Knowledge

B6 Enzymes and digestion

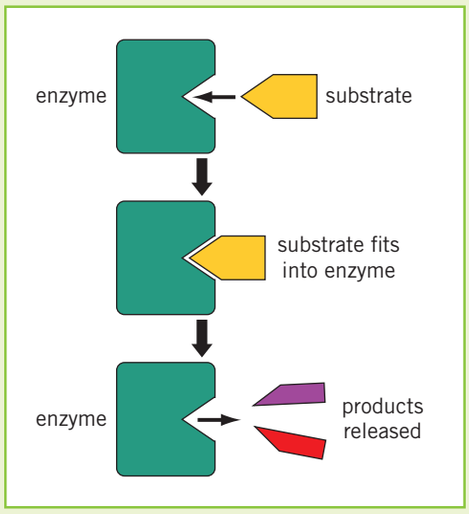
Enzymes

Enzymes are large proteins that **catalyse** (speed up) reactions. Enzymes are not changed in the reactions they catalyse.

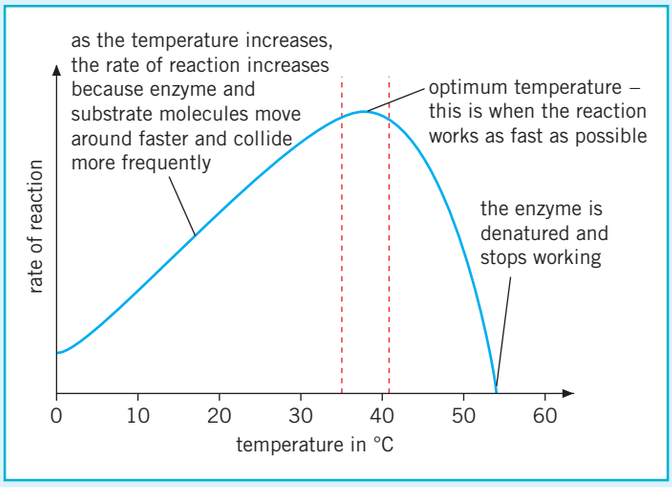
Lock and key theory

This is a simple model of how enzymes work:

1. The enzyme's **active site** (where the reaction occurs) is a specific shape.
2. The enzyme (the lock) will only catalyse a specific reaction because the **substrate** (the key) fits into its active site.
3. At the active site, enzymes can break molecules down into smaller ones or bind small molecules together to form larger ones.
4. When the products have been released, the enzyme's active site can accept another substrate molecule.



The effect of temperature on enzymes



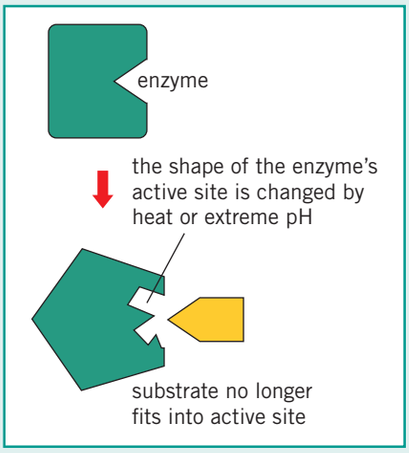
Revision tip

This is one area where biology and chemistry overlap.

The first part of the graph can be explained by the collision theory you have learnt in your chemistry lessons.

Denaturation

At extremes of pH or at very high temperatures the shape of an enzyme's active site can change.



The substrate can no longer bind to the active site, so the enzyme cannot catalyse the reaction – the enzyme has been **denatured**.

Key terms

Make sure you can write a definition for these key terms.

active site *amylase* *catalyse* *denatured* *enzyme*
lipase *optimum* *protease* *substrate*

Digestive enzymes

Digestive enzymes are produced in glands and the lining of the gut. They are released into the gut, where they come into contact with food molecules. Digestive enzymes catalyse the breakdown of large, insoluble food molecules into small, soluble molecules that can then be absorbed into the bloodstream. For example, carbohydrases break down carbohydrates into simple sugars.

