IB · DP · Biology

2 hours 15 questions

Structured Questions: Paper 2

2.4 Enzymes

2.4.1 Enzymes / 2.4.2 Immobilised Enzymes / 2.4.3 Skills: Enzyme Experiments

Easy (5 questions)	/44
Medium (5 questions)	/42
Hard (5 questions)	/52
Total Marks	**/138**

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Easy Questions

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

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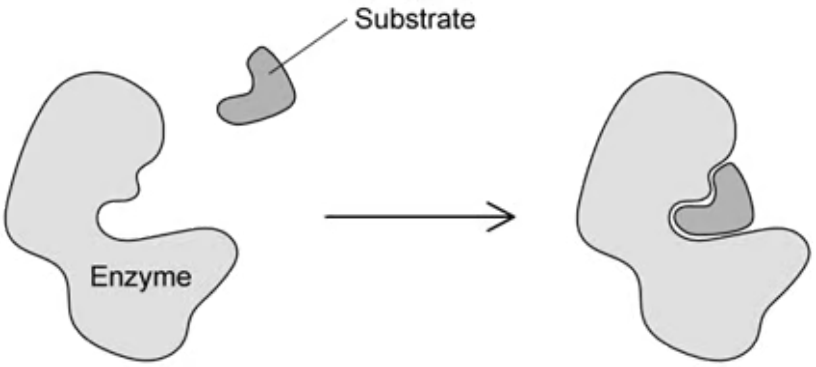
(1 mark)

(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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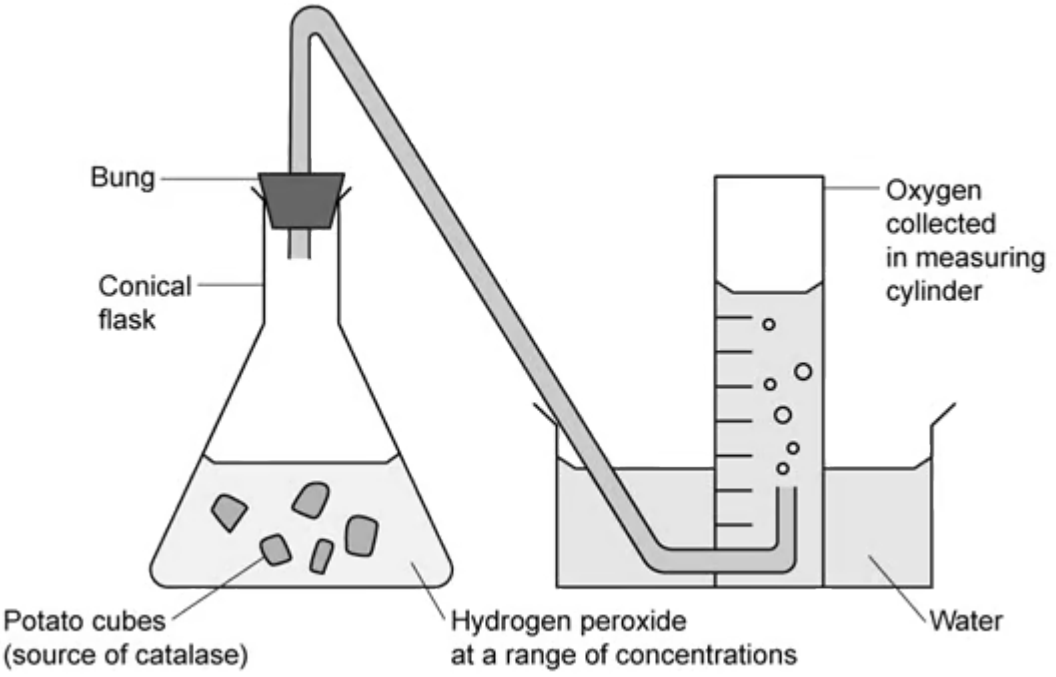
(2 marks)

2 (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.

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(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**.

