Chapter: 5: Enzymes
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1) Big-picture overview

This chapter introduces **enzymes**, which are special proteins that act as **biological catalysts** in all living organisms. You'll learn that enzymes are crucial for life because they speed up metabolic reactions to a rate that can sustain a cell's functions. The chapter explains *how* enzymes work using the **lock-and-key model**, where a specific **substrate** fits into the enzyme's **active site**. A key focus is on the factors that affect how well enzymes work, specifically **temperature** and **pH**. You'll explore the concepts of **optimum conditions** and **denaturation**, which is when the enzyme loses its shape and stops working. The chapter also includes practical experiments to investigate these factors, providing a hands-on understanding of enzyme activity.

2) Syllabus mapping

Outcome code	Outcome description	Where covered (page)
Not stated	Define "catalyst" as a substance that speeds up a chemical reaction and is not changed by the reaction.	p. 1
Not stated	Define "enzymes" as proteins that function as biological catalysts.	p. 1, 19
Not stated	Explain the mechanism of enzyme action including the terms active site, substrate, and enzyme-substrate complex.	p. 3, 11
Not stated	Describe enzyme specificity using the "lock and key" analogy of complementary shapes.	p. 3, 11
Not stated	Investigate and explain the effect of changes in temperature on enzyme activity, including the concept of an optimum temperature.	p. 5, 12, 15-17
Not stated	Explain denaturation as the irreversible change in the shape of the active site at high temperatures.	p. 5, 13
Not stated	Investigate and explain the effect of changes in pH on enzyme activity, including the concept of an optimum pH.	p. 8, 13, 18-19

3) Key terms and definitions

Term	One-sentence definition	First appears (page)	Example/application
Catalyst	[cite_start]A substance that increases the rate of a chemical reaction without being used up in the process (p. 1)[cite: 18].	p. 1	[cite_start]Manganese(IV) oxide speeds up the breakdown of hydrogen peroxide (p. 15)[cite: 257].
Enzymes	[cite_start]Proteins that function as biological catalysts to speed up metabolic reactions in living organisms (p. 1, 2)[cite: 19, 20].	p. 1	[cite_start]Amylase in saliva breaks down starch into sugar (p. 4)[cite: 62].
Substrate	[cite_start]The substance on which an enzyme acts (p. 3)[cite: 46].	p. 2	[cite_start]Starch is the substrate for the enzyme amylase (p. 4)[cite: 62].
Product	[cite_start]The molecule(s) produced from the substrate at the end of an enzyme-controlled reaction (p. 3)[cite: 46].	p. 2	[cite_start]Maltose is the product when amylase acts on starch (p. 3) [cite: 50, 60].
Active Site	[cite_start]The specific region of an enzyme molecule where the substrate binds (p. 3)[cite: 48].	p. 3	The active site of amylase has a shape that is complementary to the shape of a starch molecule.
Complementary Shape	[cite_start]The concept that an enzyme's active site and its specific substrate have shapes that fit perfectly together, like a lock and key or jigsaw pieces (p. 3)[cite: 51, 196].	p. 3	[cite_start]A protease enzyme's active site will not fit a starch molecule because their shapes are not complementary (p. 11)[cite: 197].
Denatured	[cite_start]The permanent change in the shape of a protein, such as an enzyme, caused by high temperatures or extreme pH, which deforms the active site and stops it from working (p. 5)[cite: 91, 94].	p. 5	[cite_start]Heating egg white (albumen protein) causes it to turn from a clear liquid to a white solid, an example of denaturation (p. 5) [cite: 97, 99].
Optimum	[cite_start]The specific temperature or pH at which an	p. 8	[cite_start]The optimum temperature for most human

Term	One-sentence definition	First appears (page)	Example/application
	enzyme works at its fastest (maximum) rate (p. 8)[cite: 147].		enzymes is around 37°C (p. 12)[cite: 211][cite_start]; the optimum pH for pepsin is pH 2 (p. 8)[cite: 145].
Enzyme-substrate complex	[cite_start]The temporary structure formed when a substrate molecule binds to the active site of an enzyme (p. 11)[cite: 189, 191].	p. 11	Sucrase binds with sucrose to form a temporary sucrase-sucrose complex before releasing glucose and fructose.
Specificity	[cite_start]The principle that an enzyme will only catalyse one specific reaction because its active site is complementary to only one type of substrate (p. 11)[cite: 193].	p. 11	[cite_start]An enzyme that breaks down starch cannot break down protein (p. 11)[cite: 197].

