Cambridge IGCSE · Biology 0610 · Notes

Enzymes

Read online at **pastopic.com/cambridge/biology-0610/notes/enzymes**

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Read first: **Biological molecules**

What you need to know

Enzymes come up on every paper, often inside a longer question about digestion or an experiment. The parts marked **Extended only** are tested on Papers 2 and 4 only. By the end of this topic you should be able to:

1. **Describe a catalyst**: a substance that makes a chemical reaction go faster and is not changed by the reaction.
2. **Describe enzymes** as proteins that take part in all the metabolic reactions of living things, where they act as biological catalysts.
3. **Say why living things need enzymes**: without them, the reactions in cells would be far too slow to keep the organism alive.
4. **Describe how an enzyme works**: the active site of the enzyme has a shape that is complementary to (fits) its substrate, and the substrate is turned into products.
5. **Investigate and describe how temperature and pH change enzyme activity**, using the words optimum and denatured.
6. **Extended only:** explain enzyme action using the terms active site, substrate, enzyme–substrate complex and product.
7. **Extended only:** explain why each enzyme works on only one substrate (specificity), in terms of the complementary shape and fit of the active site and the substrate.
8. **Extended only:** explain the effect of temperature in terms of kinetic energy, shape and fit, the frequency of effective collisions, and denaturation.
9. **Extended only:** explain the effect of pH in terms of shape and fit, and denaturation.

Understand it

Catalysts and enzymes

A **catalyst** is a substance that **increases the rate of a chemical reaction** and is **not changed by the reaction**. Because it comes out of the reaction unchanged, it is not used up: one catalyst molecule can be used again and again.

An **enzyme** is a **protein** that works as a **biological catalyst**. "Biological" means it is made by a living cell. Like every protein, an enzyme is a chain of amino acids, so it contains carbon, hydrogen, oxygen and nitrogen (see Biological molecules). Enzymes are **not** carbohydrates or fats, and they are **not** living things themselves, so they can't be "killed".

Enzymes are involved in **all metabolic reactions**, the chemical reactions of life: respiration, photosynthesis, building proteins, and digestion. Digestion that uses enzymes is called **chemical digestion**.

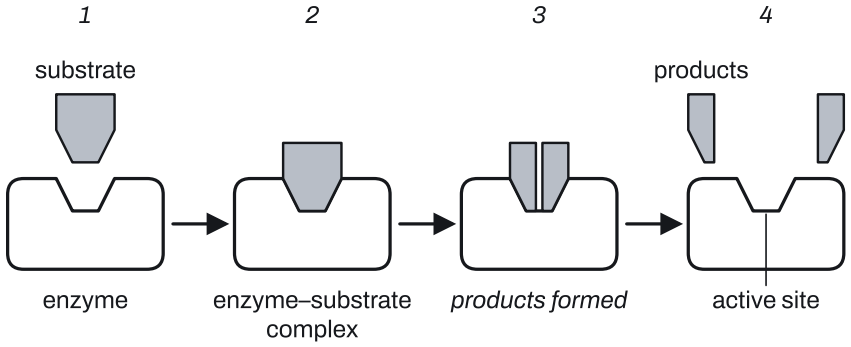
Why life needs enzymes

At body temperature, most of the reactions a cell needs would happen far too slowly on their own, far slower than the cell uses up the products. Heating a cell enough to speed them up would destroy it. Enzymes solve this: they make each reaction fast enough, at a safe temperature, **to keep the organism alive**. Each cell makes the enzymes for the reactions it needs, so enzymes also control which reactions happen.

How an enzyme works

The molecule an enzyme acts on is its **substrate**. The new molecules made are the **products**.

Each enzyme molecule has a small region called the **active site**, a pocket with a particular shape. The shape of the active site is **complementary** to the shape of the substrate: the two fit together like a key in a lock. They are **not** the same shape; one fits into the other.



A different molecule is not complementary to the active site: it can't fit, so no complex forms and there is no reaction.

1. The substrate and the enzyme **collide**, and the substrate fits into the active site.
2. **Extended only:** while the substrate is bound in the active site, the enzyme and substrate together are called the **enzyme–substrate complex**.
3. The reaction happens in the active site. In digestion, bonds in the substrate are **broken** to make smaller product molecules. (Other enzymes join molecules together; the idea is the same.)
4. The **products are released** from the active site.
5. The enzyme is **unchanged**, so its active site is free to take another substrate molecule.

