reaction needs a small "push" of energy to start, called the **activation energy** 活化能. An enzyme lowers the activation energy. This lets the reaction go quickly at the cell's normal **temperature** 温度, instead of needing high heat.



The enzyme route has a lower activation energy 活化能 *(E_A), so more molecules can react*

Measuring the rate of a reaction

You can follow an enzyme reaction in two ways:

- measure how fast **product** is made. With catalase, oxygen gas is a product, so you collect the gas and measure its volume over time.
- measure how fast substrate disappears. With amylase, you remove samples and use the iodine test; the blue-black colour fades as the starch is used up.

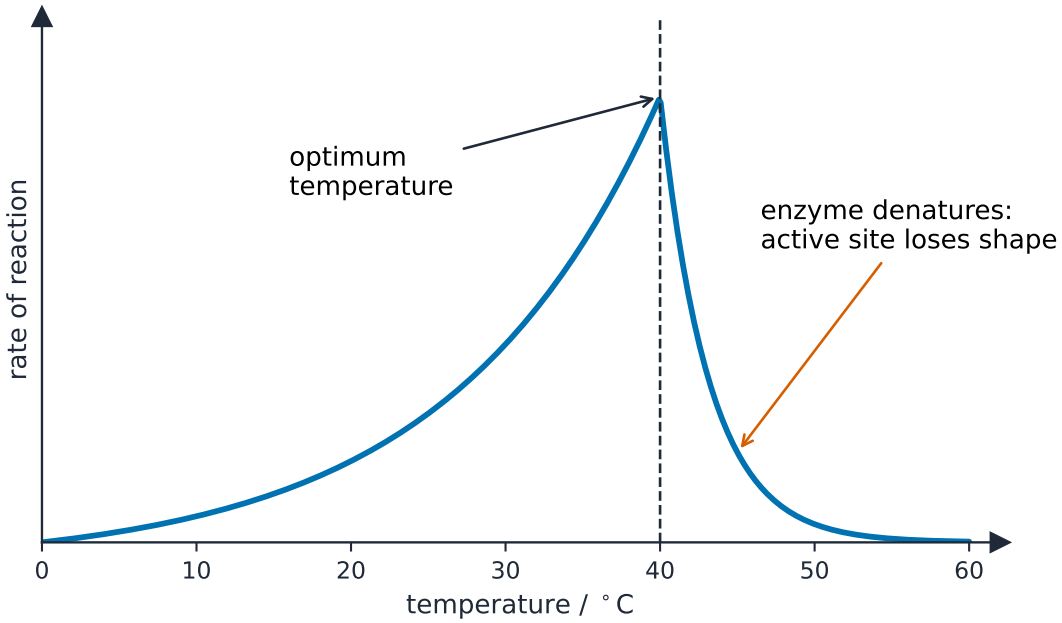
A **colorimeter** 比色计 makes this exact. It shines light through the tube and measures how much light is absorbed, so a colour change becomes a number you can plot.

The **rate of reaction** 反应速率 is steepest at the start (most substrate present), so the **initial rate** (the slope at time zero) is the fairest value to compare.

