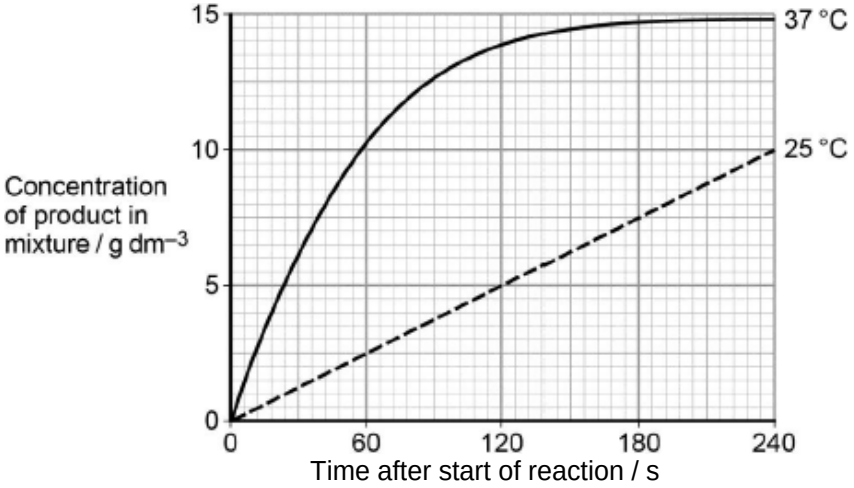
Q1. A technician investigated the effect of temperature on the rate of an enzyme-controlled reaction. At each temperature, he started the reaction using the same volume of substrate solution and the same volume of enzyme solution.

The figure below shows his results.



(a) Give **one** other factor the technician would have controlled.

.....

.....

(1)

(b) Calculate the rate of reaction at 25 °C.

Answer .....

(2)

(c) Describe and explain the differences between the two curves.

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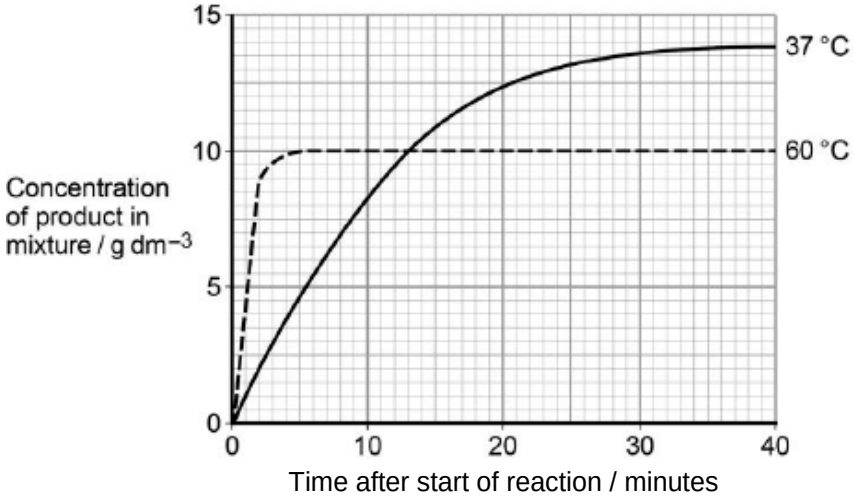
(5)
(Total 8 marks)

Q2. A technician investigated the effect of temperature on the rate of an enzyme-controlled reaction. At each temperature, he started the reaction using the same concentration of substrate.

The following graph shows his results.



(a) Give **two** other factors the technician would have controlled.

1 .....

2 .....

(1)

(b) Draw a tangent on each curve to find the initial rates of reaction.
Use these values to calculate the ratio of the initial rates of reaction at 60 °C : 37 °C.
Show your working.

Ratio = ... :1

(2)

(c) Explain the difference in the initial rate of reaction at 60 °C and 37 °C.

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(2)

(d) Explain the difference in the rates of reaction at 60 °C and 37 °C between 20 and 40 minutes.

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(Extra space) .....