When all the substrate has been used, the tube contains the enzyme and the products. The substrate's concentration falls during the reaction, while the enzyme's stays the same.

Specificity (Extended only)

Each enzyme catalyses only one reaction, with one substrate. This is **specificity**. It happens because only the substrate with the **complementary shape** can fit the active site and form an enzyme–substrate complex. Any other molecule doesn't fit, can't bind, and isn't changed.

The shape of the active site comes from the order of the amino acids in the enzyme's chain. Different enzymes have different amino acid sequences, so they fold into different shapes and have differently shaped active sites. So:

- a **protease** (such as pepsin) can't digest starch, because starch isn't complementary to its active site;
- **lipase** digests fats but not proteins, and **amylase** digests starch but not proteins or fats;
- lactase breaks down lactose but not sucrose, even though both are sugars.

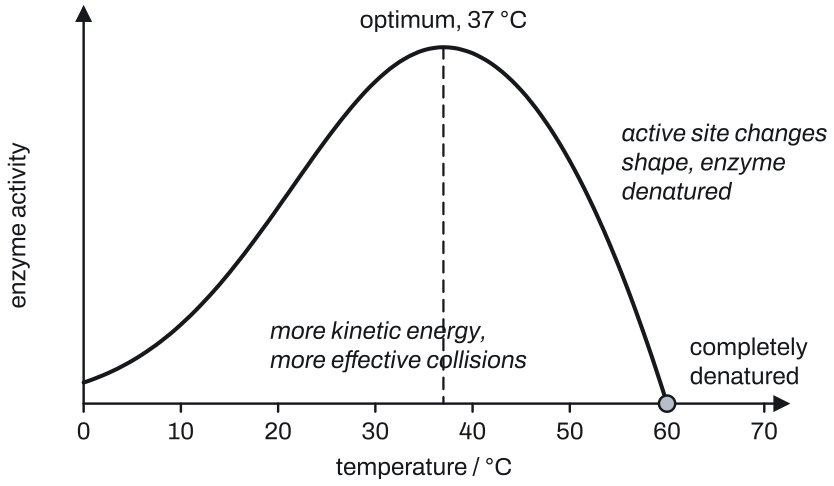
Three enzymes to know by name

These three digestive enzymes appear all the time in enzyme questions. The Human nutrition topic says where each one is made and works.

Enzyme	Substrate	Products
Amylase	starch	simple reducing sugars (maltose)
Protease	protein	amino acids
Lipase	fats and oils	fatty acids and glycerol

Extended only: pepsin and trypsin are proteases. Pepsin works in the **stomach**, where hydrochloric acid keeps the pH at about 2; trypsin works in the **small intestine**, at about pH 8. Amylase works in the mouth and the small intestine, at about pH 7.

The effect of temperature



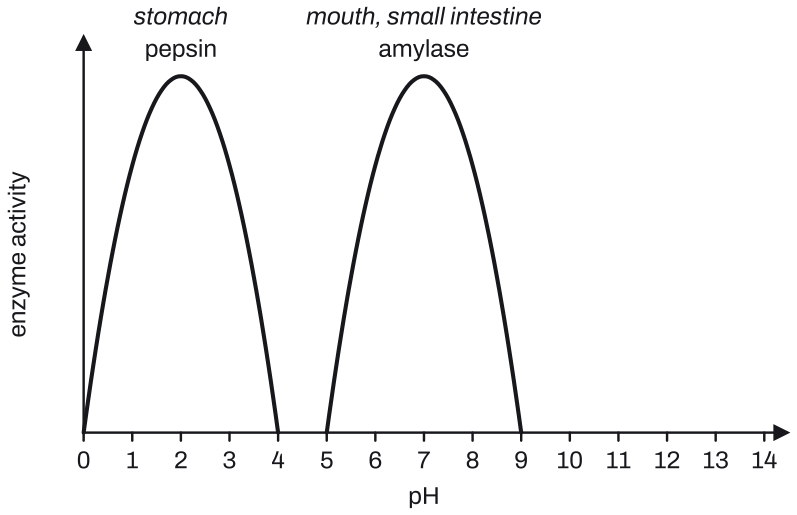
The curve always has the same shape: a **gradual rise to a peak, then a steep fall to zero**.