These products of digestion can be used to build new carbohydrates, lipids, and proteins.

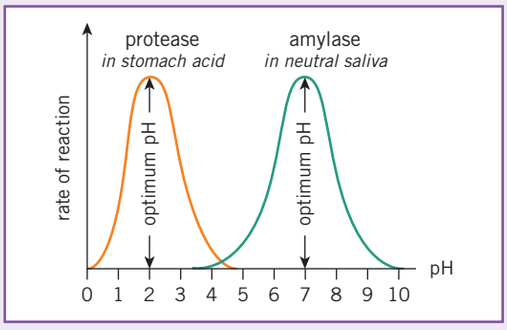
Some of the glucose produced is used in respiration.

Enzyme	Sites of production	Reaction catalysed	Site of reaction
amylase	salivary glands pancreas small intestine	starch → glucose	mouth and small intestine
proteases	stomach pancreas small intestine	proteins → amino acids	stomach and small intestine
lipases	pancreas small intestine	lipids → fatty acids and glycerol	small intestine

The effect of pH on enzymes

Different enzymes have different **optimum** pH values.

This allows enzymes to be adapted to work well in environments with different pH values. For example, the stomach produces hydrochloric acid. Enzymes in the stomach work most effectively in acid conditions.



Bile

Bile is produced in the liver and stored in the gall bladder. From there, it is released into the small intestine.

Bile has two main roles in digestion:

- It creates alkaline conditions – to allow small intestine enzymes to work effectively.
- It emulsifies fats – increasing the surface area of fats for lipase enzymes to act on.

Use of enzymes in the home and industry

Some microorganisms produce useful enzymes that we can use in our homes or in industry, for example:

Use	Enzymes used	Advantages
biological detergents	proteases and lipases	work best at low temperatures, saving electricity
baby food	proteases	pre-digest some of the protein in the food, making it easier for the baby to digest
lower-calorie foods	isomerases (Convert glucose syrup into fructose syrup)	fructose is much sweeter than sugar so less needs to be added to food products

Retrieval

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	B6 questions	Answers
1	What are enzymes?	protein molecules that catalyse specific reactions in organisms
2	Why are enzymes described as specific?	each enzyme only catalyses a specific reaction, because the active site only fits together with certain substrates (like a lock and key)
3	Describe the function of amylase.	to break down starch into glucose
4	Where is amylase produced?	salivary glands, pancreas, and small intestine
5	Describe the function of proteases.	to break down proteins into amino acids
6	Where are proteases produced?	stomach, pancreas, and small intestine
7	Describe the function of lipases.	to break down lipids into fatty acids and glycerol
8	Where are lipases produced?	pancreas and small intestine
9	What are two factors that affect the rate of activity of an enzyme?	temperature and pH
10	What does denatured mean?	shape of an enzyme's active site is changed by high temperatures or an extreme pH, so it can no longer bind with the substrate
11	Describe the effect of temperature on enzyme activity.	as temperature increases, rate of reaction increases until it reaches the optimum for enzyme activity – above this temperature enzyme activity decreases and eventually stops
12	Describe the effect of pH on enzyme activity.	different enzymes have a different optimum pH at which their activity is greatest – a pH much lower or higher than this enzyme activity decreases and stops
13	Why do different digestive enzymes have different optimum pHs?	different parts of the digestive system have very different pHs – the stomach is strongly acidic and the pH in the small intestine is close to neutral
14	Describe the role of bile in digestion.	creates alkaline conditions needed for small intestine enzymes and emulsifies fats
15	Give three commercial uses of enzymes.	biological detergents, baby foods, lower-calorie food production

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Now use the questions below to check your knowledge from previous chapters.

