

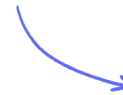
Structured Questions

Enzymes & Metabolism

Metabolism: Enzymes & Reactions / Enzyme Action / Enzyme Activity: Skills / Enzyme Reaction Rates: Skills / Activation Energy: Skills / Metabolic Pathways (HL) / Enzyme Inhibition (HL)

Easy (10 questions)	/85
Medium (10 questions)	/79
Hard (8 questions)	/90
Total Marks	/254

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Easy Questions

1 (a) Distinguish between anabolic and catabolic reactions.

Include **one** example of each reaction.

(5 marks)

(b) State the main mode of action of enzymes.

(2 marks)

2 (a) The protein Rubisco is an enzyme.

What is the function of the enzyme Rubisco in living organisms?

(2 marks)

(b) Enzymes have a specific three-dimensional conformation that enables them to carry out their roles in living organisms.

Which part of the amino acid determines the conformation of the protein?

(1 mark)

(c) In certain conditions, such as high temperatures, the 3D conformation of proteins can be lost.

(i) What is the scientific name given to when a protein loses its 3D conformation?

[1]

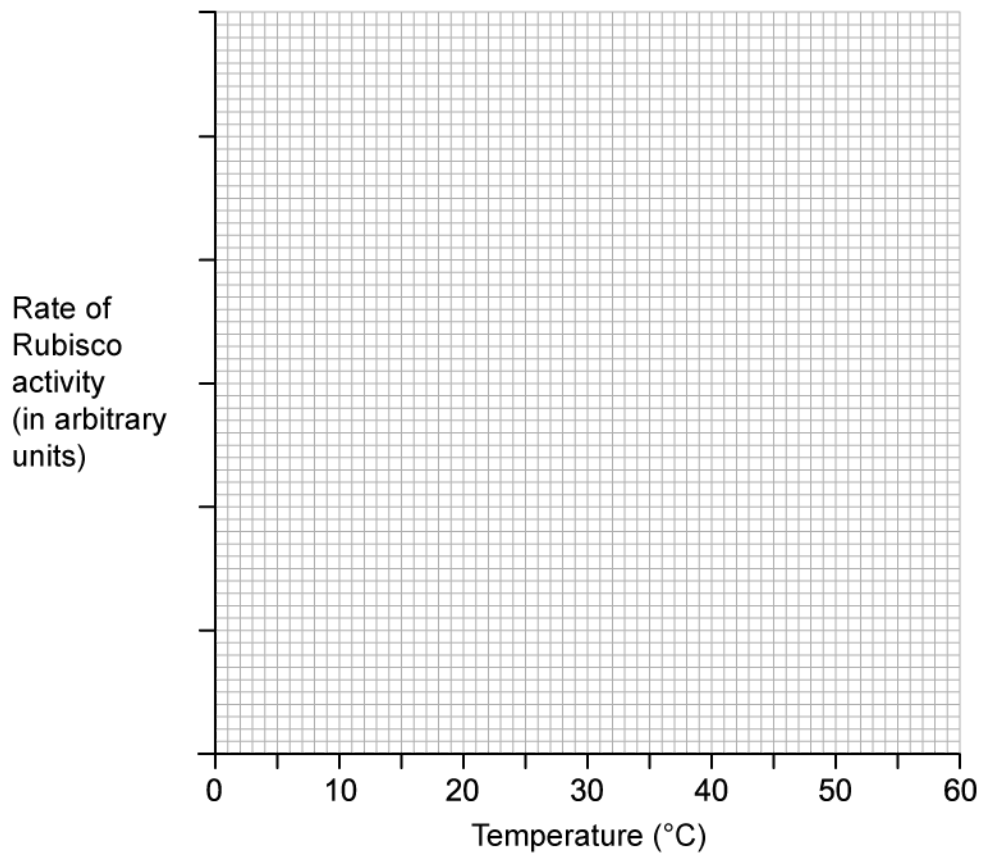
(ii) State one condition, other than temperature, that can cause the 3D conformation of a protein to be lost.

[1]

(2 marks)

(d) Sketch a graph to show how the rate of reaction of Rubisco changes over a range of temperatures.

Use the axes provided below.



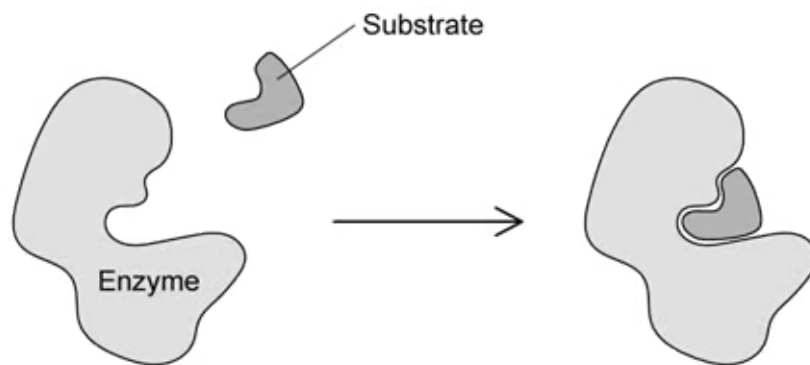
[2]

(2 marks)

3 (a) State the reason why enzymes are referred to as biological catalysts.

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(1 mark)

(b) The image below shows a representation of an enzyme-controlled reaction.



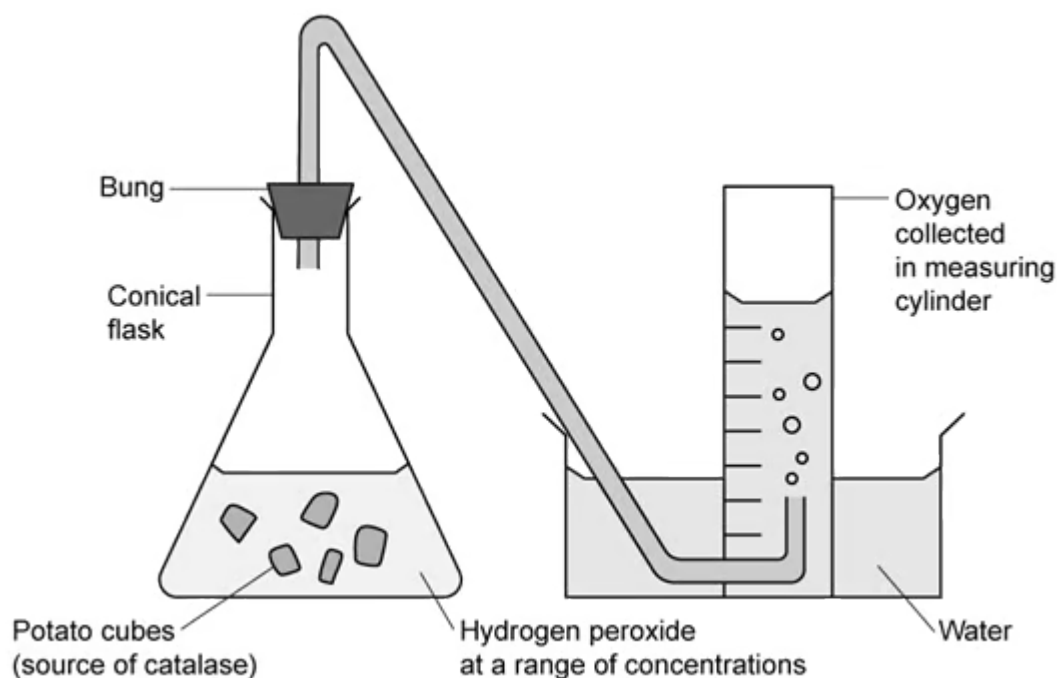
Describe the events taking place in the image.

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(3 marks)

(c) State what is meant by the term 'enzyme specificity'?

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(2 marks)

- 4 (a) A student wanted to investigate the effect of substrate concentration on the activity of an enzyme called catalase. Catalase is an enzyme that commonly occurs inside living cells where it breaks down toxic hydrogen peroxide into oxygen and water. The image below shows the experimental set up done by the student.



List **two** control variables that the student would need to be aware of in the experiment shown in the image.

.....

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(2 marks)

- (b) The student decided to make up solutions at five different hydrogen peroxide concentrations. Their measurements for these solutions are shown in the table below.

Concentration of hydrogen peroxide solution (%)	Volume of hydrogen peroxide required (cm ³)	Volume of distilled water required (cm ³)
10	10	90
8	B	C
6	6	94
A	4	96
2	2	98

Give the measurements needed to fill in gaps **A-C** in the table.

(1 mark)

- (c) After measuring out the range of hydrogen peroxide concentrations shown in part (b), the student carried out the experiment using the equipment set up in part (a). They recorded the volume of oxygen (the product) produced after one minute, and repeated this measurement three times at each concentration. Their results are shown in the table below.

Hydrogen peroxide concentration / %	Volume of oxygen produced after 1 minute / cm ³			Mean volume of oxygen / cm ³
	Repeat 1	Repeat 2	Repeat 3	
10	18	20	21	19.7
8	17	18	18	17.7
6	13	11	13	X
4	9	9	10	9.3
2	5	6	6	5.7

Use the data in the table to calculate the value missing from the square marked **X**.

(1 mark)

- (d) State the purpose of repeating the experiment three times at each concentration of hydrogen peroxide.

(2 marks)

- (e) Using the data in part (c), draw a graph of hydrogen peroxide concentration against the mean volume of oxygen.