- **The optimum temperature** is the temperature at the peak, where the enzyme works fastest. For most human enzymes it is about **37 °C**, body temperature. Enzymes from other organisms can have very different optimums: bacteria living in hot springs have enzymes with optimums of 70 °C or more.
- **Below the optimum**, activity is low but not zero. Cold slows the enzyme down but does **not** denature it: warm it up and it works again.
- **Above the optimum**, the enzyme's shape starts to change. The active site loses its shape, so the substrate no longer fits. The enzyme is **denatured**. Denaturing is permanent: cooling the enzyme down again doesn't bring its shape back.
- **Where the curve meets the axis**, every enzyme molecule is denatured and activity is zero.

Extended only: explaining the curve. Molecules are always moving; the higher the temperature, the more kinetic energy they have.

- **Rising part.** As the temperature increases, the enzyme and substrate molecules gain **kinetic energy** and move faster. They **collide more often**, so there are more **effective collisions** (collisions where the substrate fits into the active site) each second, and more **enzyme–substrate complexes** form. More products are made each second.
- **At low temperature**, the molecules have little kinetic energy, so there are few effective collisions and few enzyme–substrate complexes.
- **Falling part.** Above the optimum, the extra energy makes the enzyme vibrate so much that the bonds holding its shape break. The **active site changes shape**, so it is **no longer complementary** to the substrate. The substrate can't fit, fewer enzyme–substrate complexes form, and the rate falls. The enzyme is **denatured**. The molecules are still moving faster than ever, so it isn't a lack of collisions that slows the reaction.

The effect of pH



Each enzyme has an **optimum pH**, where it works fastest. The curve is a peak that falls on **both** sides: too acidic or too alkaline both reduce activity, and far from the optimum the activity is zero. Different enzymes have different optimum pHs, suited to where they work: pepsin (stomach) about pH 2, amylase about pH 7, trypsin (small intestine) about pH 8.

Extended only: explaining it. A pH away from the optimum changes the **shape of the active site**, so it is **no longer complementary** to the substrate. The substrate can't fit, so fewer (or no) enzyme–substrate complexes form. The enzyme is **denatured**. Unlike temperature, pH has nothing to do with kinetic energy or collisions: always explain pH with shape and fit.

In this syllabus, the two things that denature enzymes are **temperature and pH**. Changing the amount of substrate or enzyme changes the rate but never denatures anything.

Investigating enzymes

You should be able to describe these experiments and explain their results.

Amylase and starch, with iodine. Mix starch suspension and amylase in a tube kept in a water-bath at the chosen temperature. Every minute, put a drop of the mixture onto iodine solution on a spotting tile. While starch is still present the iodine turns **blue-black**; when all the starch has been digested it **stays yellow-brown**. Record the time when the blue-black colour stops appearing. The **shorter the time, the faster** the enzyme is working. Benedict's test on the mixture at the end (heated: blue → brick-red) shows that reducing sugar has been made.

Protease and protein. Milk or egg white goes clear as its protein is digested; a protein jelly in a Petri dish develops a clear patch around a hole containing protease. A **bigger** cleared area in the same time means **more** activity.

Catalase and hydrogen peroxide. Potato and liver cells contain an enzyme that breaks down hydrogen peroxide into water and oxygen. Count the bubbles or measure the volume of oxygen in a set time: more oxygen means more activity.

Controlling the investigation:

- **Temperature** is set with a thermostatically controlled water-bath; leave the enzyme and substrate in it separately for a few minutes first, so both are at the right temperature before mixing.
- **pH** is set with a **buffer solution** of known pH.
- Keep everything else the same: the volume and concentration of enzyme and substrate, the temperature (when testing pH) or the pH (when testing temperature), and the time.
- **Control:** a tube with **boiled (denatured) enzyme**, or water instead of enzyme, shows that the enzyme causes the change.
- **Finding the optimum more precisely:** repeat with smaller steps (for example every 2 °C) between the two values either side of the fastest result.

Rate from time. When the result is a time, the rate is $\frac{1}{\text{time}}$. A time of 5 minutes gives a rate of $\frac{1}{5} = 0.2$ per minute. A graph of **time taken** against temperature is upside down compared with an activity graph: its **lowest** point is the optimum.