4) Core concepts explained

Enzyme Action & Specificity (p. 2-4, 11)

- [cite_start]Enzymes are proteins that act as **biological catalysts** to speed up chemical reactions necessary for life (p. 1, 2)[cite: 19, 24].
- [cite_start]They work by binding to a specific molecule called a **substrate** at a special region on the enzyme called the **active site** (p. 3)[cite: 48].
- [cite_start]The shape of the active site is **complementary** to the shape of the substrate, meaning they fit together like a lock and key (p. 3)[cite: 51]. [cite_start]This explains why enzymes are **specific**—they only work on one type of substrate (p. 11)[cite: 193].
- [cite_start]When the substrate binds, a temporary **enzyme-substrate complex** is formed (p. 11)[cite: 189].
- [cite_start]The enzyme then helps convert the substrate into **products**, which are released from the active site (p. 3)[cite: 54].
- [cite_start]The enzyme itself is **not changed** by the reaction and can be used again and again (p. 2)[cite: 21].

Effect of Temperature on Enzyme Activity (p. 5, 12-13)

- [cite_start]Increasing the temperature from a low level gives enzyme and substrate molecules more **kinetic energy**, causing them to move faster (p. 12)[cite: 212, 214].

- [cite_start]This leads to more frequent collisions between substrates and active sites, which **increases the rate of reaction** (p. 12)[cite: 214, 215].
- [cite_start]The reaction rate is highest at the **optimum temperature** (e.g., around 37°C for human enzymes) (p. 12)[cite: 211].
- Above the optimum temperature, the high energy starts to break the bonds holding the enzyme in its specific shape. [cite_start]The active site changes shape permanently, and the substrate can no longer fit (p. 13)[cite: 217, 219].
- [cite_start]This irreversible process is called **denaturation**, and it causes the rate of reaction to fall rapidly (p. 5, 13)[cite: 91, 94, 221].

Effect of pH on Enzyme Activity (p. 8, 13)

- [cite_start]Every enzyme has an **optimum pH** at which it functions most effectively (p. 8)[cite: 144, 147]. [cite_start]For most enzymes in cells, this is around neutral pH 7 (p. 8)[cite: 146].
- [cite_start]However, some enzymes work in extreme conditions, such as **pepsin** in the stomach, which has an optimum of pH 2 (p. 8)[cite: 145].
- [cite_start]Moving away from the optimum pH (either more acidic or more alkaline) alters the shape of the enzyme's active site, reducing its efficiency and slowing down the reaction rate (p. 13)[cite: 227].
- [cite_start]Extreme changes in pH can cause the enzyme to **denature**, just as high temperatures do (p. 13) [cite: 227].
- [cite_start]Unlike heat denaturation, changes in activity due to pH can sometimes be **reversible** if the enzyme is returned to its optimum pH (p. 8)[cite: 149].

5) Diagrams and micrographs (figures)

- **Figure 5.1: Building up a cellulose molecule (p. 2)**
  - **What it shows:** A cyclical diagram illustrating how an enzyme repeatedly picks up single glucose molecules and adds them to a growing cellulose chain. It emphasizes that the enzyme is released unchanged to be used again.
  - **Labels:** enzyme, glucose molecules, start of a cellulose molecule, enzyme joins glucose molecule, cellulose molecule grows longer, enzyme released to be used again.
- **Figure 5.2: Enzyme action (p. 4)**
  - **What it shows:** A "lock and key" model. Part (a) shows a synthesis reaction where two different substrates (A and B) bind to the active site and are joined to form one product. Part (b) shows a breakdown reaction where one substrate binds and is split into two products. It highlights the complementary shapes and specificity.
  - **Labels:** enzyme molecule, substrates (A and B), active site, enzyme-substrate complex, new substance formed (product), enzyme free to take part in another reaction.
- **Figure 5.4: The effect of pH on digestive enzymes (p. 9)**
  - **What it shows:** A graph with "reaction rate" on the y-axis and "pH" on the x-axis. It displays three different curves, showing the different optimum pH values for pepsin (peak at pH 2), "most enzymes"

(peak at pH 7), and pancreatic lipase (peak at pH 8).