Previous questions		Answers
1	What is the function of saliva in digestion?	lubrication to help swallowing; contains amylase to break down starch
2	Why is active transport needed in plant roots?	concentration of mineral ions in the soil is lower than inside the root hair cells – the mineral ions must move against the concentration gradient to enter the root hair cells
3	What is the function of the guard cells?	control the opening and closing of the stomata
4	Define the term transpiration.	movement of water from the roots to the leaves through the stomata
5	How does the structure of an artery relate to its function?	carries blood away from the heart under high pressure – has a small lumen and thick, elasticated walls that can stretch
6	What is the function of a nerve cell?	carries electrical impulses around the body
7	Name four factors that affect transpiration.	temperature, light intensity, humidity, and wind speed
8	Name the five levels of organisation.	cells → tissues → organs → organ systems → organisms

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Required Practical Skills

Practise answering questions on the required practicals using the example below. You need to be able to apply your skills and knowledge to other practicals too.

Rate of enzyme reaction	Worked example	Practice
This practical tests your ability to accurately measure and record time, temperature, volume, and pH. You will need to know how to find the rate of a reaction by using a continuous sampling technique to measure the time taken for an indicator to change colour. You will be familiar with measuring the effect of pH on the rate of reaction of amylase digesting starch, using iodine as an indicator. This method can also be used to investigate the effect of temperature by placing the enzyme and substrate solutions in different temperature water baths.	A class carried out an investigation into the effect that pH has on the ability of amylase to break down carbohydrates. They timed how long it took for the amylase to break down starch at different pH values between 5 and 11. Suggest the results the class would observe. **Answer:** Optimal pH of amylase is around 7, so the time taken to break down starch will be shortest at pH 7. At pH values lower than 7 it will take longer to break down the starch – it will take the longest time at pH 5, decreasing in time taken until pH 7. Above pH 7 it will take a longer time to break down the starch, and the amylase may stop breaking down the starch entirely at pH 11.	**1** A student wanted to repeat the experiment on the following day to compare their results. Suggest why using the same enzyme solution on two different days would not give comparable results. **2** Suggest how the class might have timed how long it took for the amylase to break down the starch. **3** Give one variable the class must control for this experiment to be valid.

Practice

Exam-style questions

01 Lipase is an enzyme that breaks down lipids.

01.1 Name the products when a lipid is broken down. **[1 mark]**

01.2 Name **one** organ in the body where lipase is made. **[1 mark]**

01.3 A group of students investigated the effect of temperature on the action of the enzyme lipase.

They used the following method in their investigation:

1. Add 10 cm^3 of lipid solution to a test tube.
2. Add 2 cm^3 of lipase solution to a second test tube.
3. Place both test tubes into a water bath set at 20 °C.
4. Leave in the water bath for five minutes.
5. Add the lipid solution to the lipase solution and mix.
6. Remove a sample of the mixture every five minutes and test for the presence of lipids. Continue until no lipid is detected.
7. Repeat the experiment every 5 °C between temperatures of 20 °C and 50 °C.

Name the independent variable in the students' investigation. **[1 mark]**

01.4 Suggest why the lipase solution and lipid solution were left in the water bath for five minutes before mixing. **[1 mark]**

01.5 The students' results are shown in **Table 1**.

Table 1

Temperature in °C	Mean time taken until no lipid remained in min
20	20
25	15
30	10
35	5
40	10
45	20
50	lipid still present after 30 minutes of testing

Exam Tip

Can you think of another name for a lipid that will point you towards the answer?

Describe the effect on the breakdown of the lipid when the temperature is increased between 20 °C and 35 °C. **[1 mark]**

Exam Tip

You can make a quick sketch of the graph if you think it will help answer this question.