Key facts and formulas

There is no formula list in the IGCSE Biology exam. Everything below must be learnt.

Formula	Status
Catalyst: increases the rate of a chemical reaction and is not changed by the reaction	Learn it
Enzyme: a protein that functions as a biological catalyst, involved in all metabolic reactions	Learn it
Enzyme + substrate → enzyme–substrate complex (Extended) → enzyme + products	Learn it
Active site shape is **complementary** to the substrate (not the same shape)	Learn it
Amylase: starch → simple reducing sugars. Protease: protein → amino acids. Lipase: fats → fatty acids and glycerol	Learn it
Optimum: the temperature or pH at which the enzyme is most active; human enzymes about 37 °C	Learn it
Denatured: the active site has permanently changed shape, so the substrate no longer fits. Caused by high temperature or extreme pH, not by cold	Learn it
Extended: higher temperature (up to the optimum) → more kinetic energy → more frequent effective collisions → more enzyme–substrate complexes	Learn it
$\text{rate} = \frac{1}{\text{time taken}}$	Learn it

How to do it

In the questions we have tagged for this topic (134 questions, 2021–2025, on Papers 1–4), the types came up this often. 24 of the 134 questions mix types, so the counts add up to more than 134.

Question type	Questions
Define a catalyst or an enzyme, and recall what enzymes are like	49
Identify the active site, substrate, product and enzyme–substrate complex; explain specificity	32
Read or describe an activity graph or table	26
Explain the effect of temperature	19
Name an enzyme's substrate, products or where it works	17
Draw or choose the shape of an activity curve	16
Predict which set-up reacts fastest	11
Explain the effect of pH	8
Explain the results of an enzyme investigation	5
State a factor, other than the one given, that affects enzyme activity	5

Most are one-mark multiple choice on Papers 1 and 2. On Papers 3 and 4 enzymes come as a structured question, often with a graph, or as parts of a digestion question.

1. Define a catalyst or an enzyme, and recall what enzymes are like (49 questions)

1. **Catalyst** (2 marks): increases the rate of a chemical reaction **(1)**; is not changed by the reaction **(1)**.
2. **Enzyme**: a **protein (1)** that functions as a **biological catalyst (1)**.
3. **Statement questions**: check each option against these facts. True: enzymes are proteins; made of amino acids; contain C, H, O and N; involved in all metabolic reactions; speed up reactions; not used up; have an active site; each is specific. False: carbohydrates or fats; slow reactions down; used up or permanently changed; the active site is the same shape as the substrate; denatured by cold; most effective at pH 7 (only some are).

Variations you will meet:

- **"Draw lines" or "tick the boxes"** (Paper 3): choose exactly the right number. "Are biological catalysts", "increase the rate of reactions", "are proteins" and "are involved in all metabolic reactions" are the usual correct endings.
- **"What controls the speed of reactions in cells?"** Enzymes (not hormones, vitamins or mitochondria).
- **"What remains at the end of the reaction?"** The enzyme and the products.
- **"State the type of digestion that uses enzymes."** Chemical digestion.
- **Fill-in sentences**: "Enzymes are proteins made of a chain of smaller **molecules** called **amino acids**; they contain **carbon, hydrogen, oxygen** and **nitrogen**."

2. Enzyme action and specificity (32 questions)

1. **On a diagram**: the **enzyme** is the large molecule that appears unchanged at the start and the end; the **active site** is the pocket in it; the **substrate** is the molecule that fits the active site at the start; the **products** are the smaller pieces released at the end; (Extended) the **enzyme–substrate complex** is the enzyme with the substrate bound in it.
2. **"Describe enzyme action"** (3 marks): substrate and enzyme collide and the substrate binds to the **active site**; the active site is **complementary** in shape to the substrate; bonds in the substrate are broken (or the reaction happens) and the **products are released**; the enzyme is **unchanged** and can be used again. Extended answers add the **enzyme–substrate complex**.
3. **"Which substrate fits?"**: pick the shape that is the exact **complement** of the active site (it fills the notch), not the one with the same outline.