- **Figure 5.6: Effect of temperature on enzyme activity (p. 12)**
  - **What it shows:** A typical graph for temperature's effect. "Reaction rate" is on the y-axis and "temperature/°C" is on the x-axis. The curve rises to an optimum temperature (around 40°C in this example) and then falls sharply, showing denaturation at higher temperatures.

6) Processes and cycles

The Catalytic Cycle of an Enzyme

1. [cite_start]**Collision:** The substrate collides with the active site of the specific enzyme that has a complementary shape (p. 12)[cite: 213].
2. [cite_start]**Binding:** The substrate fits into the active site, forming a temporary **enzyme-substrate complex** (p. 11)[cite: 189].
3. [cite_start]**Reaction:** The enzyme facilitates the chemical reaction, either breaking the substrate down into smaller products or joining substrates together into a larger product (p. 3, 11)[cite: 49, 190]. [cite_start]This happens very rapidly (p. 3)[cite: 57].
4. [cite_start]**Release:** The product(s) detach from the active site, as they no longer have the correct shape to bind to it (p. 3)[cite: 54].
5. [cite_start]**Recycle:** The enzyme's active site is now free and the enzyme is unchanged, ready to bind with another substrate molecule and repeat the cycle (p. 2, 3)[cite: 21, 54].

- [cite_start]**Word Equation:** Substrate $xrightarrowtextEnzyme$ Product (p. 2) [cite: 44, 45]
- [cite_start]**Example Equation:** Sucrose $xrightarrowtextSucrase$ Glucose + Fructose (p. 3) [cite: 47]

7) Formulae and calculations

Quantity	Formula	Units	Typical values	Worked example (p. 7)
Percentage Increase	$fractextIncreaseinRatetextOriginalRatetimes100$	%	100-1000%	[cite_start]Calculate the percentage increase in reaction rate between 20°C (rate=4) and 40°C (rate=32)[cite: 134]. [cite_start] Increase = 32 - 4 =

Quantity	Formula	Units	Typical values	Worked example (p. 7)
				28[cite: 134]. [cite_start] % Increase = (28 / 4) x 100 = **700%**[cite: 134].
Percentage Change (Decrease)	$frac text{Change in Rate} text{Original Rate} times 100$	%	0-100%	[cite_start]Calculate the percentage change between 60°C (rate=38) and 70°C (rate=11)[cite: 136]. [cite_start] Change = 38 - 11 = 27[cite: 136]. [cite_start] % Change = (27 / 38) x 100 = **71%** (decrease)[cite: 137].

8) Required practicals / experiments

1. Investigating the Effect of Temperature on Amylase Activity (p. 15-17)

- **Aim:** To find out how temperature affects the rate at which amylase breaks down starch.
- [cite_start]**Apparatus:** Test tubes, syringes or pipettes, water baths at different temperatures (e.g., 10°C, 20°C, 35°C), amylase solution, starch solution, iodine solution, stop-clock (p. 15-16)[cite: 265, 266, 268].
- **Method:**
  i. Set up water baths at a range of different temperatures.
  ii. [cite_start]Place one test tube containing starch solution and another containing amylase solution into each water bath and leave for 5 minutes to equilibrate (p. 16)[cite: 273].
  iii. [cite_start]Add a few drops of iodine solution to the starch tube (it will turn blue-black) (p. 16)[cite: 267].
  iv. [cite_start]Pour the amylase into the starch-iodine solution, start the stop-clock, and return the tube to its water bath (p. 16)[cite: 274, 275].
  v. [cite_start]Record the time it takes for the blue-black colour to disappear, indicating that all the starch has been broken down (p. 16)[cite: 276, 277].
  vi. Repeat for each temperature. The rate of reaction can be calculated as 1/time.
- **Variables:**

    - **Independent Variable (IV):** Temperature (°C).
    - **Dependent Variable (DV):** Time taken for the starch to be digested (s) or the rate of reaction (s^{-1}).
    - **Control Variables:** Volume and concentration of amylase, volume and concentration of starch, pH.
- [cite_start]**Safety:** Wear eye protection (p. 14)[cite: 240]. Be careful with hot water from water baths.
- **Expected Results:** The reaction will be fastest (shortest time) at the optimum temperature (around 35°C in this experiment). It will be very slow at low temperatures and will not happen at all if the enzyme is first boiled.