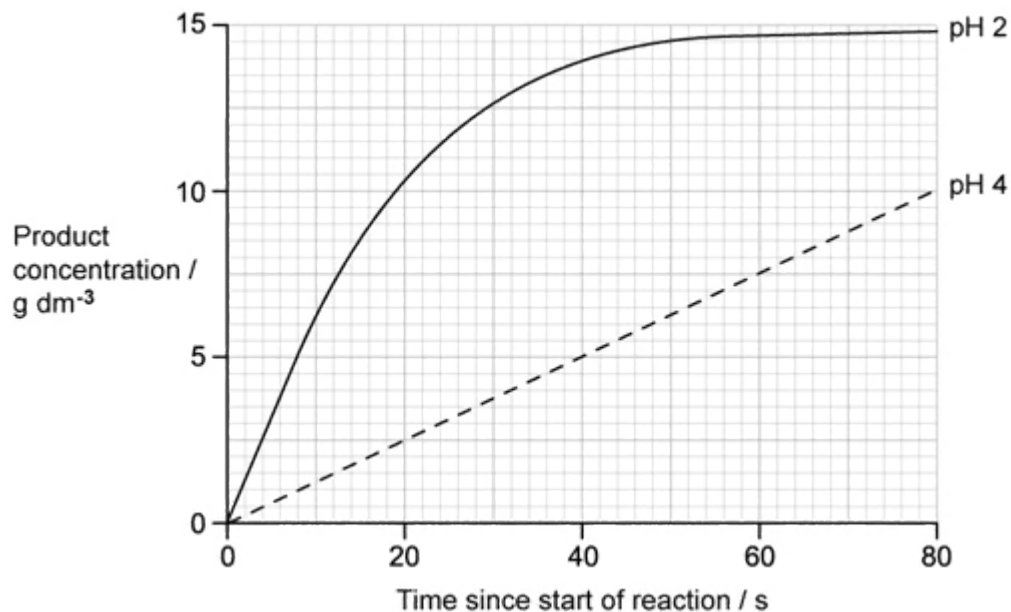
(4 marks)

(f) Deduce the conclusions that can be drawn from your graph from part (e).

(2 marks)

5 (a) A researcher investigated the effect of pH on the activity of stomach enzyme pepsin.

Their results are shown in the image below.



The rate of reaction can be calculated by using the following formula:

$$\text{reaction rate} = \frac{\text{Amount of product produced (g dm}^{-3}\text{)}}{\text{Time (s)}}$$

Calculate the rate of reaction at pH 4. Give your answer with the correct units.

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(2 marks)

(b) Describe the differences between the curves at pH 2 and pH 4.

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(2 marks)

(c) State why product production at pH 2 does not continue indefinitely but reaches a plateau at around 14.75 g.

(1 mark)

(d) (i) Predict the outcome if the pH were increased to pH 10.

[1]

(ii) Explain your answer at part i).

[2]

(3 marks)

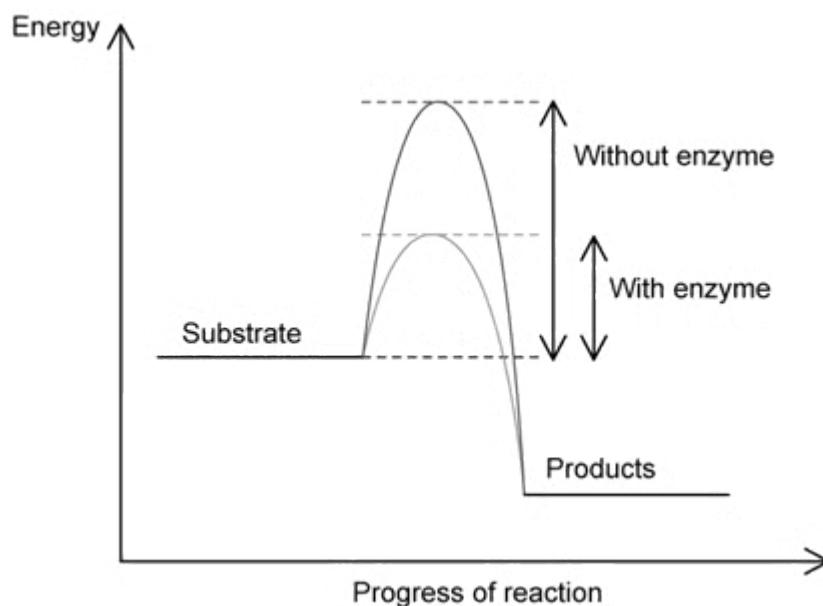
6 (a) Describe the processes that occur during an enzyme-catalysed reaction.

(4 marks)

(b) Outline the events that occur when enzymes are exposed to high temperatures.

(4 marks)

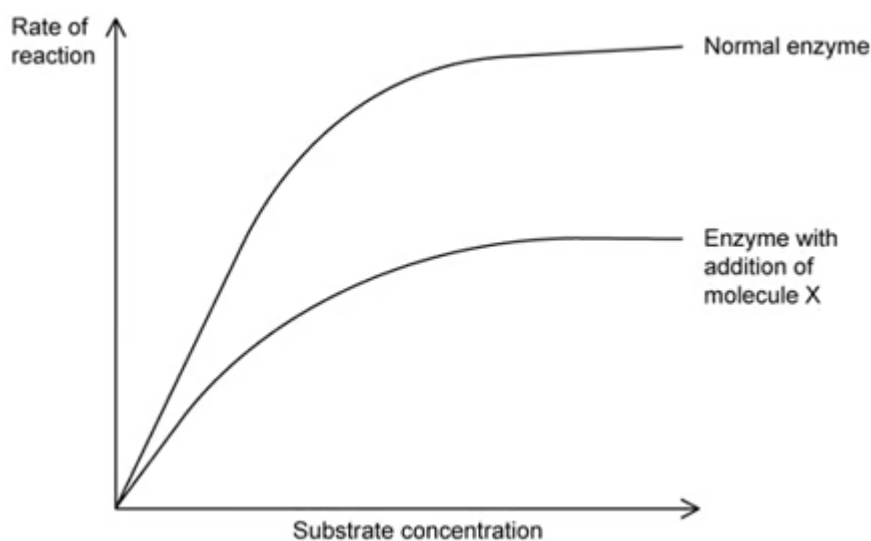
7 (a) The graph below shows how enzymes affect biological reactions.



Use the graph and your own knowledge of enzyme function to explain how enzymes function as biological catalysts.

(1 mark)

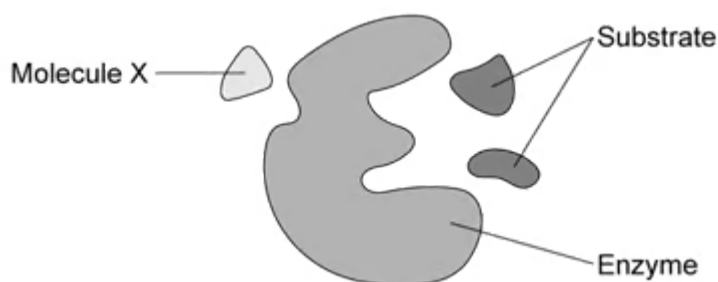
(b) The graph shows how the addition of a molecule named here as molecule X affects the rate of an enzyme-controlled reaction.



Describe how the addition of molecule **X** affects the rate of reaction in the graph.

(2 marks)

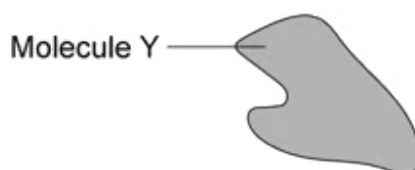
(c) The image below shows how molecule **X** interacts with the enzyme.



Use the image to explain the results shown in the graph in part **(b)**.

(2 marks)

(d) The image below shows another molecule, molecule **Y**.



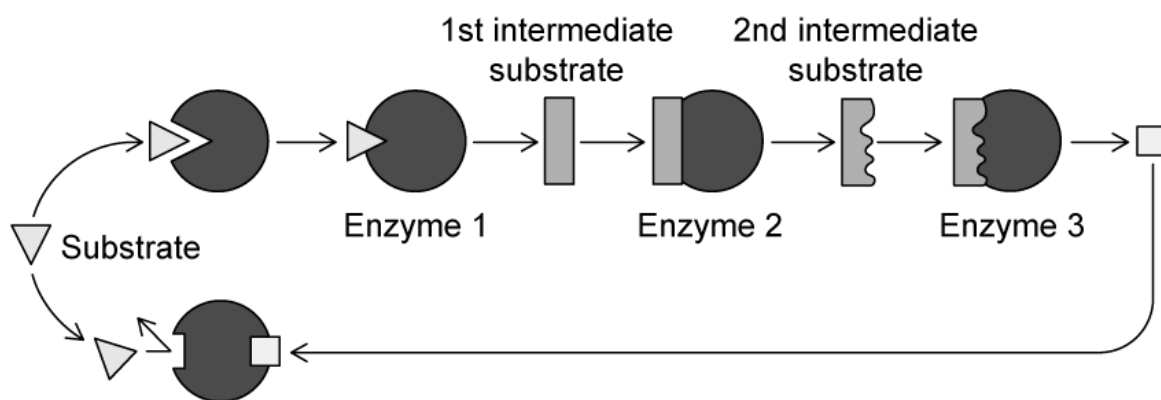
Suggest how molecule **Y** might interact with the enzyme shown in part **(c)**.

(1 mark)

(e) Sketch a line on the graph from part **(b)** to show how molecule **Y** might affect the rate of reaction.

(2 marks)

8 (a) State, with a reason, the type of enzyme inhibition shown in the image below.