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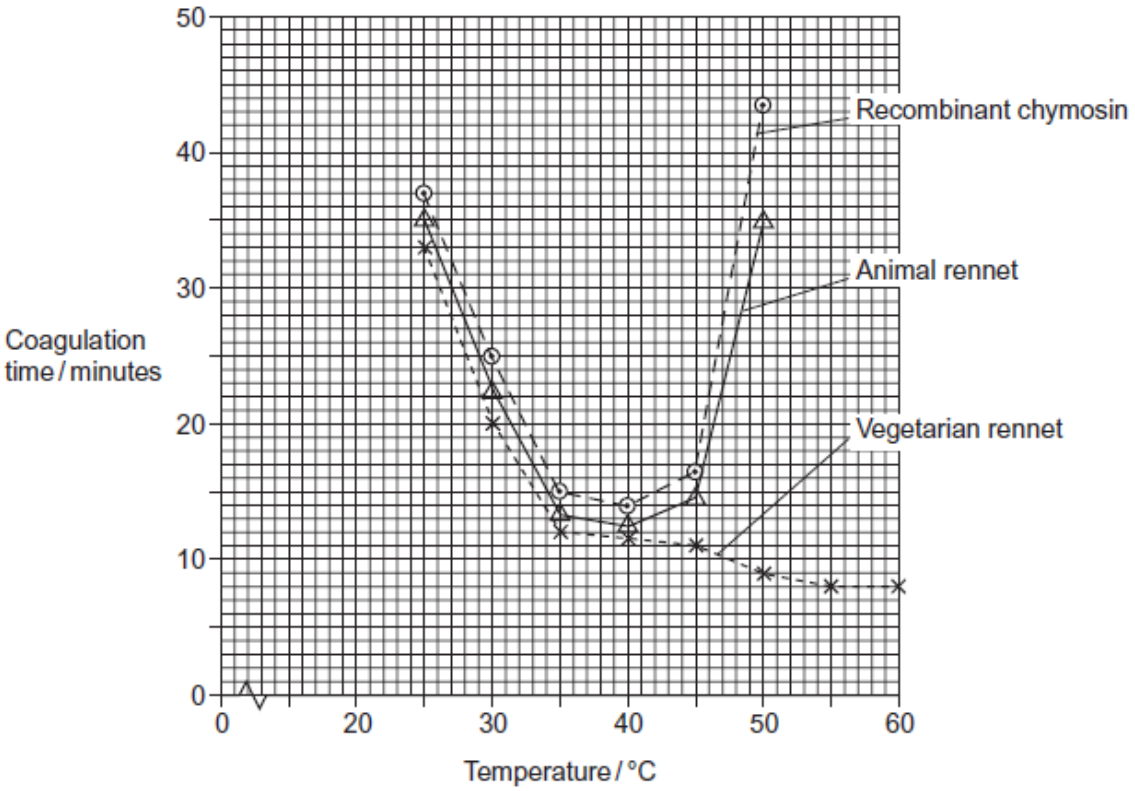
(4)
(Total 9 marks)

Q3. Different extracts may be added to milk to make cheese. All of these extracts contain chymosin.

- Animal rennet comes from calves and lambs. Rennet from these young animals contains between 80 and 95% chymosin. It also contains between 5 and 20% of another protein-digesting enzyme called pepsin.
- Vegetarian rennet comes from fungi. It contains 100% chymosin.
- Recombinant chymosin comes from bacteria which have had an animal gene for chymosin inserted in them. It contains 100% chymosin.

Scientists investigated the effect of temperature on the time these different extracts took to coagulate milk. Their results are shown below.



(a) Suggest **two** disadvantages of using animal rennet rather than recombinant chymosin as a source of chymosin for making cheese.

1 .....

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2 .....

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(2)

(b) The shape of the curve for recombinant chymosin is similar to the shape of the curve for animal rennet. Suggest why.

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(1)

(c) (i) Describe how the coagulation time for vegetarian rennet is different from that for animal rennet.

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(1)

(ii) Calculate the percentage reduction in coagulation time between 45 °C and 60 °C for vegetarian rennet. Show your working.

Answer .....%

(2)

(d) Explain the shape of the curve for animal rennet above 45 °C.

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(Extra space) .....