Variations you will meet (Extended):

- **"Explain why enzyme X doesn't digest Y"**: enzymes are specific; X's active site is not complementary to Y **(1)**; Y can't bind, so no enzyme–substrate complex forms **(1)**. For example, lipase has no effect on protein; a protease has no effect on starch.
- **"Why do two enzymes have different active sites?"** They have different sequences of amino acids, so they fold into different shapes.
- **A graph of concentration against time** during a reaction: the substrate falls, the products rise, the enzyme stays the same.
- **Another molecule with the same shape** as the substrate can sit in the active site and block it, so less substrate can bind and the rate falls. Use the fit idea for any case like this that a question describes.

3. Read or describe an activity graph or table (26 questions)

1. **"State the optimum"**: read the x-value at the **peak** (or the lowest time on a time-taken graph).
2. **"State a value where the enzyme is denatured"** or "has no activity": any x-value where the curve is on the axis past the peak. Where the question accepts a range, any value inside it scores.
3. **"State a pH at which both enzymes are active"**: any value where **both** curves are above zero.
4. **"Calculate the difference"**: read both values carefully from the grid, subtract, and give units.
5. **"Describe the results"** (up to 5 marks): trend (activity increases to a peak then decreases) **(1)**; the optimum, with its value **(1)**; where it is zero **(1)**; which part is steeper **(1)**; a data quote with **units**, including the x-value **(1)**. With two enzymes, compare them: which has the higher peak, which works over a wider range, where they overlap.

Variations you will meet:

- **Time taken, not rate.** A curve of "time for complete digestion" is lowest at the optimum and very high (or "never") where the enzyme is denatured.
- **Four enzymes on one graph**: read each question statement against the graph one at a time.

- **Matching enzymes to places**: an optimum near pH 2 → stomach; near pH 7–8 → mouth or small intestine.
- **A different organism**: the optimum is wherever the peak is, even if it is 50 °C (bacteria) or 25 °C (a plant). Don't write 37 °C unless the graph says so.

4. Explain the effect of temperature (19 questions)

Core (Paper 3): "What happens to the enzyme above the optimum?" It is **denatured**: the active site changes shape and the substrate no longer fits.

Extended (the explanation that scores):

1. **Below the optimum / at low temperature**: molecules have little kinetic energy → few effective collisions → few enzyme–substrate complexes → slow reaction.
2. **As temperature rises to the optimum**: more kinetic energy → molecules move faster → more **frequent effective collisions** between enzyme and substrate → more enzyme–substrate complexes → faster reaction.
3. **At the optimum**: the rate is highest.
4. **Above the optimum**: the enzyme is **denatured**; the **active site changes shape**; it is no longer **complementary** to the substrate; fewer enzyme–substrate complexes form → the rate falls, to zero when all the enzyme is denatured.

Variations you will meet:

- **"Explain the results between 0 °C and 40 °C in the table"** (up to 6 marks): name the reaction (amylase breaks down starch), say what the indicator shows (iodine is blue-black while starch is present), then give points 1–3 above, ending with "40 °C was the optimum" if that is where the time was shortest.
- **Multiple choice "why"**: the rate rises below the optimum because of **more kinetic energy and more collisions**; it falls above because the **substrate no longer fits the active site**. Reject "the enzyme is killed", "the enzyme is used up", "cold denatures the enzyme" and "the active site is the same shape".
- **"Where do molecules have the most kinetic energy?"** At the **highest** temperature on the graph, even though the enzyme is denatured there.
- **"At which temperature do effective collisions happen most often?"** At the **optimum** (the peak). Above it the molecules move faster, but the substrate no longer fits the active site, so fewer collisions are effective.

5. Name an enzyme's substrate, products or where it works (17 questions)

1. **Amylase**: starch → simple (reducing) sugars such as maltose.
2. **Protease**: protein → amino acids.
3. **Lipase**: fats and oils → fatty acids and glycerol.

Variations you will meet:

- **"Which substance is an enzyme?"** Pepsin, amylase, lipase, protease, trypsin: any name ending in **-ase**, plus pepsin and trypsin. Saliva, bile, fibrinogen and hormones are not enzymes.
- **Location** (Extended): pepsin → stomach (acid); trypsin → small intestine; amylase from the salivary glands (and pancreas). A protease with its optimum at about pH 2 is **pepsin** in the **stomach**.
- **Biological washing powders** contain proteases and lipases to digest protein and fat stains.