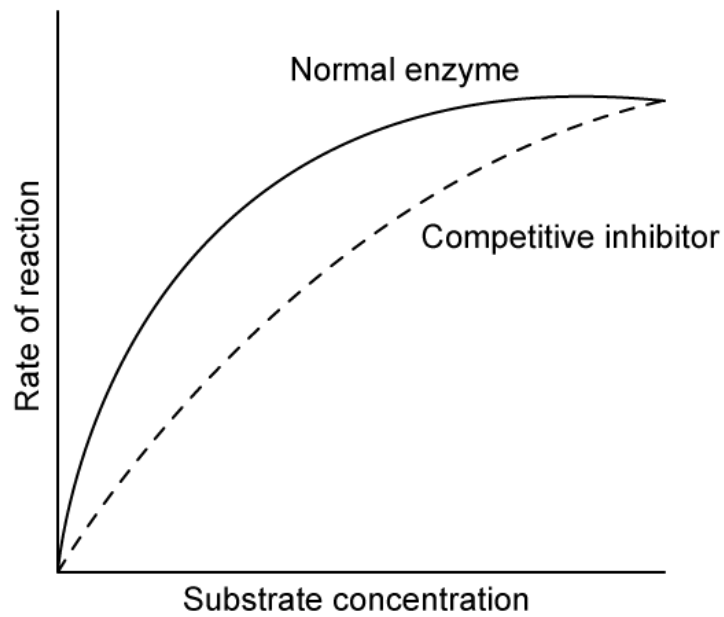
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(2 marks)

(b) Explain what is meant by allosteric inhibition.

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(3 marks)

The graph below shows the relationship between substrate concentration and rate of reaction for a normal enzyme and a competitive inhibitor.

(c)



Explain the effect competitive inhibition has on the rate of reaction.

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(3 marks)

(d) State an example of a competitive inhibitor and describe its basic function.

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(2 marks)

9 (a) Metabolic pathways exist in all living organisms.

Explain what is meant by a metabolic pathway.

(3 marks)

(b) Describe the differences between anabolism, catabolism and metabolism.

(3 marks)

(c) Metabolic paths require enzymes. Hexose kinase is the initial enzyme needed during glycolysis, it catalyses the phosphorylation of glucose by ATP. This reaction would occur without the presence of hexose kinase.

Explain the role hexose kinase has in this reaction.

(2 marks)

10 (a) This question is about metabolic pathways.

(i) Describe the meaning of the term metabolic pathway.

[3]

(ii) Outline how end-product inhibition can act to limit a metabolic pathway.

[4]

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(7 marks)

(b) Compare and contrast the allosteric and active sites of an enzyme.

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(4 marks)

Medium Questions

1 (a) Distinguish between anabolic reactions and catabolic reactions.

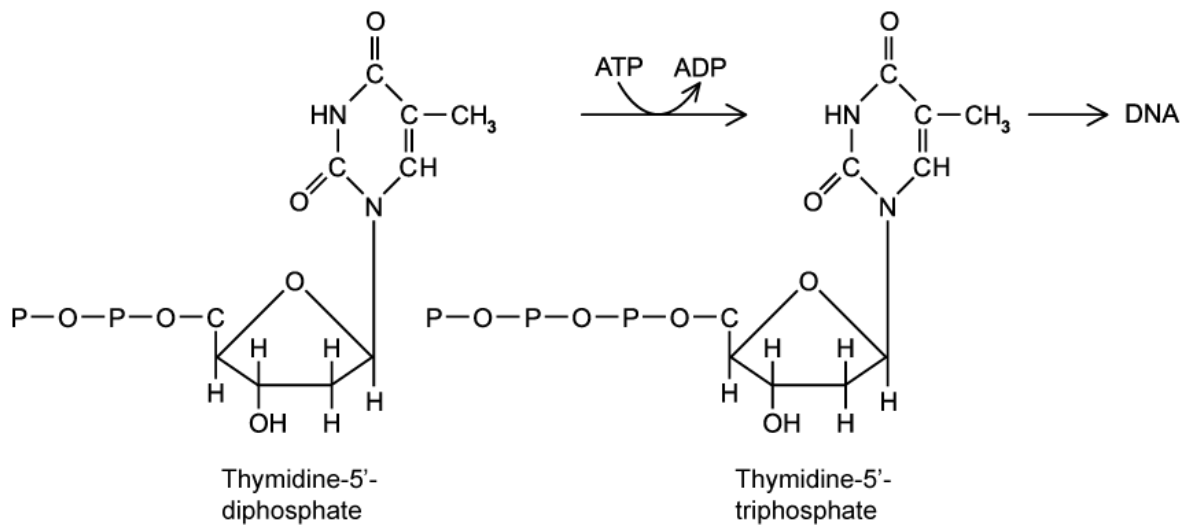
(3 marks)

(b) Complete the table with tick marks (✓) in the appropriate boxes.

Cellular reaction	Anabolic	Catabolic
Fats → fatty acids and glycerol		
Accumulation of starch from sugars in plants		
Anaerobic respiration in yeast cells		
Hydrolysis of polypeptides into amino acids		

(2 marks)

(c) The diagram below shows part of a biochemical pathway that takes place commonly in cells.



Deduce whether the pathway is anabolic or catabolic and give evidence from the diagram for your answer.

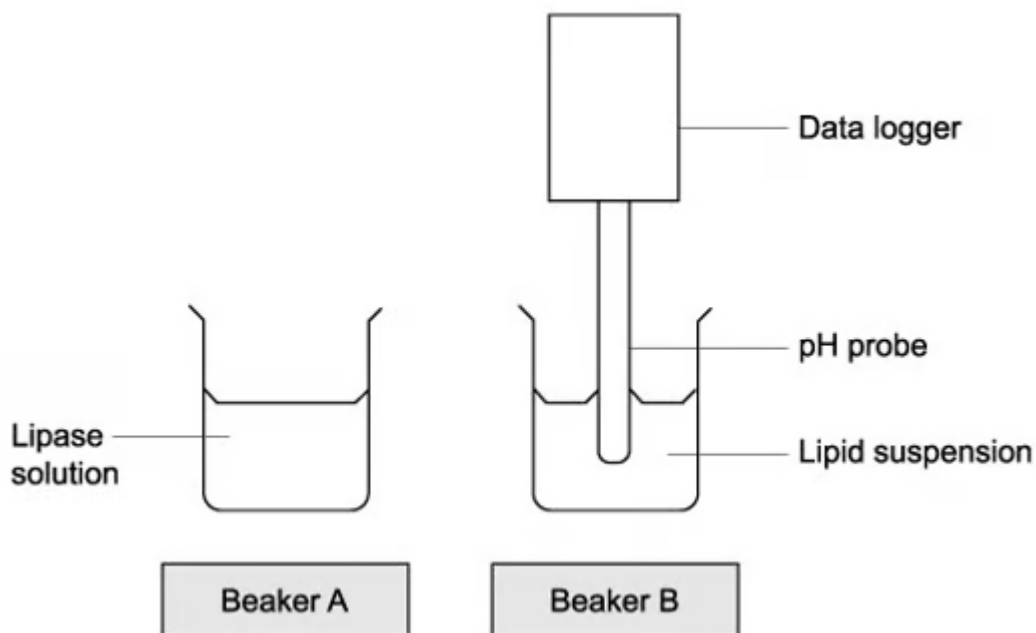
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(2 marks)

2 (a) Lipase is an enzyme that breaks down lipids. The diagram below shows an experiment set up by a teacher to investigate the effect of lipase concentration on the hydrolysis of lipids.

The pH of beaker B is measured for 3 minutes at the start of the experiment. Beaker A containing lipase solution is added to beaker B. The data logger recorded the change in pH over the next 5 minutes.



State, with a reason, the predicted change in pH after the lipase has been added.

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(3 marks)

(b) State **two** variables that must be controlled to carry out the experiment in part (a) accurately and reliably.

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(2 marks)

- (c) For the experiment in part (a), draw a results table that could be used to record the results of the investigation. Your table should include suggested enzyme concentrations, and units should be stated.

(3 marks)

3 (a) A protease is an enzyme that digests protein. A research scientist isolated protease **C** from a particular species of bacteria. The researcher investigated the effect of temperature on the rate of hydrolysis of a protein by protease **C**. The unprocessed results can be seen in the table below.

Temperature / °C	Mass of protein hydrolysed after 4 minutes / mg	Rate of hydrolysis /
10	470	
15	990	
20	1180	
25	1310	
30	1030	
35	420	
40	110	