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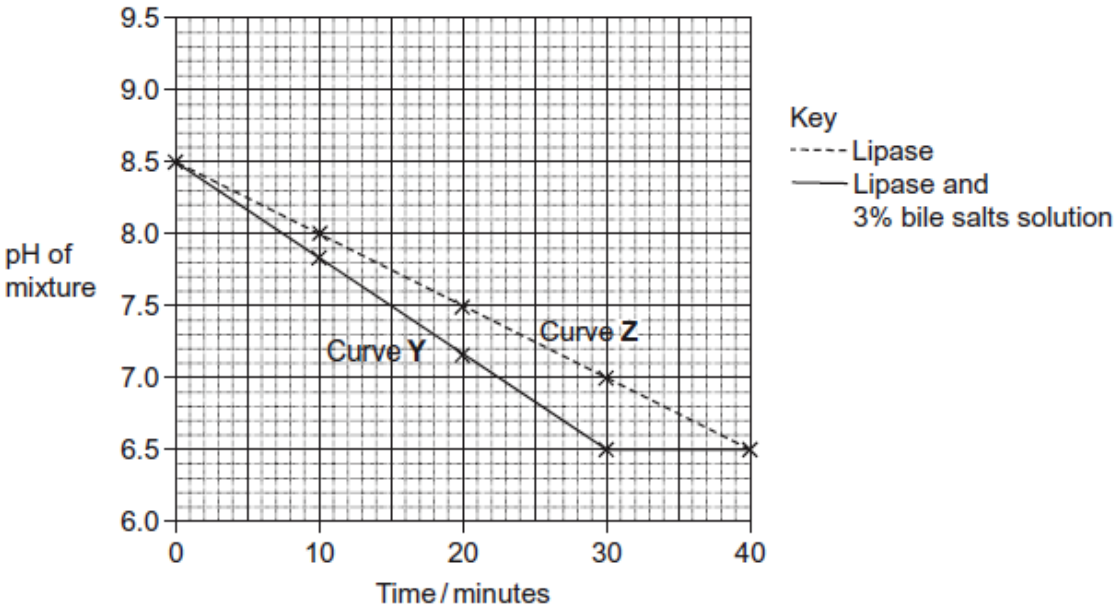
(3)
(Total 9 marks)

Q4. Scientists investigated the effect of lipase and a 3% bile salts solution on the digestion oftriglycerides. The graph below shows their results.



(a) Describe what curve **Y** shows about the effect of lipase and bile salts on the pH of the mixture.

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(2)

(b) The concentration of lipase did not change during the course of the investigation.
Explain why.

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(1)

(c) One of the scientists decided to repeat the investigation at a temperature 10°C below the original temperature.
Describe how you would expect his plotted curve to be different from curve **Z**.

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(1)
(Total 4 marks)

Q5. Some enymes digest protein. They hydrolyse the peptide bonds between amino acids. The extent to which a protein is digested is called the degree of hydrolysis (DH). The DH value may be calculated from the equation:

$$DH = \frac{100 \times \text{Number of peptide bonds hydrolysed}}{\text{Total number of peptide bonds present}}$$

(a) (i) A protein molecule contains 151 amino acids. What is the total number of peptide bonds in this molecule?

.....

(1)

(ii) A molecule of this protein is digested. The DH value of the digested protein is 18. Calculate the number of peptide bonds that have been hydrolysed.

Answer .....

(1)

(b) What would be the DH value of a protein if it were completely hydrolysed to amino acids? Explain how you arrived at your answer.

DH value .....

Explanation .....

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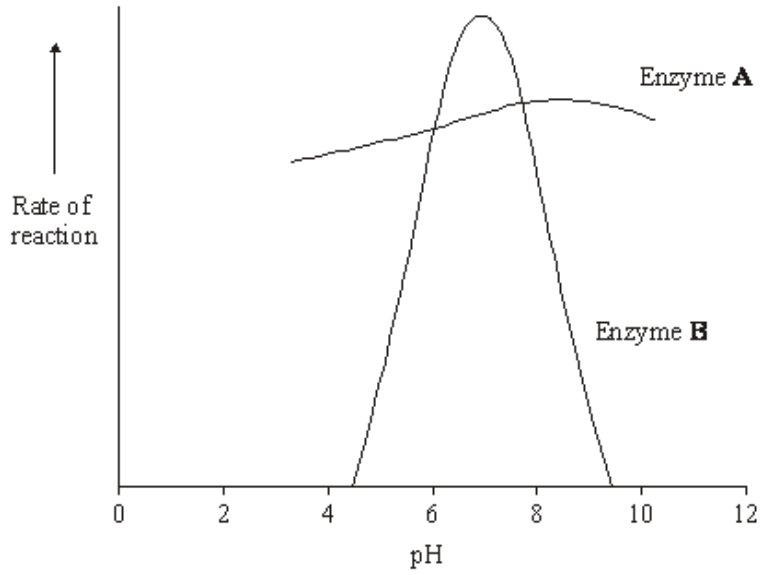
(2)