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(1 mark)

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

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(2 marks)

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

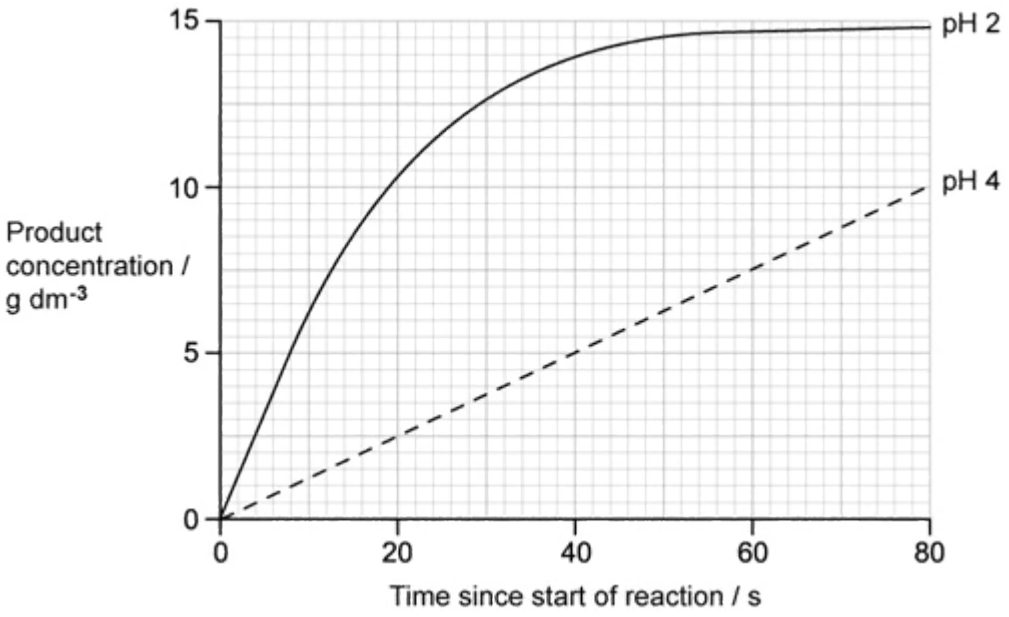
(4 marks)

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

(2 marks)

3 (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:

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

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)

4 (a) State **two** benefits of using immobilised enzymes in industrial processes.

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(2 marks)

(b) An example of the use of immobilised enzymes in industry is in the production of lactose-free milk.

(i) Identify the enzyme used in this process.

[1]

(ii) State the substrate and products of the reaction.

[2]

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(3 marks)

(c) When the enzymes are immobilised for this process they are fixed to small alginate beads. The substrate solution is then poured through the beads in order for the substrate to react with the enzyme.

State the benefits of having a large number of small beads for this process, as opposed to a small number of large beads.

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(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

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)

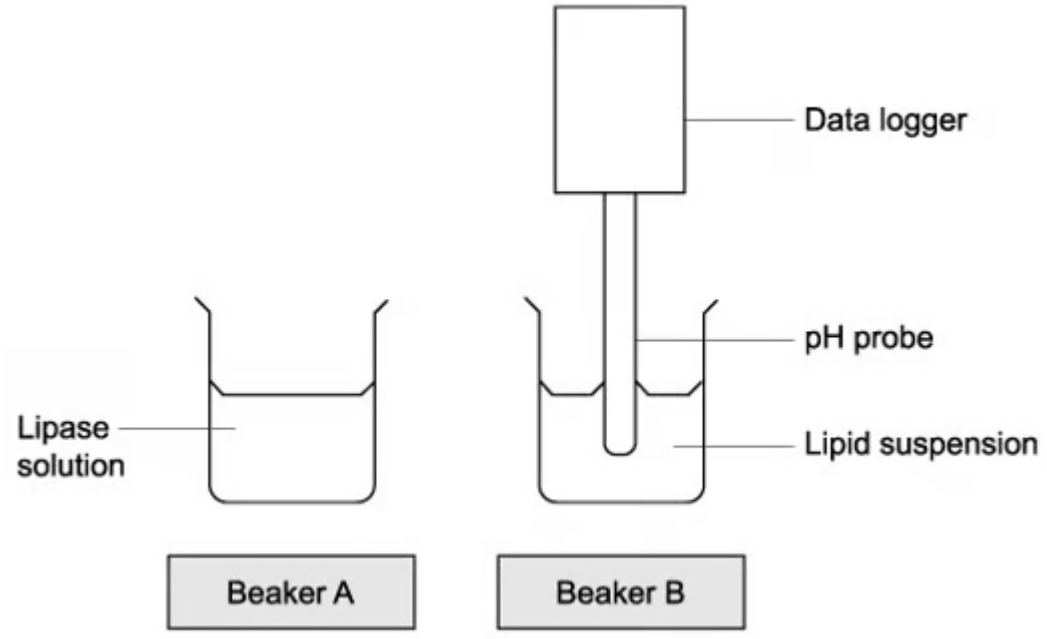
(c) List **three** methods that can be used to immobilise enzymes.