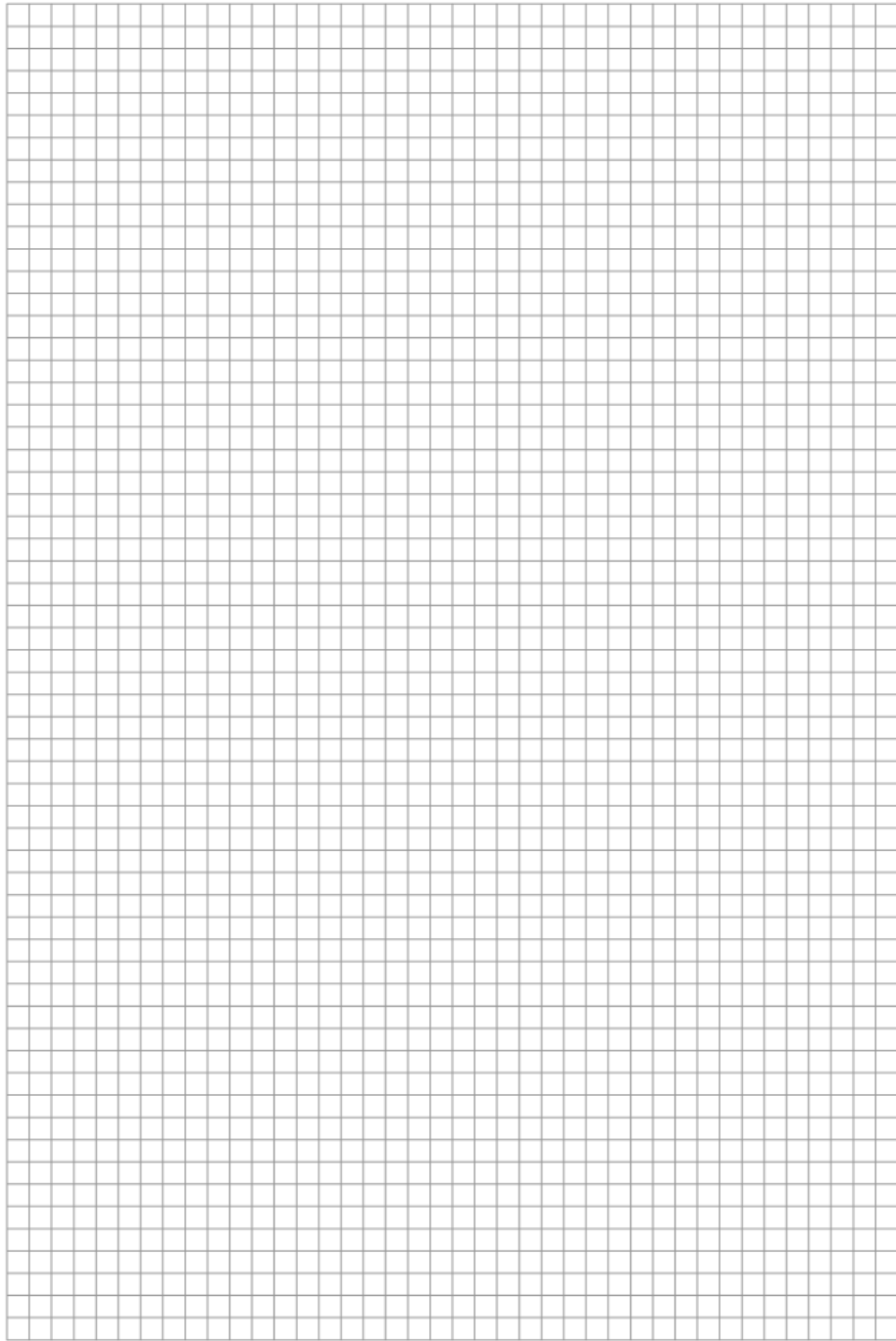
Calculate (with appropriate units) the missing details in the table above.

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(2 marks)

(b) Draw a graph of the results seen in part (a). Your graph should include an accurate scale and correct axis labels.



(4 marks)

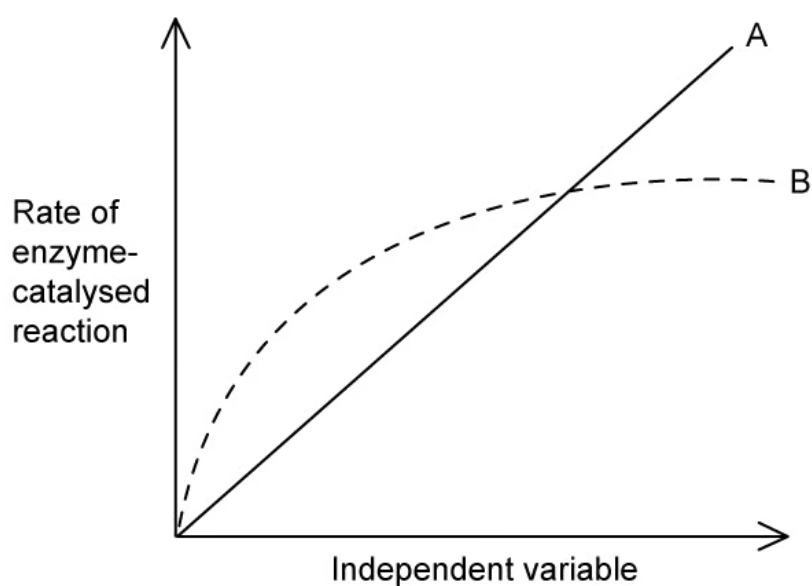
(c) Suggest how the research scientist controlled the pH throughout the experiment.

(1 mark)

- 4 (a) Explain the aspect of enzyme and substrate structure that enables successful catalysis of a biochemical reaction.

(2 marks)

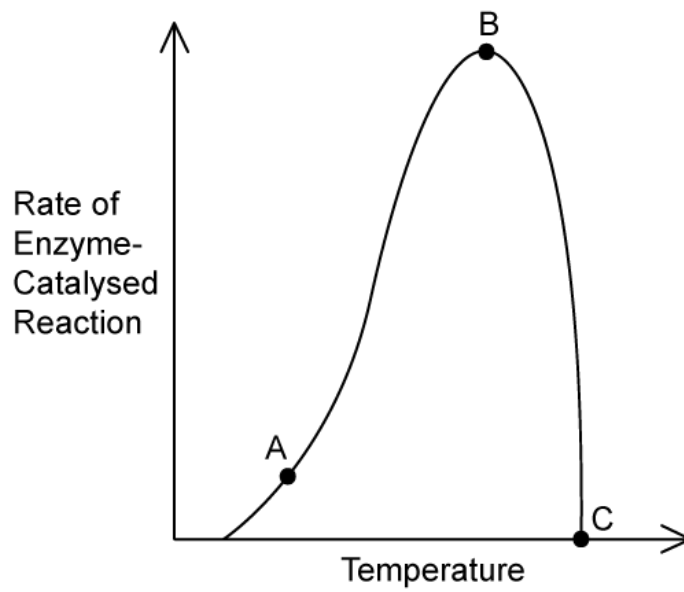
- (b) The sketch graph below shows how the rate of an enzyme-catalysed reaction varies for two separate independent variables. For curve **A** the independent variable is the concentration of enzyme.



Identify the independent variable for Curve **B**.

(1 mark)

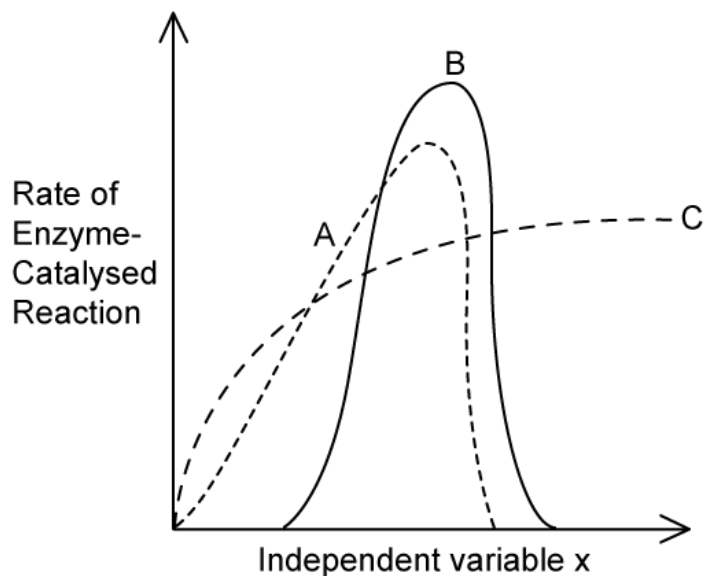
- (c) The sketch graph below shows how the rate of an enzyme-catalysed reaction varies as temperature changes.



Explain the rates of reaction at positions **A**, **B**, and **C** on the curve.

(3 marks)

5 (a) The sketch graph below shows the effects of varying the level of the independent variable, X, on the rate of an enzyme-controlled reaction. Lines **A**, **B**, and **C** represent three different independent variables which could be X.



- (i) Identify the independent variables that would cause lines **A**, **B**, and **C**.

- (ii) Use your knowledge of enzyme activity to explain the changes in reaction rate shown by lines **A**, **B** and **C**.

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(7 marks)

(b) An experiment was set up to investigate the effect of temperature on an enzyme-catalysed reaction in which the reaction mixture changes from clear-colourless to clear-dark blue as the reaction progresses.

Describe:

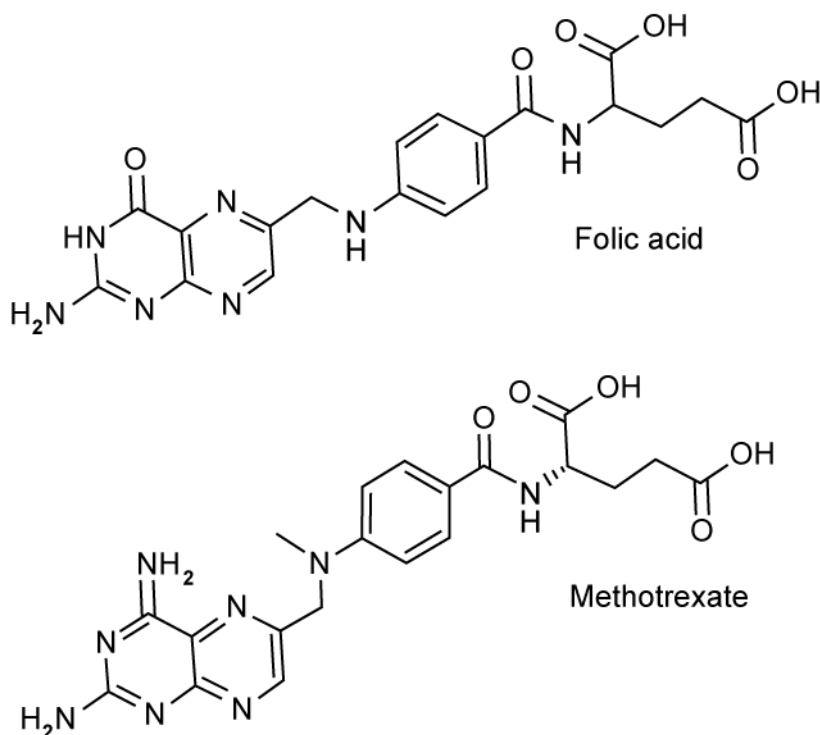
- (i) How the independent variable in the experiment could be controlled.
- (ii) How a colorimeter could be used to measure colour change.

