

Enzyme action and activity

Revision notes · How enzymes work, why they are denatured, the effect of temperature, substrate concentration and pH, and calculating rates.

For Edexcel GCSE Biology 1BI0 and Combined Science 1SC0. **Triple only** is not in Combined Science. **Higher tier** is only on the Higher paper.

Enzyme action and activity Spec 1.7-1.11

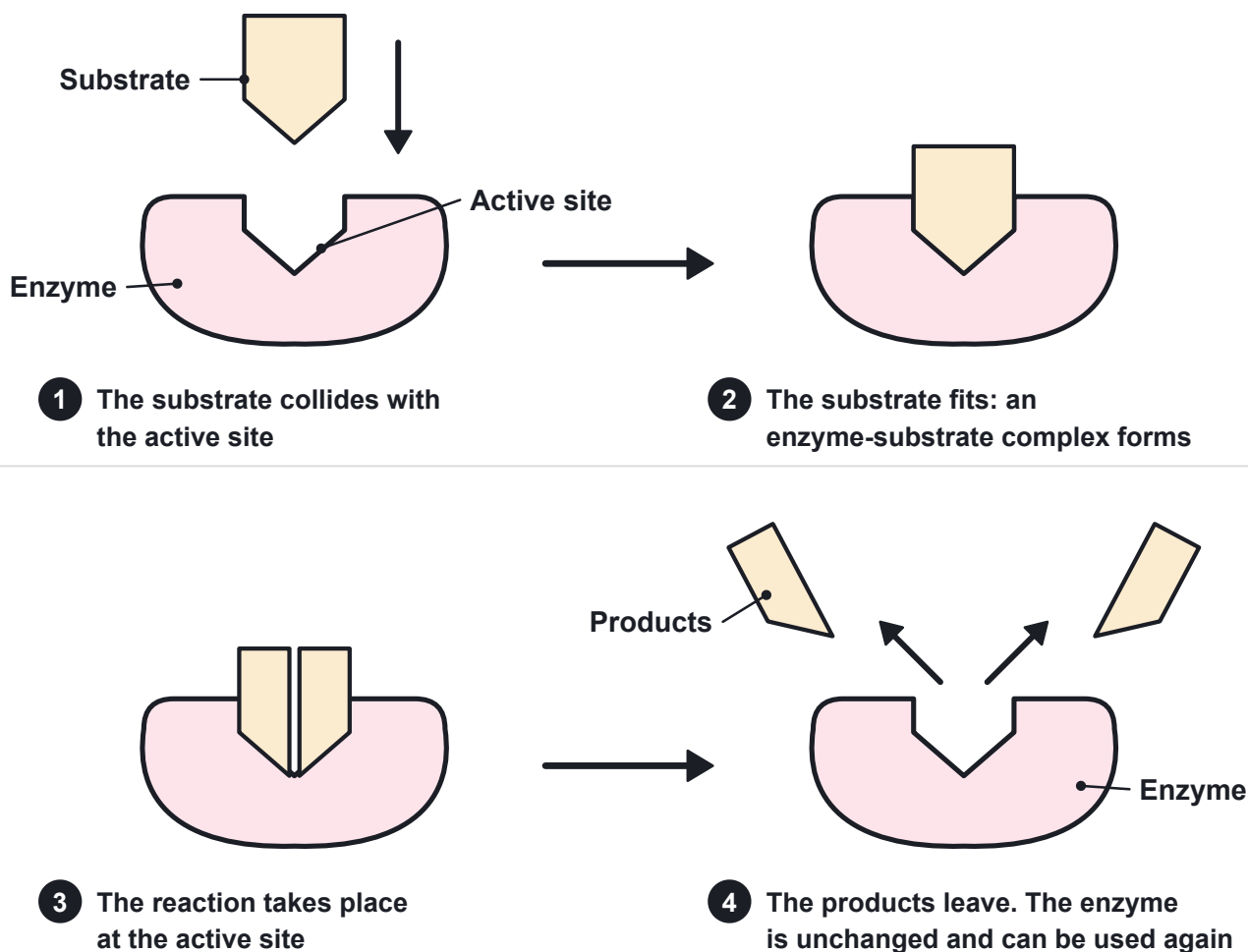
How enzymes work Spec 1.7

Enzymes are proteins that act as **biological catalysts**. A catalyst speeds up a reaction without being used up. Each enzyme has a region called the **active site**, which has a particular shape.