Enzymes **A** and **B** digest protein. The graph shows the effect of pH on the rates of reaction of these enzymes.



(c) Pepsin is a protein-digesting enzyme found in the stomach. It has an optimum pH of 2 and is fully denatured at pH 6. Sketch a curve on the graph to show the effect of pH on the rate of reaction of pepsin.

(1)

(d) Explain why the rate of reaction of enzyme **B** is low at pH 5.

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(3)

(e) Enzyme **A** is present in some washing powders used for cleaning clothes. Use the graph to suggest why enzyme **A** would be of more use in washing clothes than enzyme **B**.

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(1)

(f) Use your knowledge of protein structure to explain why enzymes are specific and may be affected by non-competitive inhibitors.

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(6)
(Total 15 marks)

Q6. Some enymes digest protein. They hydrolyse the peptide bonds between amino acids. The extent to which a protein is digested is called the degree of hydrolysis (DH). The DH value may be calculated from the equation:

$$DH = \frac{100 \times \text{Number of peptide bonds hydrolysed}}{\text{Total number of peptide bonds present}}$$

(a) (i) A protein molecule contains 151 amino acids. What is the total number of peptide bonds in this molecule?

.....

(1)

(ii) A molecule of this protein is digested. The DH value of the digested protein is 18. Calculate the number of peptide bonds that have been hydrolysed.

Answer .....

(1)

(b) What would be the DH value of a protein if it were completely hydrolysed to amino acids? Explain how you arrived at your answer.

DH value .....

Explanation .....

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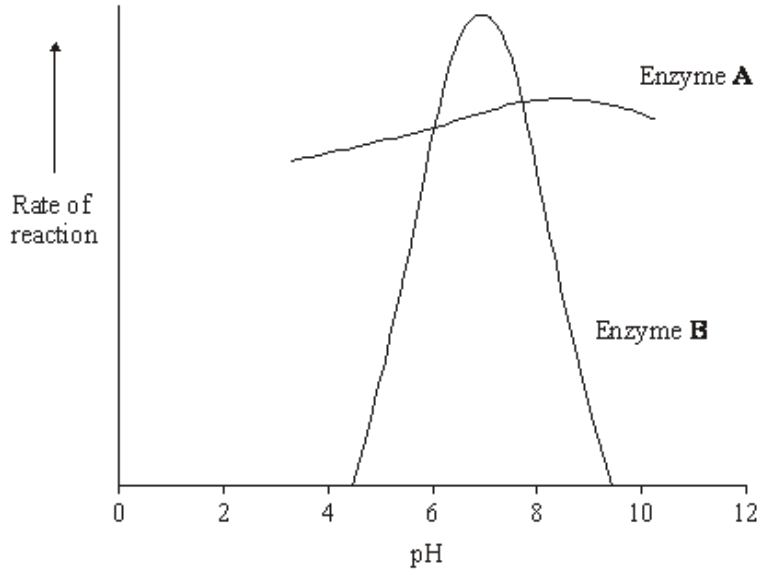
(2)

Enzymes **A** and **B** digest protein. The graph shows the effect of pH on the rates of reaction of these enzymes.



(c) Pepsin is a protein-digesting enzyme found in the stomach. It has an optimum pH of 2 and is fully denatured at pH 6. Sketch a curve on the graph to show the effect of pH on the rate of reaction of pepsin.

(1)

(d) Explain why the rate of reaction of enzyme **B** is low at pH 5.