(3 marks)

Medium Questions

1 (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.

(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)

2 (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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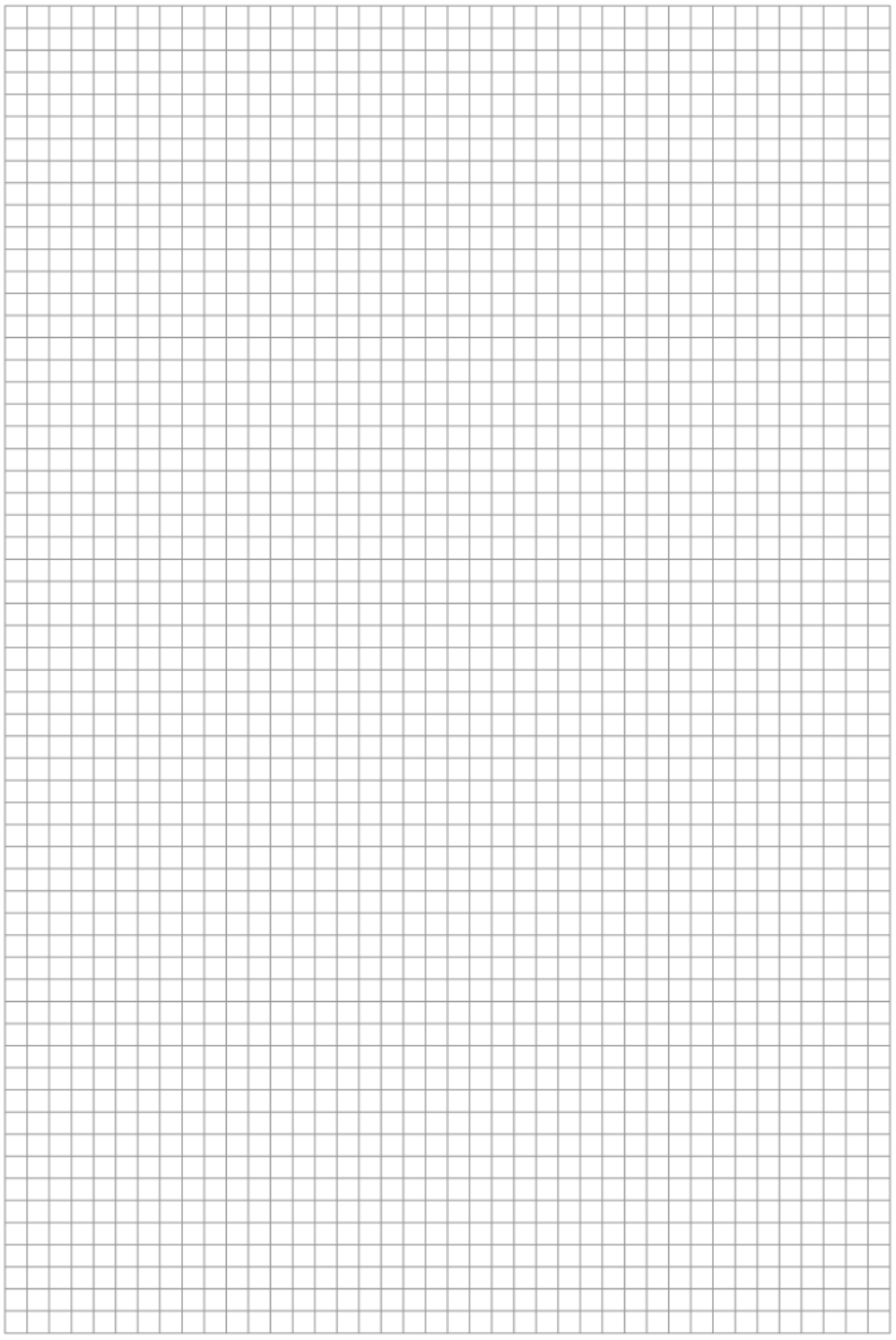
(2 marks)