The molecule an enzyme acts on is called the **substrate**. The substrate has a shape that is **complementary** to the active site, so it fits in, like a key in a lock. This is called the lock and key model.

1. The substrate collides with the active site of the enzyme.
2. The substrate fits into the active site, forming an enzyme-substrate complex.
3. The reaction takes place at the active site.
4. The product or products leave the active site and the enzyme is free to be used again.

Enzymes are **specific**. Only a substrate with a shape that fits the active site can bind to it, so each enzyme catalyses only one type of reaction.



The lock and key model. The substrate is **complementary** to the active site, and the enzyme is not used up.

*Exam tip: The mark scheme word is **complementary**. Say the shape of the substrate is complementary to the shape of the active site, not that they are 'the same'.*

Denaturing enzymes Spec 1.8

If the temperature is too high, or the pH is too far from the enzyme's optimum, the bonds that hold the enzyme in shape are broken. The enzyme changes shape, and so does the active site.

The substrate no longer fits the active site, so the enzyme cannot catalyse the reaction. The enzyme is **denatured**. This change is permanent.

*Common mistake: Enzymes are not 'killed' by heat, because they were never alive. Write that the enzyme is **denatured** and the **shape of the active site has changed**.*

Temperature, substrate concentration and pH Spec 1.9

Temperature

As temperature increases, the particles move faster and have more kinetic energy. Enzyme and substrate collide more often, so the rate of reaction increases. The rate is highest at the **optimum temperature**, which is around 37 °C for many human enzymes. Above the optimum, the active site changes shape, the enzyme is denatured and the rate falls quickly towards zero.

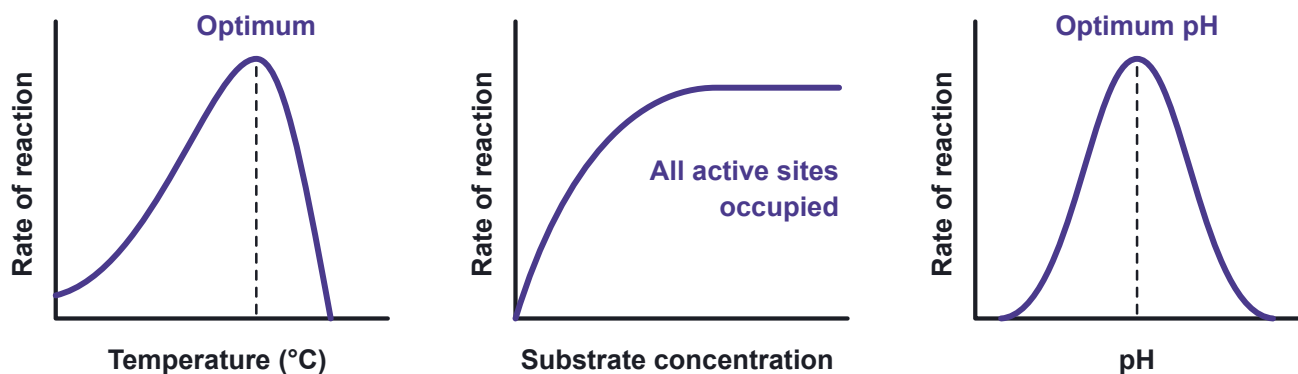
Substrate concentration

At low substrate concentration, increasing it makes the rate increase, because collisions between substrate and active sites are more frequent. Eventually all the active sites are occupied at once. Adding

more substrate then has no effect, so the rate levels off. The enzyme concentration is now limiting the rate.

pH

Each enzyme has an **optimum pH** where it works fastest. If the pH is higher or lower than the optimum the rate decreases, and at extreme pH values the active site changes shape and the enzyme is denatured. Different enzymes have different optimum pH values.