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(3)

(e) Enzyme **A** is present in some washing powders used for cleaning clothes. Use the graph to suggest why enzyme **A** would be of more use in washing clothes than enzyme **B**.

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(1)

(f) Use your knowledge of protein structure to explain why enzymes are specific and may be affected by non-competitive inhibitors.

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(6)
(Total 15 marks)

Q7. (a) *Induced fit* and *lock and key* are two models used to explain the action of enzymes.

(i) Describe the *induced fit* model of enzyme action.

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(2)

(ii) Describe **one** way that the *lock and key* model is different from the *induced fit* model.

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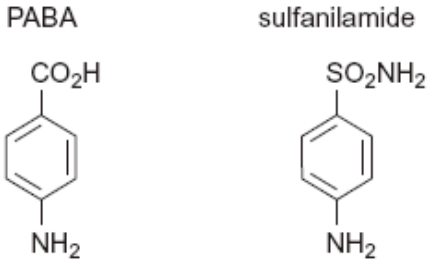
(1)

(b) Folic acid is a substance required by bacteria for cell growth. Bacteria produce folic acid by the following reaction.

The diagram shows the structure of a molecule of PABA. It also shows the structure of a molecule of a drug called sulfanilamide, which can be used to treat bacterial infections. Sulfanilamide prevents bacteria producing folic acid.



Use the diagram and your knowledge of enzymes to explain how sulphanilamide prevents bacteria producing folic acid.

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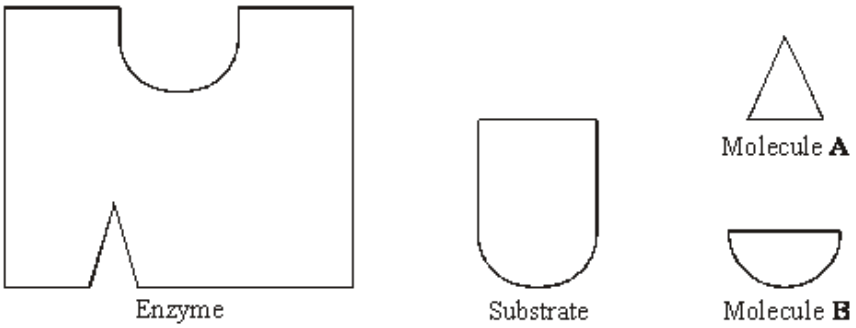
(3)
(Total 6 marks)

Q8. (a) The diagrams represent an enzyme, its substrate and two other molecules, **A** and **B**.



The addition of a non-competitive inhibitor will prevent the formation of an enzyme-substrate complex. Draw a labelled diagram based on relevant molecules selected from the diagram above to explain how this occurs.

(2)

(b) A decrease in temperature decreases the kinetic energy of molecules in a solution. Explain how a decrease in temperature decreases the rate of an enzyme-controlled reaction.

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(2)

(c) Urea breaks hydrogen bonds. Explain how the addition of urea would affect the rate of an enzyme-controlled reaction.

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(3)
(Total 7 marks)

Q9. Catalase is an enzyme. It catalyses the breakdown of hydrogen peroxide in the reaction:

$$\underset{\text{hydrogen peroxide}}{2H_2O_2} \rightarrow \underset{\text{water}}{2H_2O} + \underset{\text{oxygen}}{O_2}$$

In an investigation, samples of different substances were added to hydrogen peroxide in a series of test tubes. The rate of reaction was measured by recording the rate at which bubbles of oxygen were produced. A scale going from 0 for no bubbles to 5 for the maximum rate of bubbling was used to measure this. The results are shown in the table.

Tube	Substance added	Rate at which bubbles of oxygen were produced
A	Piece of liver	4
B	Ground liver and sand	5
C	Sand	0
D	Piece of cooled, boiled liver	0

(a) Explain the difference between the rate at which bubbles were produced in.

(i) tubes **A** and **B**;

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(2)

(ii) tubes **A** and **D**.

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(3)

(b) Explain the purpose of tube **C**.