6. Draw or choose the shape of an activity curve (16 questions)

1. **Temperature**: a **gradual rise** to a peak at the optimum, then a **steep fall** to meet the x-axis. It starts above zero at low temperature.
2. **pH**: a peak at the optimum pH, falling on **both** sides to zero.
3. **Sketching for a given optimum** (for example a human enzyme at 37 °C): draw the same shape with the peak directly above that temperature.
4. **Extended:** if asked to mark where the enzyme is **completely denatured**, label the point where the curve **meets the x-axis** after the peak, not the peak and not the falling slope.

In multiple choice, reject: a straight line, a curve that keeps rising, a curve that levels off without falling, and a temperature curve that falls gradually and rises steeply.

7. Predict which set-up reacts fastest (11 questions)

1. **Right enzyme** for the substrate (amylase for starch, protease for protein, lipase for fat).
2. **Right pH**: stomach protease in **acid** (about pH 2); amylase and small-intestine enzymes near **neutral or slightly alkaline**.
3. **Temperature near 35–40 °C** for human enzymes; not boiled, not cold.
4. The tube meeting all three is fastest. A boiled enzyme gives no reaction at all.

Variation (Extended): with fat, **smaller droplets** have a **larger surface area** for lipase to act on, so the fat is digested faster. Bile breaks fat into small droplets, so a tube with bile is faster.

8. Explain the effect of pH (8 questions, Extended)

1. At the optimum pH, the active site has the right shape and activity is highest.
2. Away from the optimum: the **active site changes shape** → no longer **complementary** to the substrate → can't bind, fewer (or no) **enzyme–substrate complexes** → the enzyme is **denatured**.
3. If the enzyme has **no** activity at that pH, say so first: "no protein/jelly is broken down, because ...".

Variations you will meet:

- **Multiple choice**: pH works through shape and fit, not kinetic energy or collisions.
- **"Which changes could denature an enzyme?"** A change in pH and a change in temperature (not a change in substrate concentration).

- **Linking to the gut**: pepsin is denatured when it reaches the higher pH of the small intestine; amylase is denatured in the stomach acid.

9. Explain the results of an enzyme investigation (5 questions)

1. **Say what the test shows.** Iodine blue-black = starch still present; yellow-brown = starch digested. Benedict's brick-red = reducing sugar made. A cleared patch in protein jelly = protein digested.
2. **Link to the enzyme**: "amylase has broken down the starch into sugar".
3. **Link to the conditions**: faster near the optimum; none if boiled or at an extreme pH; none if the enzyme doesn't match the substrate (a protease with starch stays blue-black at every temperature, because it is specific).

Variation: the tube with no enzyme (or boiled enzyme) is the **control**; it shows the change is caused by the enzyme.

10. State another factor that affects enzyme activity (5 questions)

Give the one the question didn't use: **temperature** or **pH**. Substrate concentration or enzyme concentration are also accepted. One word is enough for 1 mark.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **B1** mark for a correct result on its own, with no method needed.

Example 1

(a) Describe what is meant by a catalyst. **[2]**

(b) Enzymes are biological catalysts. State the type of molecule that enzymes are made of. **[1]**

(c) Describe how an enzyme breaks down its substrate. **[3]**

(d) State the substrate and the products of lipase. **[2]**

(e) **Extended:** Explain why lipase does not digest protein. **[2]**

(a) A substance that increases the rate of a chemical reaction **B1**, and is not changed by the reaction **B1**.

(b) Protein. **B1**

(c) Any three of: the substrate binds to the active site of the enzyme **B1**; the active site is complementary in shape to the substrate **B1**; bonds in the substrate are broken and the products are released **B1**; the enzyme is unchanged and can act on more substrate **B1**.

(d) Substrate: fat (or oil) **B1**. Products: fatty acids and glycerol **B1** (both are needed).

(e) Enzymes are specific: the active site of lipase is complementary to fat, not to protein **B1**. Protein can't bind to the active site, so no enzyme–substrate complex forms **B1**.

Example 2

A student mixed starch suspension and amylase at different temperatures. Every minute, she tested a drop of each mixture with iodine solution and recorded the time when it no longer turned blue-black.