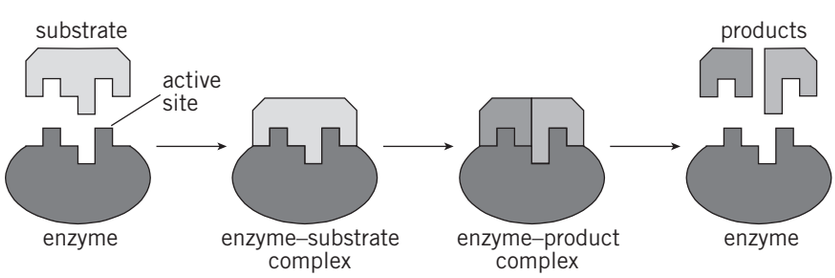
01.6 Explain the result that was observed at 50 °C. **[2 marks]**

Exam Tip

This question says 'explain' – it is asking *why* that results happened not just *what* happened.

02 **Figure 1** demonstrates the lock and key theory of enzyme action.

Figure 1



02.1 Using **Figure 1** and your own knowledge, explain what is meant by enzyme specificity. **[3 marks]**

Exam Tip

There are lots of key words in the diagram – make sure you use them all in your answer!

02.2 Explain why you only need a small volume of an enzyme to catalyse a reaction. **[2 marks]**

Exam Tip

When you're talking about enzymes, it's really important that you use the correct terms.

When the active site breaks down an enzyme becomes denatured – lots of students write that the enzyme has died or has been killed.

This is incorrect and will lose you marks in the exam.

02.3 Describe **one** example of an enzyme-controlled reaction where small molecules are joined together to form larger ones. **[1 mark]**

02.4 Measles is an infectious disease caused by a virus. It causes sufferers to have a raised body temperature. Using your knowledge of enzymes, suggest and explain **one** way in which this may be damaging to the body and **one** way in which this may be beneficial to the body. **[4 marks]**

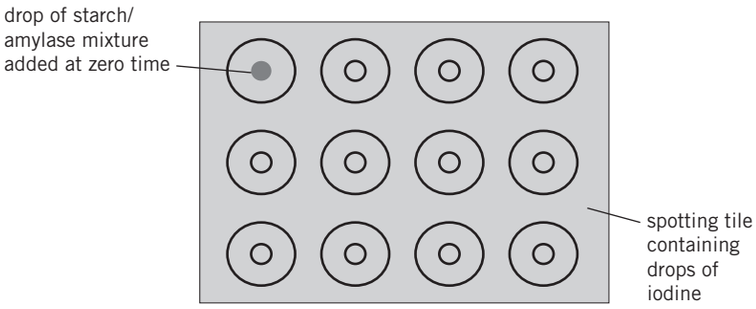
03 A group of students investigated the effect of pH on the action of the enzyme amylase.

03.1 Name the substance that is broken down by amylase. **[1 mark]**

03.2 The students placed starch solutions of known volume and concentration in a water bath at 30 °C. They then added a buffer solution, at one of five different pH values, to each starch solution. Give **two** variables that the students controlled. **[2 marks]**

03.3 The students then took each sample of starch solution, one at a time, and mixed it with a fixed volume and concentration of amylase. They used the equipment in **Figure 2** to test for the presence of starch every 30 seconds.

Figure 2



Describe how you would monitor the reaction to identify when all of the starch has been broken down. **[3 marks]**

03.4 The students' results are shown in **Table 2**.

Table 2

pH of buffer solution	Time taken for amylase to break down starch solution in s			
	Repeat 1	Repeat 2	Repeat 3	Mean
5	112	120	119	117
6	33	30	27	30
7	33	28	29	30
8	55	65	60	60
9	129	120	135	