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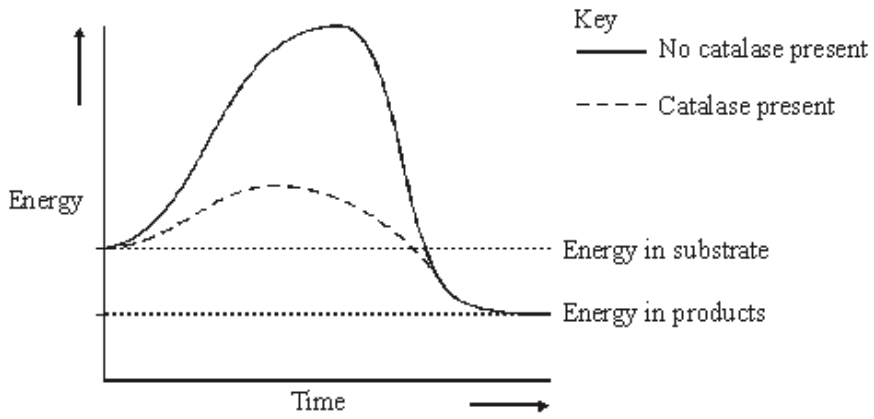
(1)

(c) The graph shows the energy changes which take place during the reaction in which hydrogen peroxide is converted to water and oxygen.



Use the graph to explain why

(i) hydrogen peroxide breaks down at a lower temperature when catalase is present than when it is not present;

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(1)

(ii) test tubes **A** and **B** became warmer when the reaction was taking place.

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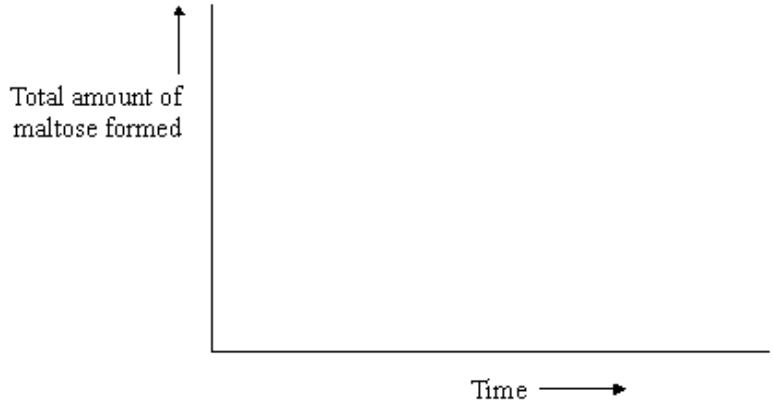
(2)

(Total 9 marks)

Q10. (a) Amylase is an enzyme which hydrolyses starch to maltose. Some amylase and starch were mixed and the mixture incubated at 37 °C until the reaction was complete.

(i) Sketch a curve on the axes below to show the progress of this reaction.



(1)

(ii) Explain why the rate of the reaction decreases as the reaction progresses.

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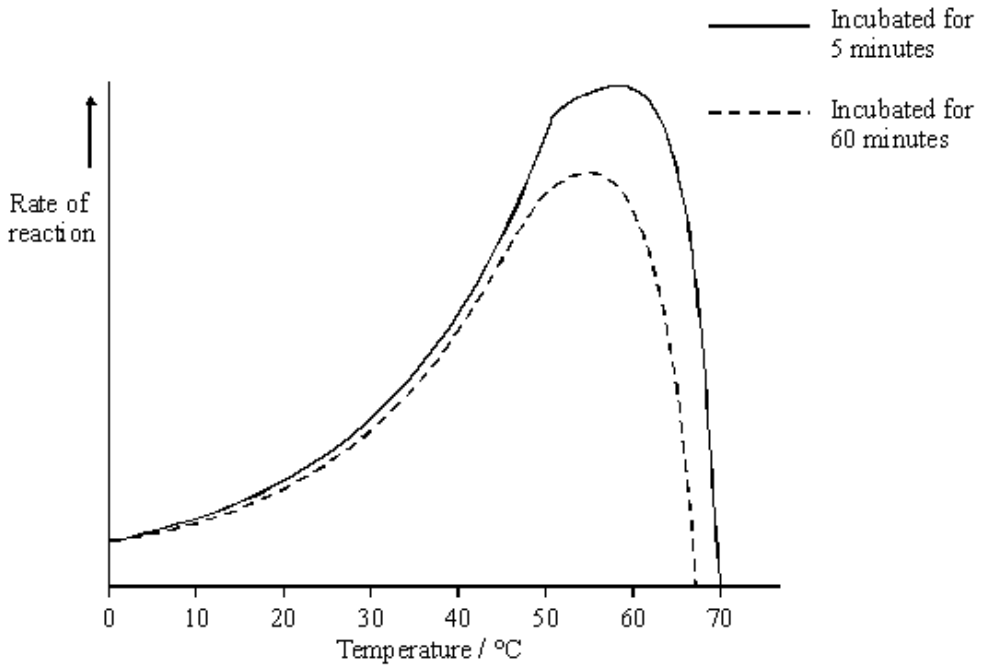
(2)