Temperature / °C	**10**	**20**	**30**	**40**	**50**	**60**
Time / minutes	16	10	6	4	8	still blue-black after 20

(a) State the temperature at which the amylase was most active. **[1]**

(b) Calculate the rate of reaction at 20 °C, using rate $= \frac{1}{\text{time}}$. **[1]**

(c) **Extended:** Explain the results between 10 °C and 40 °C. **[4]**

(d) Explain the result at 60 °C. **[2]**

(e) Suggest how the student could find the optimum temperature more precisely. **[1]**

(a) 40 °C, because it had the shortest time. **B1**

(b) $\frac{1}{10} = 0.1$ per minute. **B1**

(c) Any four of: amylase breaks down starch, so the iodine stops turning blue-black when the starch has gone **B1**; at 10 °C the molecules have little kinetic energy, so there are few effective collisions and few enzyme–substrate complexes **B1**; as the temperature rises, the molecules gain kinetic energy **B1**; enzyme and substrate collide more frequently, so more enzyme–substrate complexes form **B1**; the starch is broken down faster, so the time falls from 16 to 4 minutes **B1**; 40 °C is (close to) the optimum **B1**.

(d) The amylase is denatured: its active site has changed shape **B1**, so starch no longer fits (is no longer complementary) and isn't broken down, so starch remains **B1**.

(e) Repeat at smaller intervals, such as every 2 °C, between 30 °C and 50 °C. **B1**

Example 3

Two proteases, P and Q, were each placed in a hole in a layer of protein jelly at different pH values. After one hour, the area of jelly broken down was measured.

pH	1	2	3	4	5	6	7	8	9	10	11
P / mm²	60	110	70	25	5	0	0	0	0	0	0
Q / mm²	0	0	0	0	15	40	75	95	80	35	0

(a) State the optimum pH of each protease. **[2]**

(b) State the pH at which both proteases are active. **[1]**

(c) Calculate the difference between the areas broken down by the two proteases at their optimum pH. **[1]**

(d) Suggest which protease comes from the stomach. Give a reason. **[1]**

(e) **Extended:** Explain the result for protease P at pH 8. **[3]**

(a) P: pH 2 **B1**. Q: pH 8 **B1**.

(b) pH 5. **B1**

(c) $110 - 95 = 15$ mm². **B1**

(d) P, because the stomach contains acid, and P works best at low pH (pH 2). **B1**

(e) No jelly was broken down (no activity) **B1**; P is denatured: its active site has changed shape **B1**; so it is no longer complementary to the protein and no enzyme–substrate complexes form **B1**.

Example 4

Three multiple-choice questions, 1 mark each.

(a) Four tubes contain egg white (protein) and pepsin. In which is the protein digested fastest?

Tube	pH	Temperature / °C	Pepsin
A	2	37	fresh
B	8	37	fresh
C	2	5	fresh
D	2	37	boiled

(b) A graph shows the **time taken** to digest starch against temperature. The time is 30 min at 10 °C, 12 min at 25 °C, 5 min at 35 °C and 18 min at 50 °C. At which temperature is the enzyme most active? **A** 10 °C **B** 25 °C **C** 35 °C **D** 50 °C

(c) **Extended:** Why is the rate of an enzyme reaction lower at 15 °C than at 35 °C (below its optimum of 40 °C)?

A The enzyme is denatured at 15 °C. **B** The active site is the same shape as the substrate. **C** There are fewer effective collisions between enzyme and substrate. **D** The substrate has been used up.

(a) A B1. Pepsin works in the stomach, so it needs acid (B is too alkaline), body temperature (C is too cold) and a working enzyme (D is denatured).

(b) C B1. The shortest time means the fastest reaction.

(c) C B1. At lower temperature the molecules have less kinetic energy, so they collide less often. Cold doesn't denature enzymes (A), the active site is complementary, not the same (B), and nothing suggests the substrate has run out (D).