Factors that affect enzyme activity

Temperature

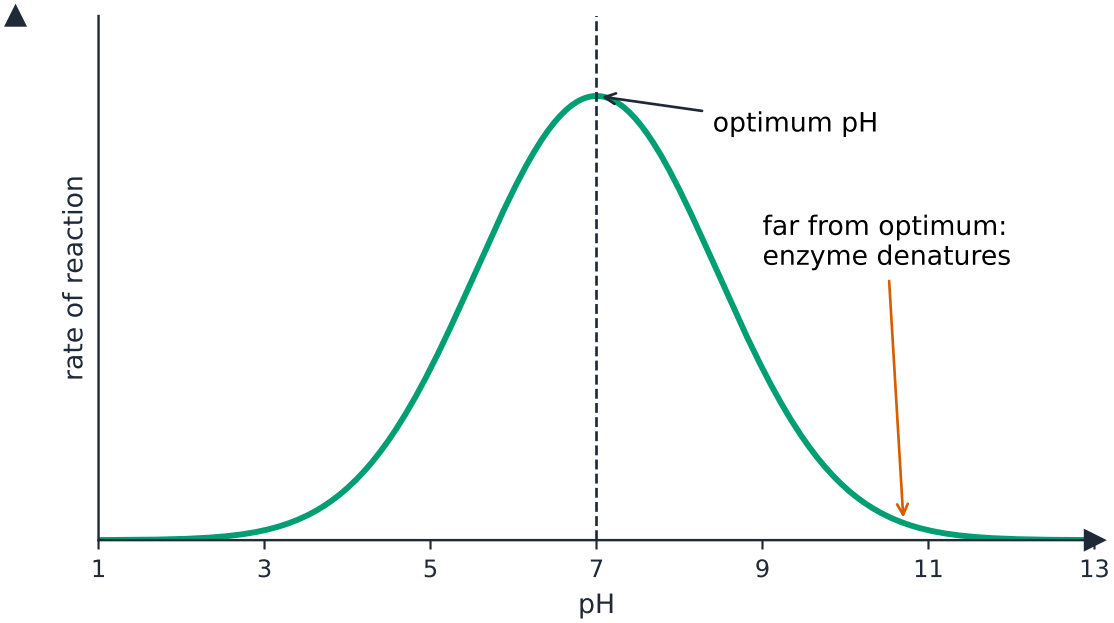
As temperature rises, molecules gain more **kinetic energy** 动能 and **collide** 碰撞 more often, so the rate rises. But above the **optimum temperature** 最适温度 the enzyme begins to **denature** 变性: the heat breaks the bonds holding its shape, so the active site changes and no longer fits the substrate. The rate then falls quickly.



Rate rises to the optimum 最适, *then falls fast as the enzyme denatures* 变性

pH

Each enzyme has an optimum pH. If the pH moves too far from it, the enzyme denatures and the rate drops. To study pH fairly, you keep it steady with a **buffer solution** 缓冲液.



The rate peaks at the optimum pH 最适 pH and falls away on either side

Enzyme concentration

With plenty of substrate, more enzyme means more active sites, so the rate goes up in proportion to enzyme concentration.

Substrate concentration

At first, adding more substrate speeds the reaction. But once every active site is busy, adding more makes no difference —the rate levels off at a maximum.

Inhibitor concentration

An **inhibitor** 抑制剂 is a molecule that slows an enzyme. The more inhibitor present, the lower the rate.

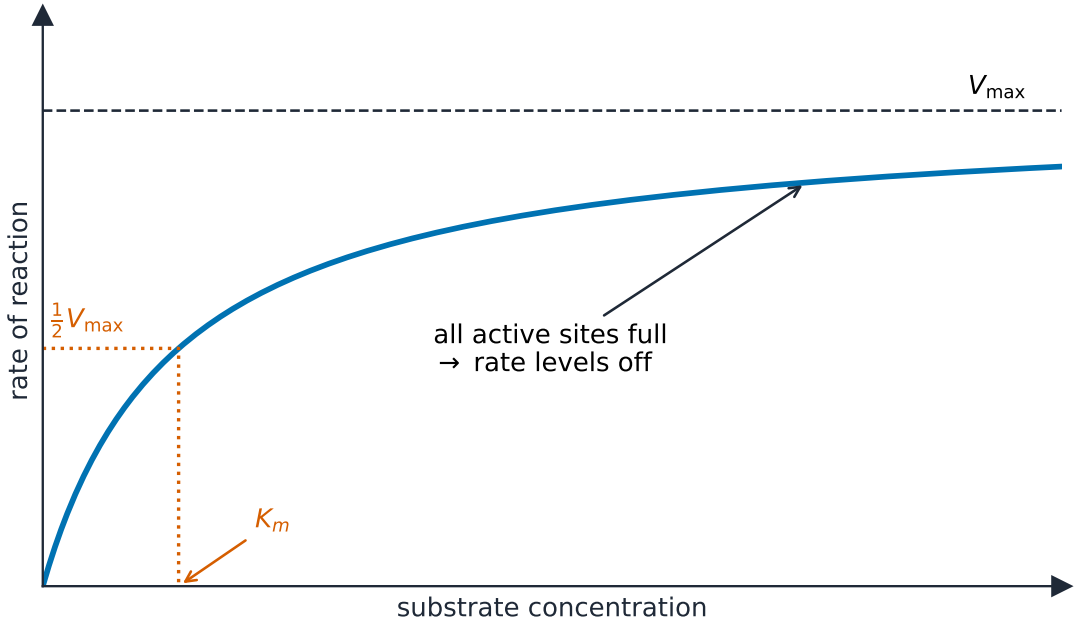
V_max and the Michaelis–Menten constant

The levelling-off rate, when all active sites are full, is the maximum rate, written V_{max}.