Calculate the mean time taken for the action of amylase at pH9. **[1 mark]**

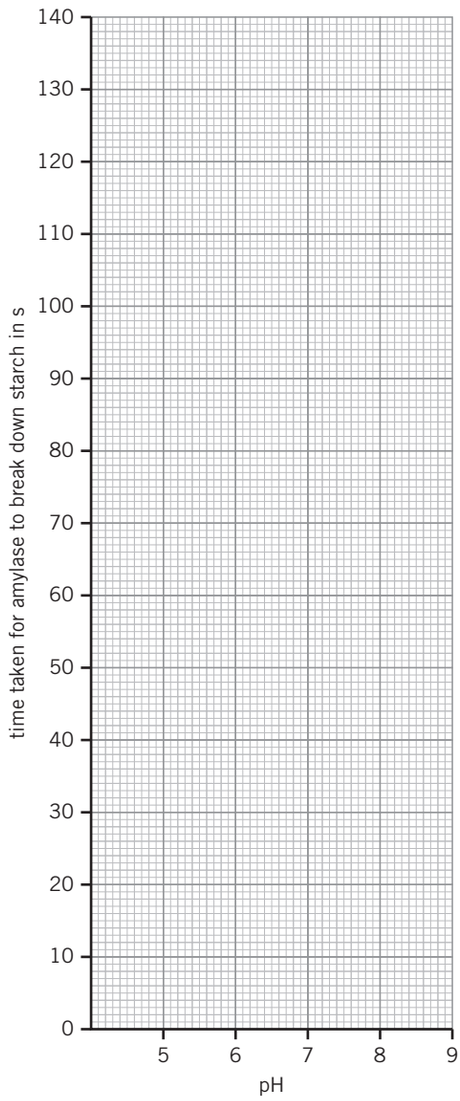
Exam Tip

Go through the text with a highlighter and pick out anything that was kept the same.

03.5 Plot the students' mean results on **Figure 3**. **[3 marks]**

03.6 Use **Figure 3** to calculate the optimum pH for amylase to catalyse the breakdown of starch. **[1 mark]**

Figure 3



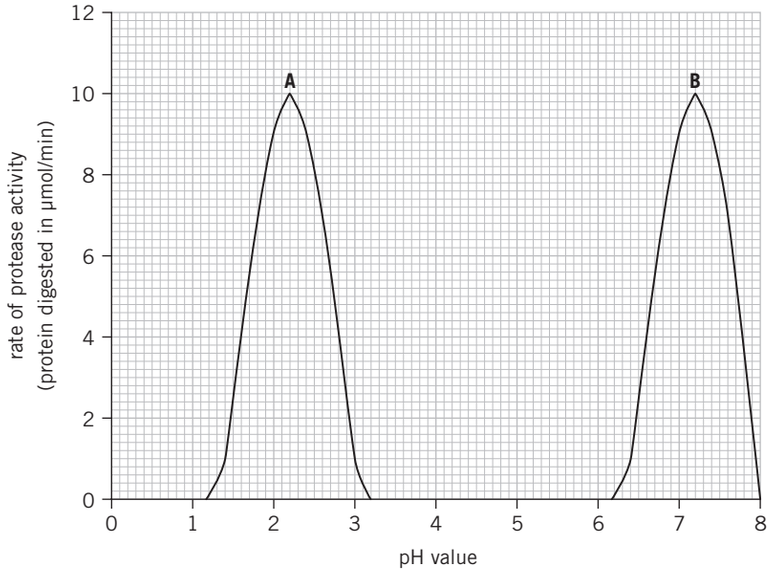
Exam Tip

Always use an 'X' to plot points. This is for lots of reasons:

- You get marks in the exam for plotting points so we need to make sure the examiner can see them.
- If you use a dot it can be hard for the examiners to see exactly which value it represents, as a dot may be too large.
- If you draw a line of best fit that covers up your dots then the examiner can't see them, and can't give you marks for things they can't see.
- Don't be tempted to put a dot with a circle around it – this is really unclear what point you are referring to and you won't get any marks!

04 **Figure 4** shows how pH affects the activity of two different types of protease enzyme – enzyme **A** and enzyme **B**.

Figure 4



Exam Tip

These graphs are very common exam questions.

Make sure you can draw them, recognise their shapes, and explain fully what is going on in each part of the graph.