Common mistakes

- **Leaving half the catalyst definition out.** Most candidates remember "speeds up a reaction" but forget "not changed by the reaction", which is the second mark. Saying a catalyst "is not involved in the reaction" is wrong: it takes part, it just comes out unchanged.
- **"The active site is the same shape as the substrate."** Examiners never give credit for this. Write **complementary**.
- **"The enzyme is killed" or "dies".** Enzymes are molecules, not organisms. Write **denatured**.
- **Saying low temperatures denature enzymes.** Cold only slows them down, by lowering kinetic energy.
- **Using denaturation to explain the whole of a falling curve at once**, or to explain a pH effect with kinetic energy. Temperature below the optimum: kinetic energy and collisions. Above the optimum, and any pH effect: shape of the active site, fit, denaturation.
- **Putting the "completely denatured" point at the peak** or halfway down the slope. It is where the curve reaches zero activity.
- **Drawing the temperature curve symmetrical**, or levelling off at the top. It rises gradually and falls steeply to the axis.
- **Reading a time-taken graph as if it were a rate graph.** The shortest time is the fastest reaction.
- **Describing a graph without numbers**, or giving numbers without units. "Describe" needs the trend, the optimum value, and a data quote with its units.
- **Saying the product binds to the enzyme and the substrate is formed.** It's the other way round.
- **Vague names**: "sugar" for the substrate of amylase (it's starch), or "fatty acids" alone for lipase's products (both fatty acids **and** glycerol).
- **Mixing up enzyme and substrate specificity with antibodies.** Antibodies have complementary shapes to antigens, but they don't have active sites and aren't catalysts.

How to get the marks

- **Definitions** are marked point by point: two points for a catalyst, "protein" + "biological catalyst" for an enzyme. Learn them word-perfect in meaning, in your own words.
- **Use the key terms exactly**: active site, substrate, product, complementary, enzyme–substrate complex (Extended), optimum, denatured, kinetic energy, effective collisions. Mark schemes list these words.

- **"Describe" a graph** means what it shows, not why. Give the trend, the optimum with its value, where activity is zero, and one data quote with both coordinates and units. Don't explain unless asked.
- **"Explain" a graph** needs the reasons: kinetic energy and collisions below the optimum; active-site shape, fit and denaturation above it (or away from the optimum pH).
- **Answer about the data given.** If the peak is at 50 °C, the optimum is 50 °C, not 37 °C. If the question says 40 °C, use 40 °C.
- **Count the marks.** A 6-mark explanation needs about six separate points: name the reaction, say what the test shows, then the chain of reasoning.
- **Sketching curves**: draw the right shape, with the peak exactly at the stated optimum, and meet the axis after the peak.
- **"State" or "name"** needs a word or two: "pH", "stomach", "amino acids". Don't add extra answers: a wrong second answer can cancel a right one.
- **Tick boxes, circles and lines**: use exactly as many as asked; each extra wrong one can lose a mark.

Quick check

1. Define the term enzyme.
2. State the substrate and the product of amylase.
3. The times for an enzyme to digest a sample of protein were 12 min at 25 °C, 5 min at 35 °C, 3 min at 45 °C and 20 min at 55 °C. (a) At which temperature was the enzyme most active? (b) Calculate the rate at 35 °C, using rate $= \frac{1}{\text{time}}$.
4. State two factors that can denature an enzyme.
5. **Extended:** (a) Explain why a protease cannot break down starch. (b) Explain why an enzyme works faster at 30 °C than at 20 °C, if its optimum is 40 °C.

Answers

1. A protein that functions as a biological catalyst (it speeds up a reaction in a living thing and is not changed by it).
2. Substrate: starch. Product: simple reducing sugars (maltose).
3. (a) 45 °C, the shortest time. (b) $\frac{1}{5} = 0.2$ per minute.
4. High temperature (above the optimum) and a pH far from the optimum.
5. (a) Enzymes are specific. Starch is not complementary in shape to the protease's active site, so it can't bind and no enzyme–substrate complex forms. (b) At 30 °C the molecules have more kinetic energy, so the enzyme and substrate collide more frequently; there are more effective collisions and more enzyme–substrate complexes form each second.

Past questions to try

- **0610/31/M/J/24 Q2**: the catalyst definition, reading enzyme activity data and naming another factor.
- **0610/32/F/M/22 Q6**: biological washing powders at different temperatures, and how enzymes work.
- **0610/41/O/N/22 Q2**: comparing two proteases on a pH graph and explaining the difference (Extended).
- **0610/22/O/N/22 Q9**: where effective collisions happen most on a temperature graph (Extended).