(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.

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(1 mark)

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

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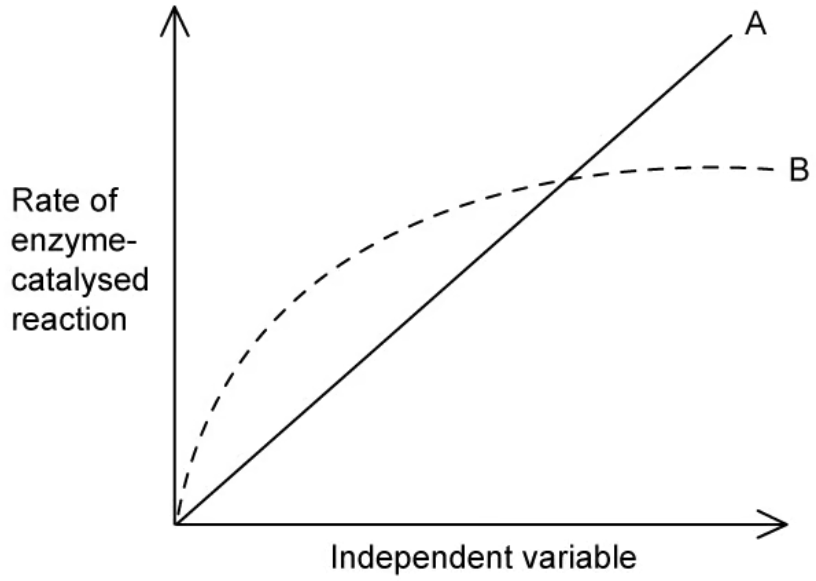
(2 marks)

(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**.

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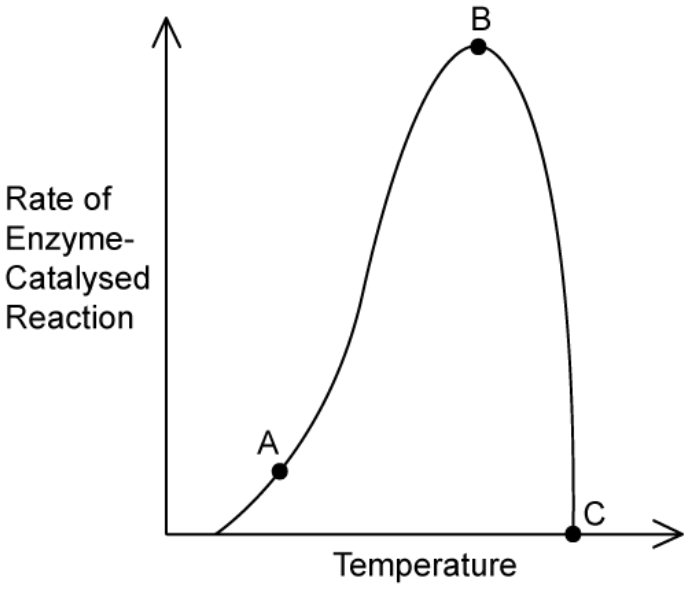
(1 mark)

(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)

4 (a) Enzymes can be used in various industrial processes.

Suggest **one** reason why the use of enzymes in industry offers a commercial benefit over non-enzymatic processes.