The **Michaelis–Menten constant** 米氏常数 (K_{m}) is the substrate concentration that gives **half** of V_{max}. It tells you about the enzyme's **affinity** 亲和力 (pulling power) for its substrate:

- a **low** K_{m} means the enzyme reaches half-speed at a low substrate concentration, so it has a **high** affinity.
- a **high** K_{m} means a **low** affinity.

So K_{m} lets you compare how strongly different enzymes hold their substrates.

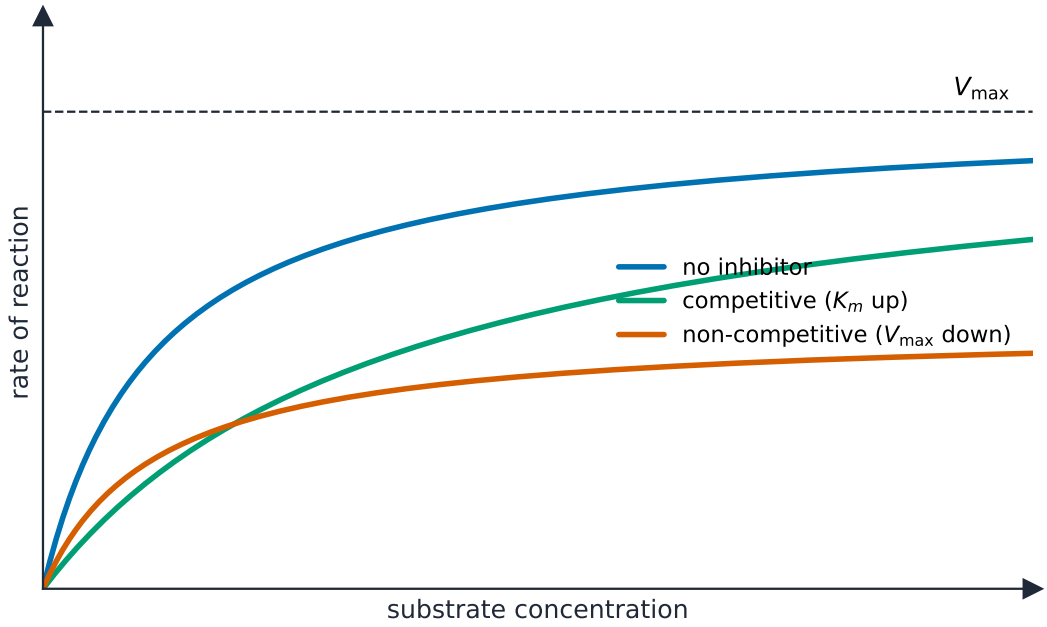


Rate climbs to V_{max} when all active sites are full; K_m is the substrate concentration giving half V_{max}

Reversible inhibitors

Some inhibitors are **reversible** 可逆: they can leave the enzyme again. There are two types.

Type	Where it binds	Effect of adding more substrate	Effect on V_{max} and K_m
competitive inhibitor 竞争性抑制剂	in the active site (it has a similar shape to the substrate)	more substrate out-competes it, so its effect is reduced	V_{max} unchanged; K_m rises
non-competitive inhibitor 非竞争性抑制剂	at another site, changing the active site's shape	adding more substrate does not help	V_{max} falls; K_m unchanged



A competitive 竞争性 inhibitor raises K_m (more substrate overcomes it); a non-competitive 非竞争性 one lowers V_{max}

Immobilised enzymes

An **immobilised enzyme** 固定化酶 is fixed in place —for example, trapped inside small beads of **alginate** 海藻酸盐—instead of floating free in solution. The substrate solution flows past the beads.

A free enzyme usually works a little faster, because the substrate can reach it easily. But immobilised enzymes have big practical advantages:

- the enzyme is not washed away, so it can be used again and again.
- the product is pure —it is not mixed with enzyme.
- the enzyme is more stable, so it survives changes in temperature and pH better.
- the process can run continuously, with substrate flowing in and product flowing out.

Biological washing powders contain enzymes that digest food and blood stains at low temperatures