2. Investigating the Effect of pH on Amylase Activity (p. 18-19)

- **Aim:** To find out how pH affects the rate at which amylase breaks down starch.
- [cite_start]**Apparatus:** Test tubes, syringes or pipettes, spotting tile, starch solution, amylase solution, iodine solution, buffer solutions at different pH values (e.g., pH 3, 6, 7, 9), stop-clock (p. 18)[cite: 305, 307, 309, 310].
- **Method:**
    i. [cite_start]Place starch solution into several test tubes (p. 18)[cite: 305].
    ii. [cite_start]Add a different buffer solution to each tube to create a range of pH values (p. 18)[cite: 307].
    iii. [cite_start]Place drops of iodine solution into the wells of a spotting tile (p. 18)[cite: 309].
    iv. [cite_start]Add amylase solution to the first test tube, start the stop-clock, and shake (p. 18)[cite: 310, 311].
    v. [cite_start]Every 30 seconds, use a pipette to take a sample from the test tube and add it to a drop of iodine on the tile (p. 18)[cite: 312, 313].
    vi. [cite_start]Record the time when the sample no longer turns the iodine blue-black (p. 18)[cite: 314, 315].
    vii. [cite_start]Repeat the entire process for each of the other pH tubes (p. 18)[cite: 316].
- **Variables:**
    - **Independent Variable (IV):** pH.
    - **Dependent Variable (DV):** Time taken for starch to be digested (s).
    - **Control Variables:** Temperature, volume and concentration of amylase and starch.
- [cite_start]**Safety:** Wear eye protection (p. 14)[cite: 240]. Handle acid and alkali buffers with care.
- **Expected Results:** The reaction will be fastest (shortest time) at the optimum pH (around pH 6-7 for amylase). The reaction will be very slow or not occur at all in very acidic or very alkaline conditions.

9) Data handling and graphing

- **Graphs:** The main type of graph used in this chapter is the **line graph**. [cite_start]It is used to show the relationship between a continuous independent variable (like temperature or pH) and a continuous dependent variable (like reaction rate or volume of product) (p. 7, 9, 12)[cite: 121, 150, 203].
- **Axes:**
    - [cite_start]**X-axis (horizontal):** The independent variable you are changing, e.g., **Temperature (°C)** or **pH** (p. 7)[cite: 132].

    - [cite_start]**Y-axis (vertical):** The dependent variable you are measuring, e.g., **Rate of reaction (arbitrary units)** or **Volume of O_2 produced (cm^3) ** (p. 7)[cite: 132].
- **Trends to look for:**
    - [cite_start]**Temperature Graph:** Look for the rise to a peak (**optimum temperature**) followed by a steep drop as the enzyme **denatures** (p. 12)[cite: 210]. The curve is typically asymmetrical.
    - [cite_start]**pH Graph:** Look for a symmetrical, bell-shaped curve with a clear peak (**optimum pH**) and a decrease in rate on either side as the pH becomes too acidic or alkaline (p. 9)[cite: 162].
- **Typical Exam Prompts:**
    - "Plot a graph of the results."
    - "State the optimum temperature/pH for this enzyme." (p. 7) [cite_start][cite: 133].
    - "Explain the shape of the graph between X°C and Y°C."
    - "Calculate the percentage increase/decrease in the rate of reaction between two points." (p. 7) [cite_start][cite: 134, 135].