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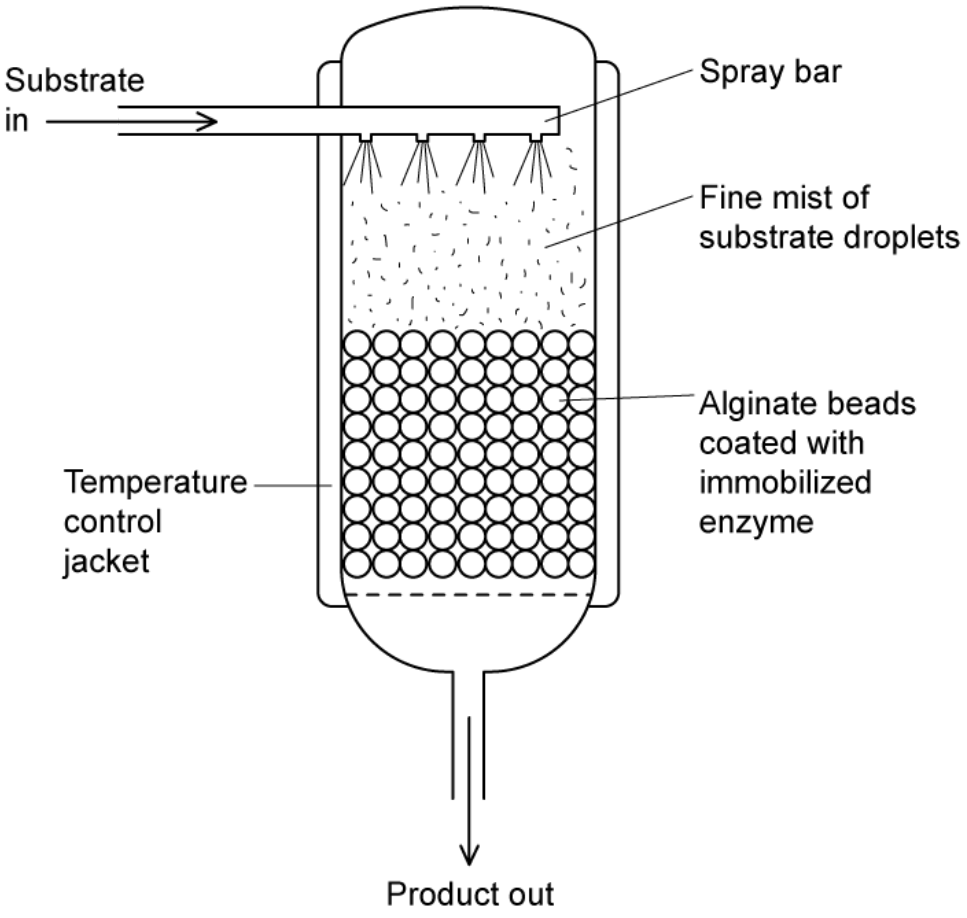
(1 mark)

(b) The diagram below shows a typical packed-bed immobilised enzyme reactor for a continuous production process in the food industry.



State **three** benefits of using immobilised enzymes, as opposed to enzymes that are allowed to mix freely with the substrate.

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(3 marks)

(c) The process of binding an enzyme to an immobile matrix for the purposes of enzyme immobilisation has, in some cases, led to a reduction in the enzyme's activity level.

Suggest, with a reason, how the process of immobilisation could cause the change in enzyme activity after immobilisation.