04.1 Name the substance that proteases break down into amino acids.

[1 mark]

04.2 Describe the role of amino acids in the body.

[2 marks]

04.3 Use **Figure 4** to identify the optimum pH of enzyme **A**. **[1 mark]**

04.4 Suggest and explain where enzymes **A** and **B** are found in the body. **[4 marks]**

04.5 Explain the advantage of adding enzymes to biological washing powders. **[4 marks]**

04.6 Explain why many biological washing powders recommend not washing clothes on a 60 °C cycle. **[2 marks]**

Exam Tip

Draw construction lines on your graph – this is your working out!

Exam Tip

Think about enzyme action at high temperatures.

05 A student was studying the effect of pH on the enzyme activity of an unknown carbohydrase. They were provided with the following apparatus:

- test tubes and rack
- spotting tiles
- 10 cm^3 measuring cylinder
- 3 cm^3 pipettes
- glass stirring rod
- stopwatch
- safety goggles
- starch solution
- carbohydrase solution
- iodine solution
- thermometer
- pH buffer solutions

Explain how the student could investigate the effect of pH on the rate of reaction of the enzyme. **[6 marks]**

Exam Tip

Practice at planning experiments is if vital for exam success!

Plan a clear step-by-step method that could be followed by another person, stating volumes, equipment, and any safety precautions.

06 Biological washing powders contain enzymes. A scientist carried out an investigation to determine if a new type of protease enzyme should be included in washing powder.

06.1 Describe the function of proteases. **[1 mark]**

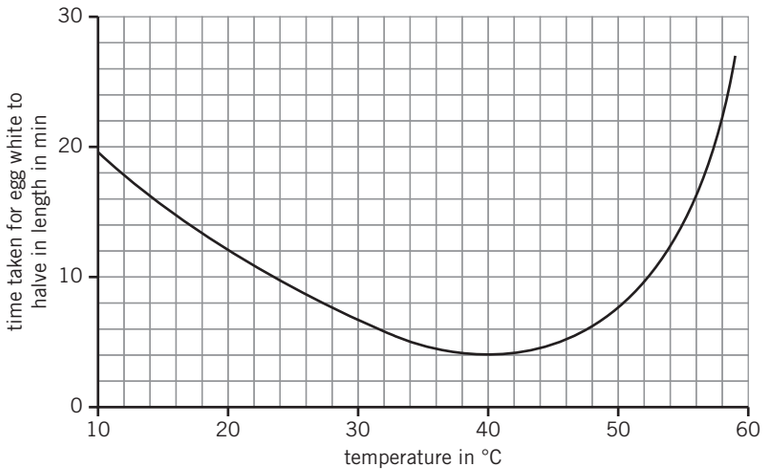
06.2 Protease function can be studied by looking at the time it takes to digest cooked egg white.

- The scientist placed a 2 cm^3 piece of egg white into a test tube.
- They then added a fixed volume of the protease enzyme to the test tube and timed how long it took for the egg white to halve in length.
- The experiment was repeated at temperatures between 10 °C and 60 °C.
- A control was also set up using water instead of protease at each temperature. The egg white in the control samples remained undigested after two hours.

Name the equipment the scientist should have used to change the temperature. **[1 mark]**

06.3 **Figure 5** shows the scientist's results.

Figure 5



Identify the optimum temperature for protease activity. **[1 mark]**

06.4 Calculate the rate of reaction for the enzyme to break down the egg white at 20 °C. Give the unit of rate. **[3 marks]**

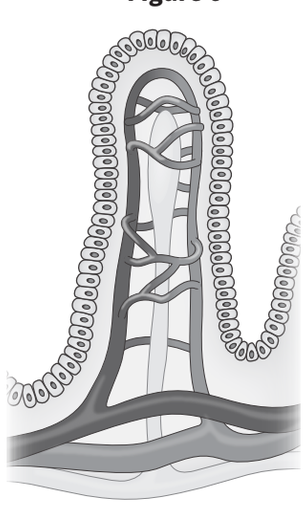
06.5 Using information in **Figure 5** and your own knowledge, suggest and explain **one** advantage and **one** disadvantage of using this enzyme in a biological washing powder. **[4 marks]**

Exam Tip

You may be surprised to see this question in biology, but we know the exam is going to be full of surprises! It's the same method we use in chemistry to find the gradient.