10) Common misconceptions and exam tips

- **Misconception:** Enzymes are "killed" by high temperatures.
    - **Correct understanding:** Enzymes are proteins, not living things, so they cannot be killed. [cite_start]High temperatures cause them to **denature**—an irreversible change in their 3D shape (p. 5) [cite: 91, 94].
    - **Quick tip:** Use the keyword **denature**, not "killed" or "died".
- **Misconception:** At low temperatures, enzymes are denatured.
    - **Correct understanding:** Low temperatures only make enzymes **inactive** because molecules have very little kinetic energy. [cite_start]The enzyme is not damaged, and its activity will be restored if the temperature is raised (p. 5)[cite: 90].
    - **Quick tip:** Low temp = inactive. High temp = denatured.
- **Misconception:** All enzymes have an optimum temperature of 37°C and an optimum pH of 7.
    - **Correct understanding:** While many human enzymes work best at body temperature and neutral pH, this is not universal. [cite_start]For example, pepsin's optimum is pH 2 (p. 8) [cite: 145][cite_start], and enzymes in thermophilic bacteria can have optimum temperatures above 50°C (p. 5-6)[cite: 111].
    - **Quick tip:** Always refer to the specific enzyme or data provided in the question; don't assume.
- **Misconception:** An enzyme is "used up" during a reaction.
    - **Correct understanding:** Enzymes are catalysts and are not changed or used up by the reaction they catalyse. [cite_start]They can be used repeatedly (p. 2)[cite: 21].
    - **Quick tip:** Think of an enzyme like a tool (e.g., a stapler). It joins things together but can be used again immediately.

11) Exam-style practice

Multiple Choice Questions

1. What is the definition of a catalyst?
   A. A protein that is changed by a reaction.
   B. A substance that slows down a chemical reaction.
   C. A substance that increases the rate of a reaction and is not changed by it.
   D. A biological molecule that works best at 100°C.
   [cite_start]*(Answer: C. This is the definition provided on p. 1[cite: 18].)*
2. The "lock and key" hypothesis refers to the...
   A. Substrate and product having the same shape.
   B. Enzyme and substrate having complementary shapes.
   C. Enzyme being denatured by the substrate.
   D. Enzyme being used up after one reaction.
   [cite_start]*(Answer: B. The active site and substrate fit together specifically[cite: 51].)*
3. What happens to an enzyme when it is denatured?
   A. It gains kinetic energy.
   B. It becomes inactive temporarily.
   C. Its active site permanently changes shape.
   D. It works more efficiently.
   [cite_start]*(Answer: C. Denaturation is a permanent change in the shape of the active site[cite: 93, 221].)*
4. Which factor would likely denature a human enzyme?
   A. A temperature of 20°C.
   B. A temperature of 70°C.
   C. A pH of 7.
   D. A low substrate concentration.
   [cite_start]*(Answer: B. Most human enzymes denature above 50°C[cite: 91].)*
5. The enzyme pepsin works in the stomach. What is its likely optimum pH?
   A. pH 2
   B. pH 7
   C. pH 8
   D. pH 14
   [cite_start]*(Answer: A. The stomach is highly acidic, and pepsin's optimum is pH 2[cite: 145].)*
6. In an experiment, catalase is used to break down hydrogen peroxide. What are the products?
   A. Hydrogen and oxygen
   B. Water and hydrogen
   C. Water and oxygen
   D. Catalase and water
   [cite_start]*(Answer: C. Catalase breaks down hydrogen peroxide into harmless water and oxygen[cite: 243].)*
7. What name is given to the substance an enzyme acts upon?
   A. Product
   B. Active site

C. Catalyst

D. Substrate

[cite_start]*(Answer: D. The substance an enzyme works on is its substrate[cite: 46].)*

8. Why does reaction rate increase from 10°C to 30°C?

   A. The enzyme starts to denature.

   B. Molecules have more kinetic energy, leading to more collisions.

   C. The pH becomes more optimal.

   D. More enzyme-substrate complexes are permanently formed.

   [cite_start]*(Answer: B. Increased temperature increases kinetic energy and the frequency of effective collisions[cite: 214].)*

9. An enzyme that digests starch is called...

   A. Protease

   B. Lipase

   C. Amylase

   D. Catalase

   [cite_start]*(Answer: C. Amylase digests starch (amylose)[cite: 62].)*

10. What is a key difference between an enzyme and an inorganic catalyst?

    A. Enzymes are not used up, but inorganic catalysts are.

    B. Enzymes are denatured by boiling, but inorganic catalysts are not.

    C. Enzymes are not proteins.

    D. Enzymes work on many different substrates.

    [cite_start]*(Answer: B. Boiling denatures enzymes, but not inorganic catalysts like manganese(IV) oxide[cite: 104, 257].)*