How temperature, substrate concentration and pH affect the rate of an enzyme-controlled reaction.

Summary of the effects on enzyme activity			
Factor	Below the optimum / low	At the optimum	Above the optimum / high
Temperature	Rate increases as particles move faster and collide more often	Highest rate	Enzyme denatured, rate falls
pH	Rate decreases as pH moves away from the optimum, and the enzyme is denatured at extreme pH	Highest rate	Rate decreases as pH moves away from the optimum, and the enzyme is denatured at extreme pH
Substrate concentration	Rate increases	Not applicable	Rate stops increasing when all active sites are occupied

Exam tip: When a graph falls after a peak, always give the reason: the enzyme has been **denatured**. When a graph levels off, say all the **active sites are occupied**.

Core practical: the effect of pH on enzyme activity Spec 1.10

A common version of this investigation uses amylase, an enzyme that breaks down starch, and iodine solution to show when the starch has gone.

Core practical: Independent variable: pH; dependent variable: time for the starch to be broken down. Keep temperature, volumes and concentrations the same each time.

1. Put drops of iodine solution into the wells of a spotting tile.
2. Add starch solution and a buffer solution of a known pH to a test tube. Put this tube, and a tube of amylase solution, in a water bath at a set temperature (for example 35 °C) for a few minutes.
3. Add the amylase solution to the starch and buffer, mix and start the stopwatch.
4. At regular intervals, for example every 30 seconds, use a dropping pipette to add a drop of the mixture to a well of iodine solution.

- Record the time when the iodine solution stops turning blue-black and stays orange-brown. This shows all the starch has been broken down.
- Repeat for buffer solutions of different pH values, and repeat each pH to calculate a mean.

Variable	How it is controlled
Temperature	Use a water bath
Volume and concentration of enzyme	Use the same amount of the same solution each time
Volume and concentration of starch	Use the same amount of the same solution each time

Typical results: the shortest time is at the optimum pH, where the enzyme works fastest. Times get longer at pH values further from the optimum. Plot the rate (or time) against pH on a graph and draw a smooth curve through the points. Wear eye protection, because iodine solution and some buffers are irritants, and wipe up any spills.

Rate calculations for enzyme activity Spec 1.11

The **rate of reaction** tells you how fast a reaction is happening. It is a compound measure, because it combines an amount with a time.

$$\text{rate} = \text{amount of product formed} \div \text{time taken}$$

The units depend on what you measure, for example cm^3/s for a volume of gas, or g/min for a mass. If an experiment measures the time taken for a reaction to finish, such as the time for starch to disappear, the rate can be found as $1 \div \text{time}$, with units of s^{-1} .

Calculating a rate

An enzyme produces 12 cm^3 of gas in 40 seconds. Calculate the rate of reaction in cm^3/s .

- rate = amount of product $\div$ time
- $12 \div 40 = 0.3$

Answer: $0.3 \text{ cm}^3/\text{s}$

Maths skill: A longer time means a slower reaction. If the time doubles, the rate ($1 \div \text{time}$) halves.

Quick check

- What is the name of the part of an enzyme that the substrate fits into?
- Why does an enzyme stop working at a high temperature?
- Why does the rate level off as substrate concentration increases?
- In the pH core practical, what colour shows that starch is still present with iodine solution?
- Calculate the rate when 30 cm^3 of gas is collected in 60 s.

Quick check answers

Enzyme action and activity

1. The active site.
2. The shape of the active site changes, so the substrate no longer fits. The enzyme is denatured.
3. All the active sites are occupied.
4. Blue-black.
5. $0.5 \text{ cm}^3/\text{s}$.