07 The small intestine is covered in villi. A diagram of a villus is shown in **Figure 6**.

Figure 6



07.1 Identify which type of structure a villus is classified as. **[1 mark]**

cell organ tissue organ system

07.2 Use information in **Figure 6** and your own knowledge to explain how a villus is adapted to its function. **[3 marks]**

07.3 Explain why villi cells have a large number of mitochondria. **[2 marks]**

08 Trypsin is an example of a protease enzyme.

08.1 Name the type of molecule broken down by trypsin. **[1 mark]**

08.2 Trypsin is produced in the pancreas and released into the small intestine. Identify the optimum pH for trypsin activity. Choose **one** answer. **[1 mark]**

pH 2 pH 4 pH 8 pH 9

08.3 Trypsin is specific for catalysing one type of reaction. Using the lock and key theory, explain what is meant by enzyme specificity. **[3 marks]**

Exam Tip

Key words are important for this question.

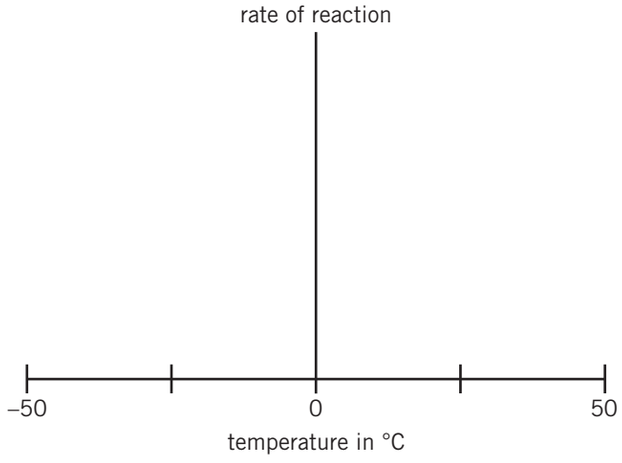
09 Cryophilic bacteria are a group of bacteria capable of growing and reproducing at low temperatures, ranging from −20 °C to +10 °C. They are found in permanently cold environments, such as polar regions and the deep sea. They are able to survive because their enzymes are able to work at low temperatures.

Exam Tip

Don't worry if you've never heard of cryophilic bacteria before. This is just about applying the science you know to a new context.

09.1 On **Figure 7**, draw and label a line to represent the rate of reaction at different temperatures of an enzyme found in humans. **[2 marks]**

Figure 7



Exam Tip

Your line needs to be bell-shaped!

Exam Tip

This graph may look a bit confusing, but that's just because the y-axis is in the middle. Treat it like any other graph.

09.2 Draw and label a second line on **Figure 7** to represent the rate of reaction at different temperatures of an enzyme found in cryophilic bacteria. **[2 marks]**

10 Living cells could not function without enzyme-controlled reactions.

10.1 Explain how changing pH affects the rate of an enzyme-controlled reaction. **[3 marks]**

10.2 The enzyme trypsin breaks down casein (a form of protein) in milk. Give the name of the group of digestive enzymes that trypsin belongs to. **[1 mark]**

Exam Tip

Use example pHs: "at low pH…" and "at high pH…"

10.3 Trypsin breaks down casein, changing its colour from white to clear. Some scientists took a range of milk samples and mixed them with trypsin at different temperatures. They measured the rate at which trypsin breaks down casein using a spectrophotometer.

A spectrophotometer measures the amount of light transmitted through the liquid.

Suggest a method, using the spectrophotometer, to determine the optimum temperature for trypsin action. **[4 marks]**

10.4 The scientists noticed that the glass of the test tube containing the milk solution was cloudy.

Suggest and explain the effect of the clouded glass on the scientists' results. **[3 marks]**