(4 marks)

- 6 (a)** Folate is a chemical used by cancer cells to make DNA during cell division. Folate is produced through the conversion of folic acid catalysed by the enzyme dihydrofolate reductase.

Methotrexate is a medicinal drug given to people with cancer, and other autoimmune diseases, as it acts as an inhibitor for the enzyme dihydrofolate reductase.

The image below shows the chemical structure for the enzyme's normal substrate, folic acid, as well as the structure of its inhibitor, methotrexate.



Using the images, suggest the method of inhibition used by methotrexate. Explain your answer.

(2 marks)

(b) Folate is not just used by cancer cells during replication, but by any cells of the human body that replicate quickly.

Methotrexate is commonly used as part of chemotherapy treatment for cancer sufferers.

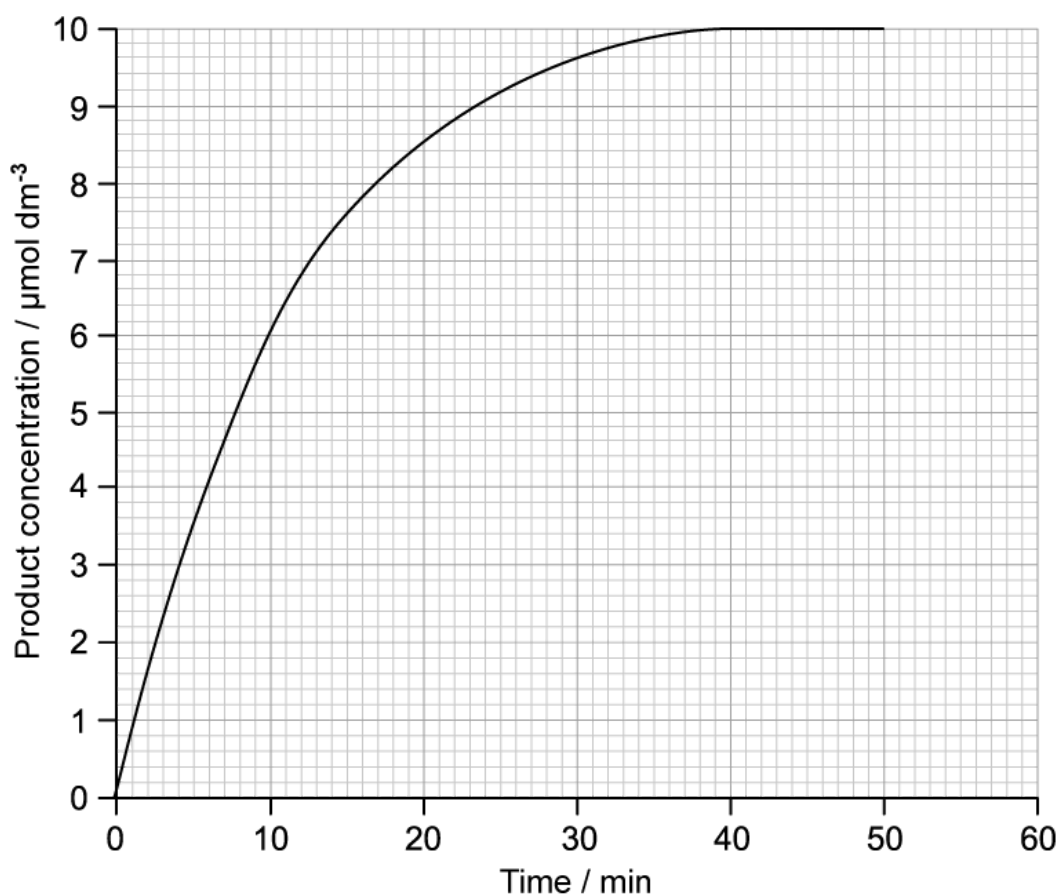
Using this information, suggest why people that undergo chemotherapy lose their hair.

(3 marks)

7 (a) Trypsin is an enzyme produced by the pancreas that hydrolyses proteins in the small intestine.

The activity of trypsin was investigated by placing a small amount of the enzyme with a known concentration of protein.

The graph below shows the progress of this reaction when it is carried out at 25 °C.



Calculate the initial rate of the reaction in the graph. Show your working.

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(2 marks)

(b) The procedure was repeated at the same temperature in the presence of a competitive inhibitor of trypsin.

Predict the results that will be obtained using the competitive inhibitor.

(2 marks)

- (c) Describe how your prediction for part b) would be different if a non-competitive inhibitor was used rather than a competitive inhibitor.

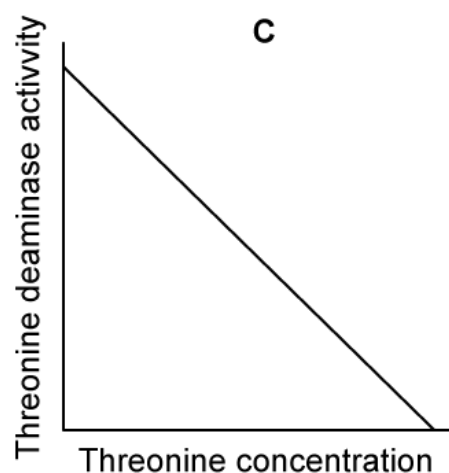
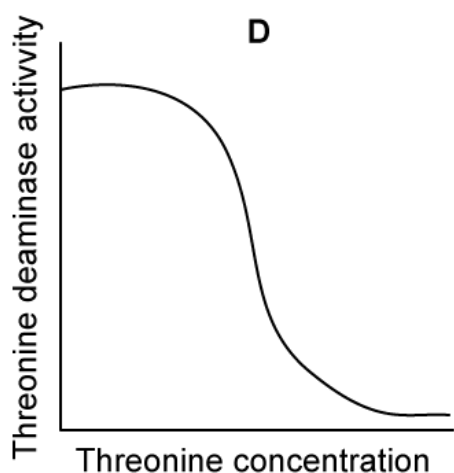
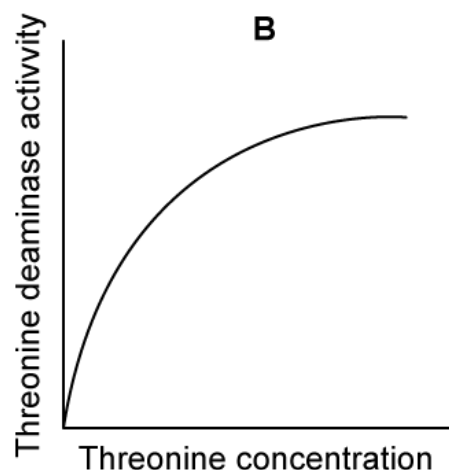
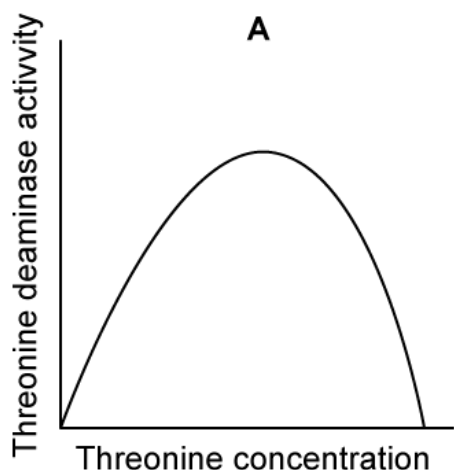
(2 marks)

- (d) The investigation was extended to compare the initial reaction rates of trypsin obtained from different species of animal.

Suggest **two** advantages of calculating the **initial** reaction rates of enzyme catalysed reactions here rather than the reaction rates at another point during the experiment.

(2 marks)

8 (a) Threonine deaminase catalyses the conversion of threonine into an intermediate substrate, before producing the end product of isoleucine.



State which graph represents the relationship between threonine concentration and threonine deaminase concentration.

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(1 mark)

(b) Explain the effect a build up of isoleucine concentration would have on the activity of threonine deaminase.

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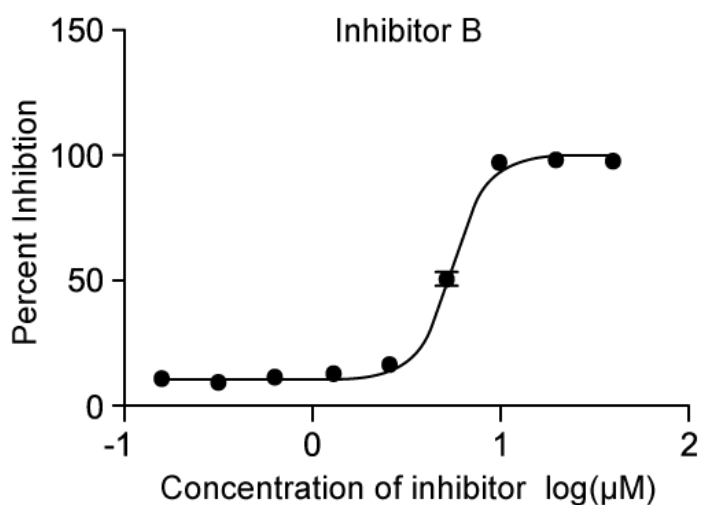
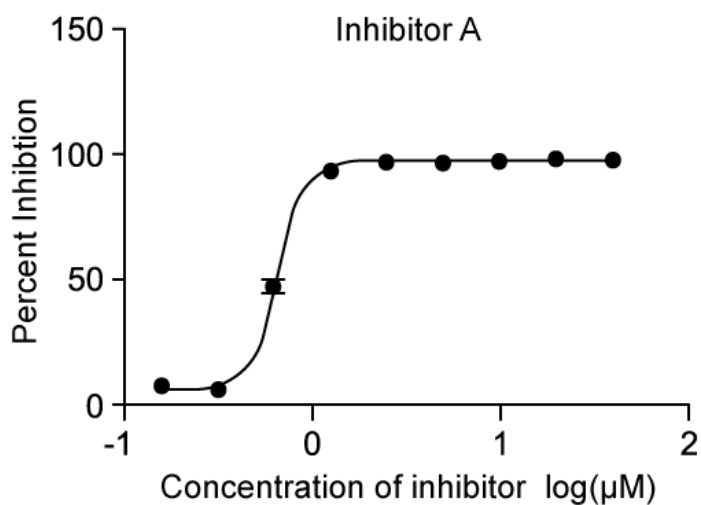
(3 marks)

(c) Explain how feedback inhibition is an example of negative feedback.