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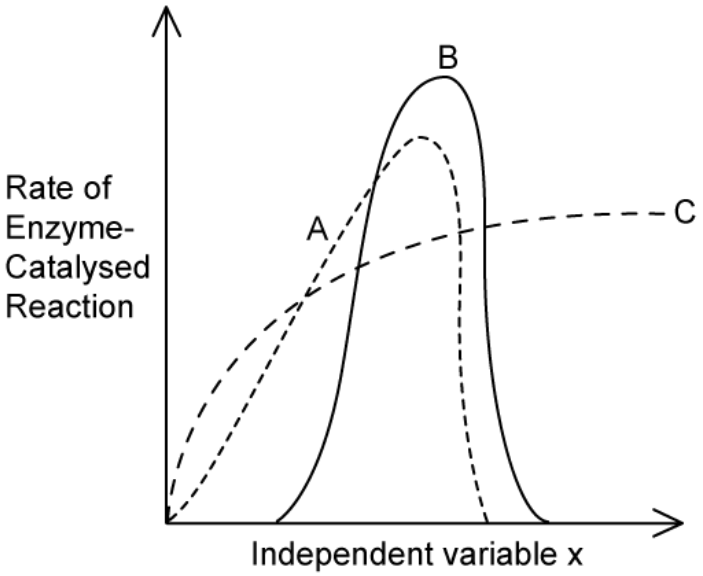
(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

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**.

(7 marks)

(b) Outline the method used in the production of lactose-free milk from dairy milk.

(4 marks)

(c) 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.

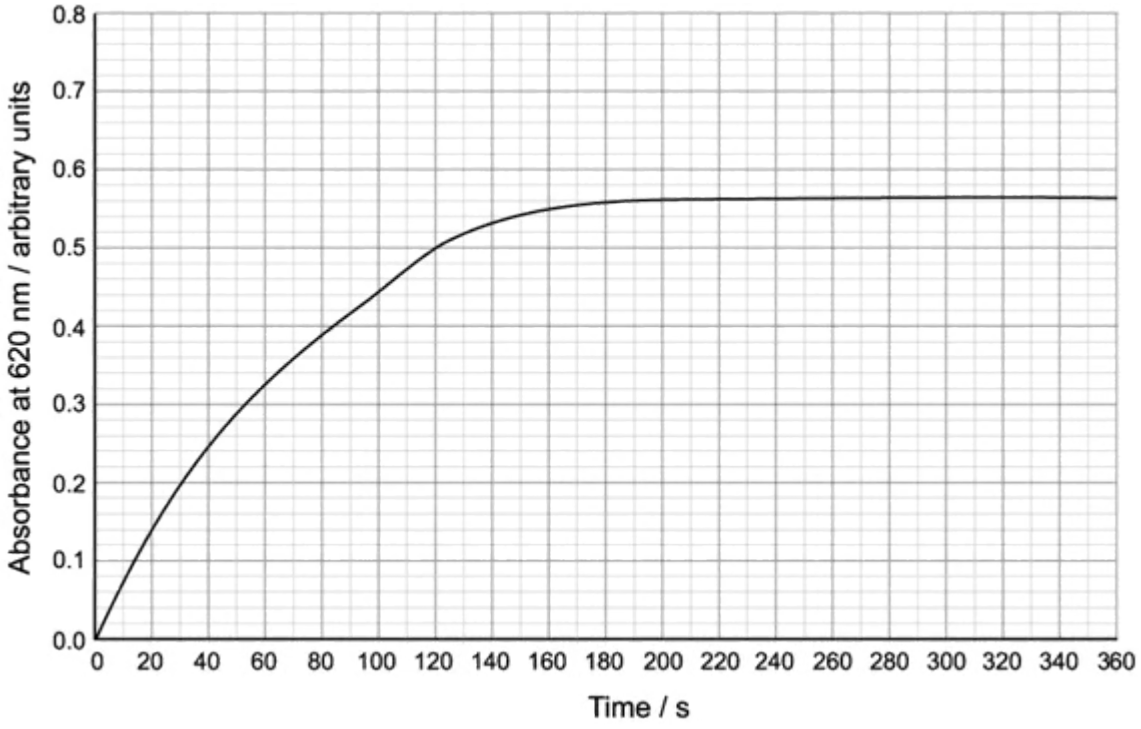
(4 marks)

Hard Questions

1 (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.