Short-answer Questions

1. **Define** the term 'active site'.
   - [cite_start]*Model Answer:* The active site is the specific region/part of an enzyme molecule (1) that combines with the substrate molecule (1) (p. 3)[cite: 48].
2. **Explain** why enzymes are described as 'specific'.
   - [cite_start]*Model Answer:* An enzyme is specific because its active site has a unique shape (1) that is complementary to only one type of substrate, so it will only catalyse one reaction (1) (p. 11)[cite: 193, 196].
3. A student boils a sample of amylase before adding it to a starch solution. **Predict and explain** the result of testing this solution with iodine after 10 minutes.
   - *Model Answer:* The solution will remain blue-black (1). This is because boiling has denatured the amylase enzyme, changing the shape of its active site. [cite_start]Therefore, the starch cannot be broken down (1) (p. 5)[cite: 94, 105].
4. **Sketch** a graph to show how pH affects the rate of reaction of an enzyme with an optimum pH of 8. Label the axes.
   - *Model Answer:* [Student sketches a symmetrical bell-shaped curve]. X-axis labelled 'pH', Y-axis labelled 'Rate of reaction' (1). The peak of the curve must be at pH 8 (1). The curve must start at a low rate, rise to the peak, and fall again (1).

5. **State** two ways to increase the rate of an enzyme-controlled reaction that is currently at 20°C and its optimum pH.
    - *Model Answer:* Increase the temperature (towards the optimum) (1). Increase the concentration of the substrate or the enzyme (1).

Structured Questions

1. An experiment was carried out to investigate the effect of temperature on an enzyme that digests fat stains in a biological washing powder.

a) **Identify** the substrate and the name for this type of enzyme. (2)

b) **Explain** why the stain was removed most effectively at 35°C but much less effectively at 15°C and 70°C. (4)

c) **Suggest** two variables that should have been kept constant to make the experiment a fair test. (2)

Marking Points:

a) **IDENTIFY:** Substrate: Fat/lipid (1). [cite_start]Enzyme type: Lipase (1) (p. 11, 8)[cite: 199, 148].

b) **EXPLAIN:**

* At 35°C, this is likely the optimum temperature, so the rate of reaction is fastest (1).
* [cite_start]At 15°C, molecules have low kinetic energy, so there are fewer collisions between the enzyme and substrate, resulting in a very slow reaction rate (1) (p. 12)[cite: 214].
* At 70°C, the temperature is too high, and the enzyme has been denatured (1).
* [cite_start]This means the active site has changed shape, and the fat can no longer bind to it (1) (p. 5)[cite: 93, 94].

c) **SUGGEST:** Volume/concentration of washing powder solution (1). Size/type of fat stain (1). Volume of water used / Duration of wash / Type of fabric. (Any two)

2. The diagram below shows the 'lock and key' model of enzyme action. [Image similar to Figure 5.2a]

a) **IDENTIFY** structures X, Y, and Z. (3)

b) **DESCRIBE** what is happening in the diagram. (3)

c) **EXPLAIN** what would happen to this reaction if the temperature was increased to 60°C. (2)

Marking Points:

a) **IDENTIFY:** X: Enzyme (1). Y: Substrates (1). Z: Product (1).

b) **DESCRIBE:**

* The substrates (Y) are binding to the active site of the enzyme (X) (1).
* The active site and substrates have complementary shapes (1).
* [cite_start]An enzyme-substrate complex is formed, and the substrates are joined to form the product (Z), which is then released (1) (p. 3, 11)[cite: 51, 189].

c) **EXPLAIN:**

* [cite_start]The enzyme would be denatured by the high temperature (1) (p. 5)[cite: 91].
* [cite_start]Its active site would change shape, the substrate would no longer be able to bind, and the reaction would stop (1) (p. 5)[cite: 94].