(3 marks)

9 (a) *Plasmodium falciparum* is a protozoan parasite of humans that causes malaria. Scientists have sequenced the proteome of this parasite and have determined a number of enzymes involved in its metabolic pathways. One such enzyme is hexokinase which is involved in the phosphorylation of glucose within the parasite.

The scientists tested two potential enzyme inhibitors, Inhibitor A and Inhibitor B, on the activity of hexokinase. The results are shown in the graphs below.



Compare and contrast the effect of the two inhibitors on the percentage inhibition.

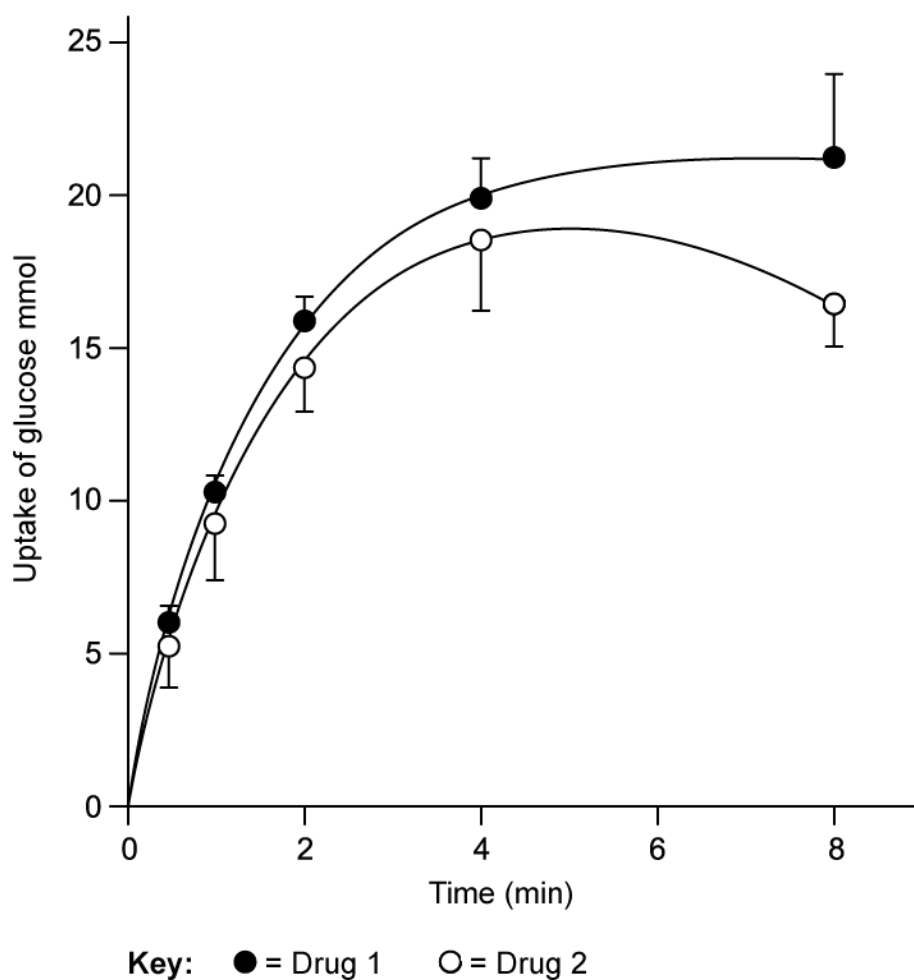
(2 marks)

(b) Deduce, with reasons, whether the inhibitors act as competitive or non-competitive inhibitors.

(2 marks)

(c) The *Plasmodium falciparum* parasite depends on glycolysis for its survival, particularly the uptake of glucose from its host cells which is mediated by hexokinase.

The scientists investigated the action of hexokinase within *Plasmodium falciparum*. They tagged hexokinase with two different potential drugs that inhibit its action. Their results are shown in the graph below.



Describe how to calculate the rate of reaction from the graph.

(2 marks)

(d) The scientists concluded that drug 1 was less effective than drug 2.

Evaluate this conclusion.

(3 marks)

10 (a) Explain the effect of inhibitors on the activity of enzymes.

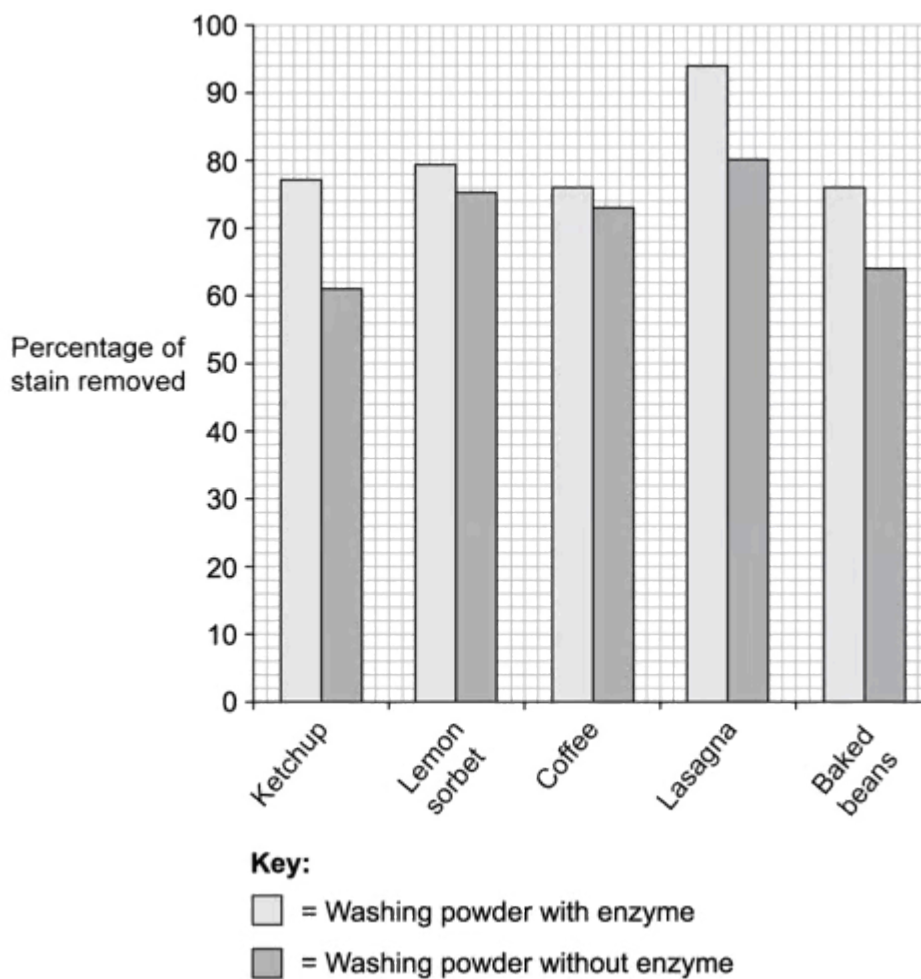
(8 marks)

(b) Distinguish between an enzyme catalysed reaction and a non enzymatic reaction.

(3 marks)

Hard Questions

1 (a) Washing powders often contain different types of enzymes that break down substances in stains. An investigation was carried out into washing powder that contained enzymes and washing powder that did not contain enzymes. The graph below shows the results of this investigation.



Some of the substances that cause food stains are large insoluble proteins.

Explain how washing powder containing enzymes would be able to remove these stains.

(2 marks)

- (b)** The manufacturers of the washing powder containing enzymes claimed that their washing powder was more effective at removing tough stains compared to the washing powder without enzymes.

Based on the results of the investigation in part a), evaluate the claim of the manufacturers.

(3 marks)

- (c)** The investigation at part a) was carried out at 40 °C.

Suggest a reason for this.

(1 mark)

- (d)** The investigation was repeated at a temperature of 85 °C.