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(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)

2 (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]

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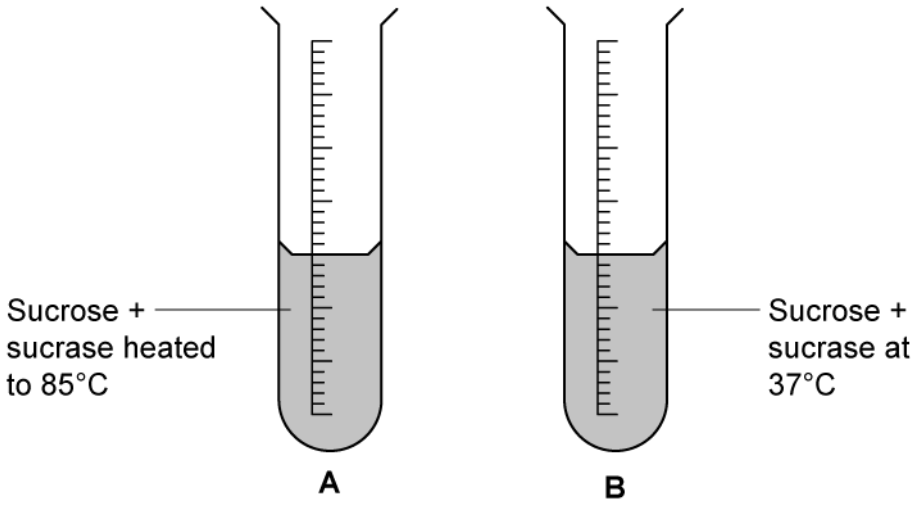
(4 marks)

(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]

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(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.

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(2 marks)

3 (a) A significant amount of research has been conducted on the enzyme composition of extremophile microorganisms, in order to discover new enzymes that can be used in the home in extreme conditions. One such organism, *Planococcus halocryophilus*, is a psychrophile (it grows at cold temperatures around 0°C). Trials with the enzymes of *P. halocryophilus* have discovered applications of these enzymes in the detergent industry.

Suggest how these trial results are encouraging for the laundry detergent industry.

(3 marks)

(b) Many commercially-produced biological laundry detergents contain a range of different enzymes.

Explain why a range of enzymes can improve the detergent's performance in the home.

(3 marks)

(c) Papain is a proteolytic enzyme derived from the papaya fruit. It has been used in contact lens cleaning solutions to remove denatured protein-containing deposits that accumulate on the surfaces of contact lenses during long periods of wear. The periodic removal of protein deposits increases wearer comfort and extends the wearing time.

The main protein component of tear film fluid is lysozyme.

Suggest a reason for the presence of lysozyme in tear film fluid.

(2 marks)

(d) Lysozyme and other proteins present in tear film fluid can denature rapidly when in contact with contact lens material. This denatured material loses its original function and forms deposits on the lens surface.

(i) Describe the mode of action of papain against the denatured protein deposits on the surfaces of the contact lenses.

[1]

(ii) Explain the effect that the action of papain would have on these contact lens deposits.

[1]

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(2 marks)

4 (a) The enzyme glucoamylase is a catabolic enzyme that hydrolyses the α-1,4 glycosidic bonds in starch to produce glucose for use in industry.

The enzyme used in this process can be covalently bonded to a substrate of beads to become immobilised. Once immobilised they are able to be used in 11 successive cycles before they need to be replaced.

Suggest a potential method that could be used to determine whether the immobilised enzymes need to be replaced.

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(1 mark)

(b) Glucoamylase has an optimum temperature of 60°C when free in solution, however when it is immobilised the optimum temperature is raised to between 60°C and 80°C.

Explain why this is an advantage to the manufacturers using this immobilised enzyme to produce glucose.

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(4 marks)

(c) Some scientists think that the reason for the increase in optimum temperature of the immobilised enzyme is due to the covalent bonding between the enzyme and the beads that hold them in position. They believe that covalent bonding helps to reduce the influence of high kinetic energy on the bonds within the enzyme structure.

Suggest how this would cause the enzyme to have a higher optimum temperature.

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(2 marks)

(d) One of the sources of glucoamylase for this process is from a species of fungi called *Aspergillus niger.*

Aspergillus niger is a saprotroph.

Suggest **two** advantages of using saprotrophic fungi as a source of enzymes for the industry.

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(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Outline how changes in substrate concentration affects the rate of enzyme action.

(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.

(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.

(7 marks)