12) Quick revision checklist

- ☐ I can define 'enzyme' as a protein that acts as a biological catalyst. (p. 1) [cite_start][cite: 19]
- ☐ I can define 'catalyst' as something that speeds up a reaction without being used up. (p. 1) [cite_start][cite: 18]
- ☐ I can explain the 'lock and key' model using the terms: enzyme, substrate, active site, and complementary shape. (p. 3) [cite_start][cite: 48, 51]
- ☐ I can explain why enzymes are specific to one substrate. (p. 11) [cite_start][cite: 193]
- ☐ I can describe how increasing temperature affects the rate of reaction up to the optimum. (p. 12) [cite_start][cite: 214]
- ☐ I can define 'denaturation' and explain how it is caused by high temperatures. (p. 5) [cite_start][cite: 91, 93]
- ☐ I can sketch and interpret a graph of temperature vs. rate of reaction. (p. 12) [cite_start][cite: 210]
- ☐ I can describe how pH affects the rate of reaction. (p. 8) [cite_start][cite: 144]
- ☐ I can define 'optimum pH' and give examples (pepsin, amylase). (p. 8) [cite_start][cite: 145, 147]
- ☐ I can explain how extreme pH denatures an enzyme. (p. 13) [cite_start][cite: 227]
- ☐ I can sketch and interpret a graph of pH vs. rate of reaction. (p. 9) [cite_start][cite: 162]
- ☐ I can describe an experiment to investigate the effect of temperature on amylase. (p. 15-16)
- ☐ I can describe an experiment to investigate the effect of pH on amylase. (p. 18)

13) Flashcards (ready-to-use)

Question	Answer
What is an enzyme?	A protein that functions as a biological catalyst to speed up metabolic reactions. (p. 1) [cite_start][cite: 19]
What is a catalyst?	A substance that increases the rate of a chemical reaction and is not changed by it. (p. 1) [cite_start][cite: 18]
What is the substrate?	The molecule on which an enzyme works. (p. 3) [cite_start][cite: 46]
What is the active site?	The specific part of the enzyme molecule where the substrate binds. (p. 3) [cite_start][cite: 48]
What does 'complementary shape' mean?	The active site and the substrate have shapes that fit together perfectly, like a lock and key. (p. 3) [cite_start][cite: 51]
Why are enzymes specific?	Because only one type of substrate has the complementary shape to fit the active site of a particular enzyme. (p. 11) [cite_start][cite: 193]
What is an enzyme-substrate complex?	The temporary structure formed when the substrate is bound to the enzyme's active site. (p. 11) [cite_start][cite: 189]

Question	Answer
What is denaturation?	The permanent change in the shape of an enzyme's active site, caused by high temperatures or extreme pH. (p. 5) [cite_start][cite: 94]
What is the effect of low temperature on an enzyme?	It makes the enzyme inactive due to low kinetic energy, but it is not damaged. (p. 5) [cite_start][cite: 90]
What is the effect of high temperature on an enzyme?	It denatures the enzyme, causing the reaction rate to stop. (p. 5) [cite_start][cite: 91]
What is the 'optimum temperature'?	The temperature at which the enzyme has the highest rate of activity. (p. 8) [cite_start][cite: 147]
What is the 'optimum pH'?	The pH at which the enzyme has the highest rate of activity. (p. 8) [cite_start][cite: 147]
What happens to enzyme activity far from the optimum pH?	The enzyme is denatured, and the reaction rate decreases or stops. (p. 13) [cite_start][cite: 227]
Give an example of an enzyme that works in acidic conditions.	[cite_start]Pepsin, found in the stomach, which has an optimum pH of 2. (p. 8) [cite: 145]
How can you test for the breakdown of starch?	Using iodine solution. It turns blue-black in the presence of starch; the colour disappears when starch is broken down. (p. 16) [cite_start][cite: 267, 276]
Name the enzyme that digests starch.	Amylase. (p. 4) [cite_start][cite: 62]
Name the enzyme that digests protein.	Protease. (p. 12) [cite_start][cite: 201]
Name the enzyme that digests lipids (fats).	Lipase. (p. 8) [cite_start][cite: 148]
What are the products when catalase acts on hydrogen peroxide?	Water and oxygen. (p. 14) [cite_start][cite: 243]

14) 60-second recap

Enzymes are proteins that act as biological catalysts, dramatically speeding up reactions in living cells. Their function relies on the 'lock and key' model: a specific substrate fits into the enzyme's active site because their

shapes are complementary. This specificity means one enzyme only does one job. Enzyme activity is highest at an optimum temperature and pH. Below the optimum temperature, enzymes are simply inactive. However, at temperatures that are too high or at extreme pH levels, enzymes are denatured—their active site permanently changes shape, and they stop working. We can measure enzyme activity by tracking how fast a substrate is used up or a product is formed.

15) References to pages

16) Excluded "Going further" sections (not summarized)

Section title	Pages
Intracellular and extracellular enzymes	p. 9
Investigate a range of plant tissues to find out which is the best source of catalase.	p. 15
Total excluded:	**2**