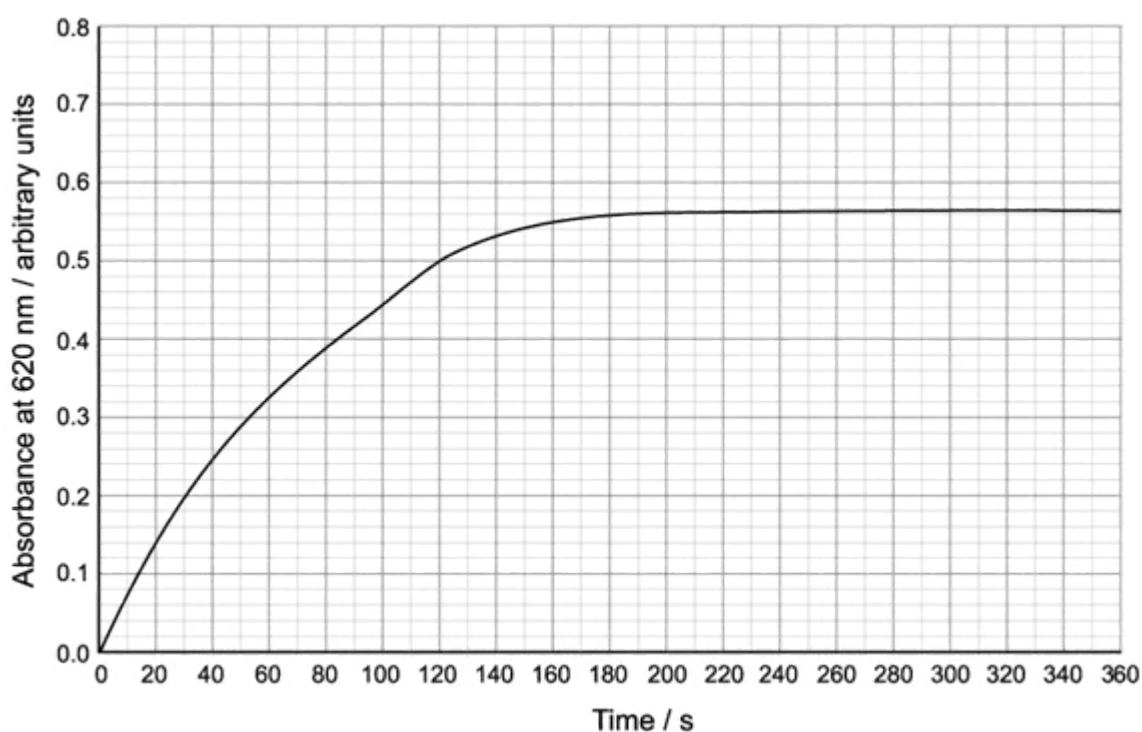
Predict, with a reason, the expected results from this investigation.

(3 marks)

- 2 (a)** Certain plants that reproduce sexually contain an enzyme called pyrophosphatase. This enzyme plays a role in ensuring self-incompatibility, which is a mechanism that prevents a plant from fertilising itself. The selective advantage of self-incompatibility is that more cross-breeding can occur within a species, which has long term benefits for evolution and for maintaining a large pool of alleles.

Known volumes of pyrophosphatase and substrate can be mixed in a cuvette with a dye that starts as colourless and develops into a blue colour over time. The rate of colour development can be measured in a colorimeter by measuring the absorbance of light at a wavelength of 620 nm (red light).

The graph shows the mean rate of reaction of pyrophosphatase measured over five repeats at 20°C.



State why the wavelength of 620 nm was selected for this experimental measurement.

.....
(1 mark)

- (b)** Use the graph from part (a) to calculate the rate of the reaction at 100 seconds. Give your answer in suitable units.

(3 marks)

- (c)** (i) Predict the effect that a higher enzyme concentration at the start of the experiment would have on the results calculated in part (b).

[1]

- (ii) Explain your answer in part (i).

[1]

(2 marks)

- (d)** As the temperature increases, the rate at which pyrophosphatase works also increases up to a point, before decreasing.

Explain why these changes in the reaction rate take place.

(3 marks)

3 (a) In humans, the enzyme sucrase hydrolyses sucrose. This reaction occurs in the small intestine at 37°C.

(i) Explain why sucrase can only hydrolyse sucrose.

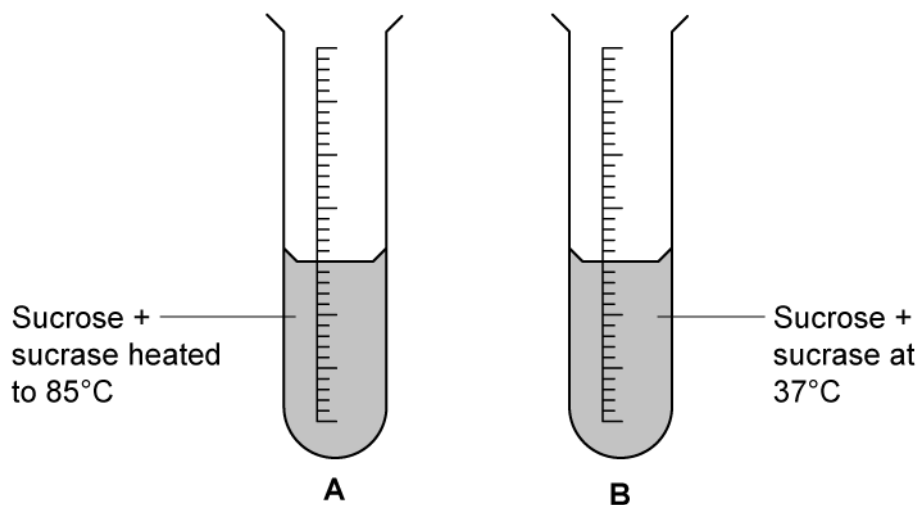
[2]

(ii) Describe how sucrase enables this reaction to take place at normal body temperature.

[2]

(4 marks)

(b) A solution containing sucrose and sucrase was divided equally between two test tubes. One test tube (**A**) was heated to a temperature of 85°C, and the other (**B**) was kept at 37°C, as shown in the diagram below. Both test tubes were monitored for 30 minutes.



(i) Identify which test tube(s) would contain monosaccharides.

[1]

(ii) Explain your answer in part (i).

[2]

(3 marks)

(c) Suggest **two** sources of error that could arise from an experiment to measure the effect of temperature on the rate of an enzyme-controlled reaction.

Assume that in this experiment, the dependent variable is measured as the volume of a gas produced.

(2 marks)

4 (a) Outline how changes in substrate concentration affects the rate of enzyme action.

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(3 marks)

(b) Sometimes the active site of enzymes can be blocked or "inhibited" by substances that aren't the specific substrate for that enzyme.

Suggest how this would affect the rate of reaction of an enzyme-catalysed reaction **as well as** some possible uses of enzyme inhibitors in medicine.

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(5 marks)

(c) Plan an investigation to determine how changing the temperature of amylase affects the rate of reaction of the digestion of starch to maltose.

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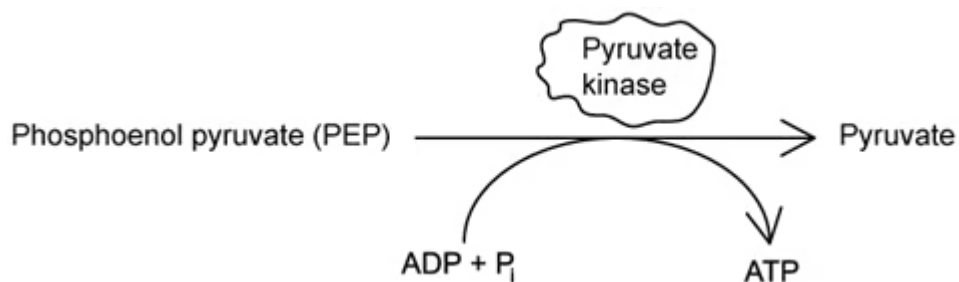
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(7 marks)

- 5 (a) Many products of multi-step cellular reactions act as inhibitors of the enzymes that catalyse the preceding steps in a metabolic pathway.

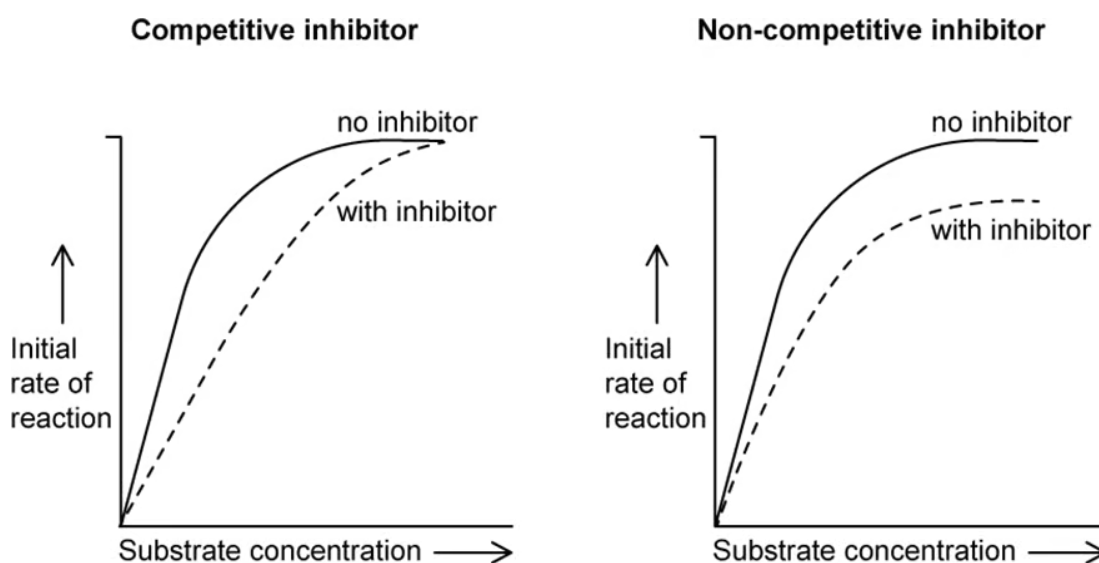
For example, ATP acts as a non-competitive inhibitor of the enzyme pyruvate kinase, which catalyses the final step of glycolysis.



Suggest how the inhibition of pyruvate kinase by ATP allows cells to prevent overproduction and wasting of cellular energy.

(3 marks)

- (b) The graphs below shows the effects of increasing substrate concentration on enzyme activity in the presence and absence of a competitive and a non-competitive inhibitor.



Sketch a line on both graphs to indicate the effect of increasing inhibitor concentration in each case. Explain the position and shape of each line.

(4 marks)

(c) Compare and contrast the features of a substrate and a competitive inhibitor.

(4 marks)

When studying plant species in areas of high biodiversity, or any extreme environment, it is often useful to look at the metabolic pathways linked to the adaptations of the plants. To investigate the metabolic pathways scientists can determine the proteome of the plant, or just focus on the proteome of specific specialised cells. Suggest why just studying the proteome alone might not be enough to fully understand the metabolic pathways in the plant.

(d)

(2 marks)

6 (a) Copper (II) ions act as non-competitive inhibitors of the enzyme catalase.

Describe how copper (II) ions work to inhibit the activity of catalase.

(2 marks)

(b) Catalase is found in all living things that are exposed to oxygen. It protects cells from damage by breaking down the toxic chemical hydrogen peroxide into water and oxygen.

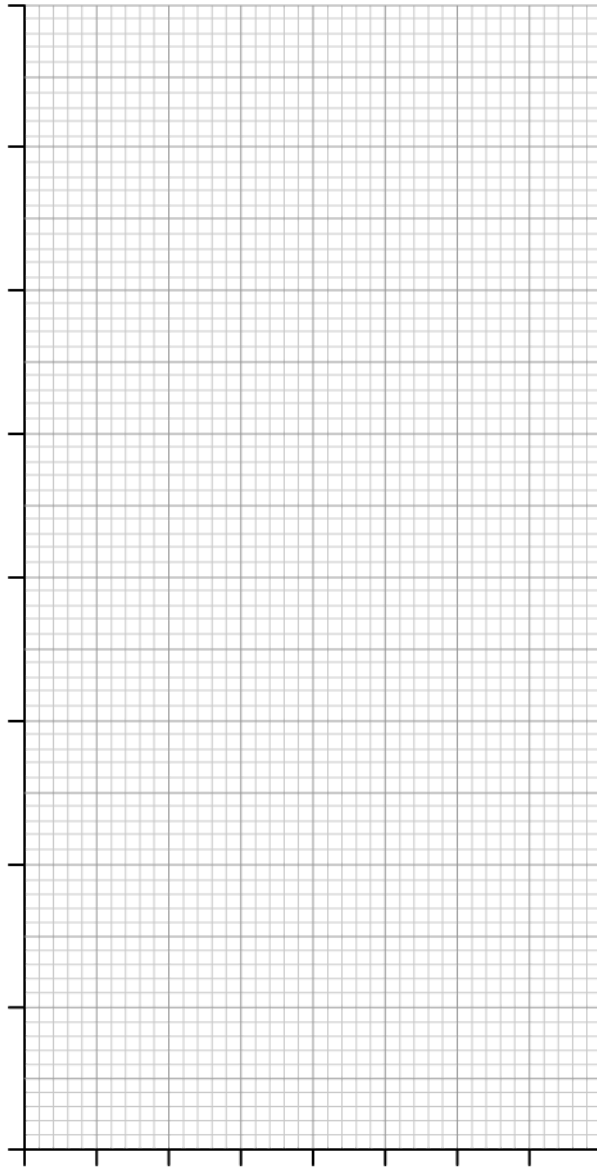
Numbers of fish living in copper contaminated water have shown a decline in numbers. Scientists can study the action of catalase in fish in order to understand the full impact of copper contamination on the fish.

A group of students carried out an experiment to explore the effects of copper sulfate on the action of catalase. They measured the activity of catalase exposed to different concentrations of copper sulfate.

The results of their experiment are shown in the table below.

Concentration of copper sulfate (moles dm^{-3})	Volume of oxygen gas produced (cm^3)
0.00	15.70
0.05	11.32
0.10	8.12
0.15	6.25
0.20	4.98

In the space provided below, draw a graph of the results in the table.



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(4 marks)

(c) What can the students conclude from their results?

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(2 marks)

- (d)** Three rivers in the Scottish Highlands were polluted with copper, which affected the aquatic wildlife. Scientists were provided with one dead brown trout, *Salmo trutta*, from each of the rivers.

Scientists were unable to take a direct measurement of the copper ion concentration in the river.

Using the information provided in part **(b)**, suggest the dependent, independent and control variables of an experiment using the fish tissue to compare the copper ion pollution in the three rivers.

(3 marks)

7 (a) Antifreeze is a chemical often used in vehicles, such as cars, to act as an engine coolant.

A small number of people have accidentally consumed antifreeze and become poisoned as a result. Once a person consumes antifreeze it is important that they receive treatment straight away, otherwise, there is a risk of death. This is because if the methanol goes to the liver it can be broken down by the enzyme alcohol dehydrogenase into toxic products such as methanoic acid and formaldehyde. If the methanol can't bind to the enzyme it will just be excreted via the kidneys and the person can be saved.

One method of treating methanol poisoning, in the rare instances where no other treatment is available, is to use large quantities of the alcohol ethanol.

Suggest how ethanol might be able to save someone from methanol poisoning.

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(3 marks)

(b) Although it may be an effective antidote, suggest why it is not recommended that people with methanol poisoning consume ethanol other than in extreme circumstances where no other treatment is available.

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(1 mark)

(c) One medicinal chemical that can be used to treat antifreeze poisoning is called fomepizole, which is a competitive inhibitor of the enzyme alcohol dehydrogenase.

Fomepizole is 160,000 times more likely to bind to alcohol dehydrogenase than methanol.

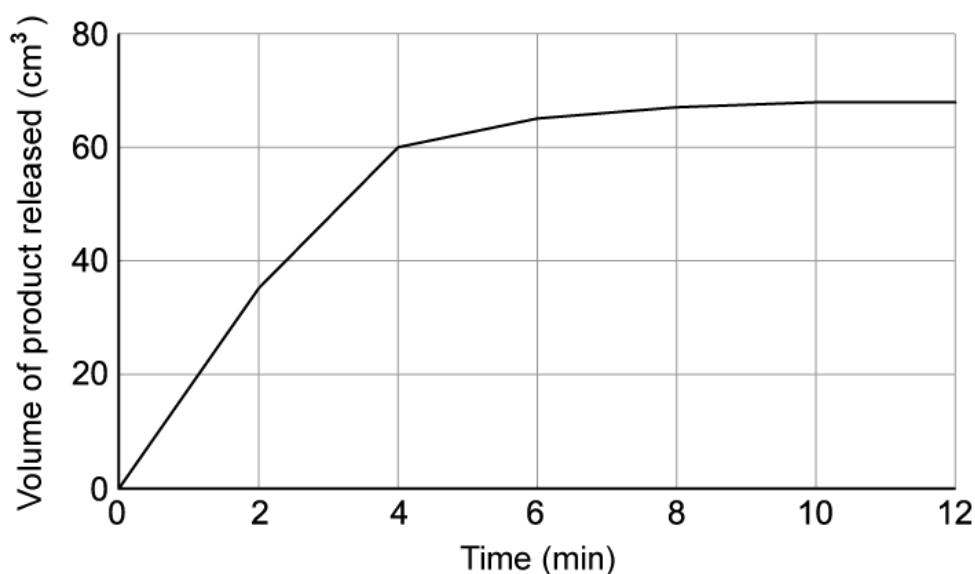
Using your knowledge of enzyme structure, suggest how this might be possible.

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(2 marks)

- (d) Scientists were trying to investigate the rate of reaction of alcohol dehydrogenase by measuring the quantity of product, methanoic acid, produced over time, with a fixed quantity of methanol added at the start.

The graph below shows their results.



Use the graph below to calculate the rate of reaction of alcohol dehydrogenase after 3 minutes.

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(3 marks)

8 (a) Phosphofruktokinase (PFK) is an enzyme that catalyses an important step in the glycolysis process of respiration. PFK is inhibited by ATP.

PFK is known as the "pacemaker" enzyme for respiration.

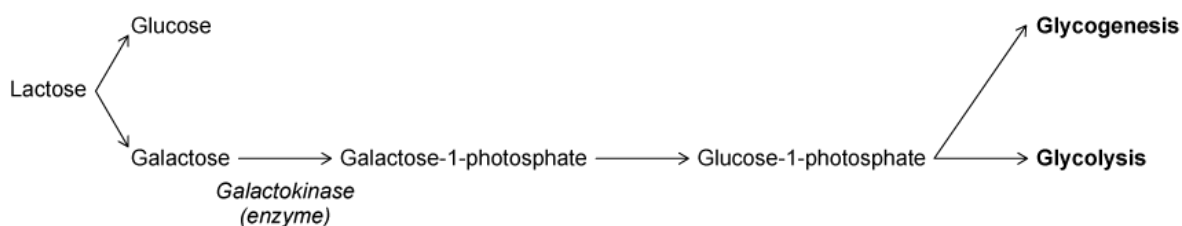
Suggest what is meant by the term "pacemaker" in this context.

(3 marks)

(b) Describe and explain the similarities and differences between competitive and non-competitive enzyme inhibition.

(5 marks)

(c) The image below shows the pathway the human body uses to metabolise lactose.



There is a genetic condition that exists called galactosemia, which causes large quantities of galactose to build up in the body, particularly in the liver tissues.

If left untreated, it can be very harmful to sufferers, in the worst cases, it can lead to death.

Galactosemia is rare and only occurs in around 1 per 60,000 births for people of European ancestry, often skipping a generation before re-emerging.

Using the information from the question and your own knowledge, suggest the cause of galactosemia, some symptoms, a type of treatment for the condition.

(7 marks)