The effect of temperature on the rate of reaction of an enzyme was investigated. A test tube containing the enzyme and a test tube containing the substrate were incubated separately at each of the temperatures being investigated. After 5 minutes, they were mixed and the rate of reaction was determined. The experiment was repeated but, this time, the enzyme and the substrate were left for 60 minutes before they were mixed. The results of the investigation are shown in the graph.



(b) The enzyme solution used in this investigation was made by dissolving a known mass of enzyme in a buffer solution. Explain why a buffer solution was used.

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(1)

(c) (i) Use the graph to describe how incubation time affects the rate of the reaction.

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(2)

(ii) The maximum rate of reaction with an incubation time of 60 minutes is less than the maximum rate of reaction with an incubation time of 5 minutes. Explain why.

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(3)

(d) Explain how inhibitors affect the rate of enzyme-controlled reactions.

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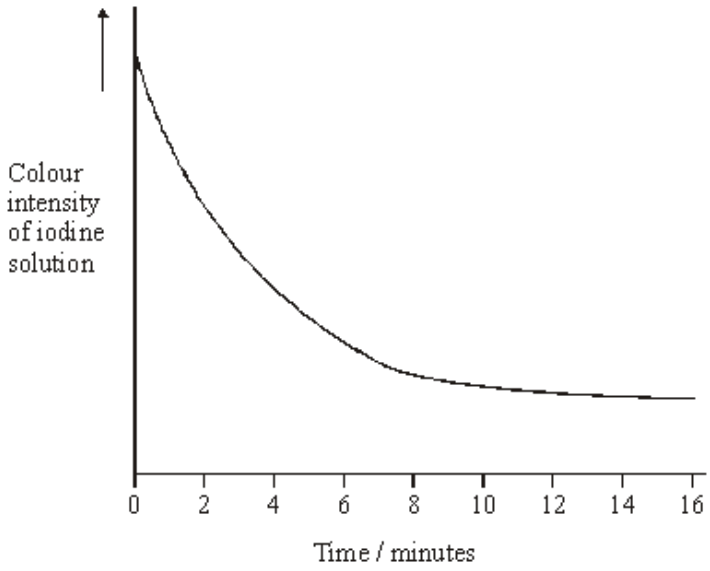
(6)
(Total 15 marks)

Q11. In an investigation into carbohydrase activity, the contents from part of the gut of a small animal were collected. The contents were added to starch solution at pH 7 and kept in a water bath at 25°C. At one-minute intervals, samples were removed and added to different test tubes containing dilute iodine solution. The colour intensity of each sample was determined. The graph shows the results.



(a) Explain the change in colour intensity.

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(2)

(b) Draw clearly labelled curves on the graph to show the expected result if the experiment was repeated

(i) at 35 °C;

(ii) at pH 2.

(2)

(c) Explain how

(i) raising the temperature to 35 °C affects carbohydrase activity;

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(ii) decreasing the pH affects carbohydrase activity.

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(7)
(Total 11 marks)

Q12. (a) Explain how the shape of an enzyme molecule is related to its function.

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(3)

(b) Bacteria produce enzymes which cause food to decay. Explain how vinegar, which is acidic, can prevent the action of bacterial enzymes in some preserved foods.

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(3)
(Total 6 marks)

M1. (a) Concentration of substrate solution / of enzyme solution / pH;

1

(b) 1. 2.5 / 0.04;

1 mark for correct value

2. g dm^{-3} $minute^{-1}$ / g dm^{-3} s^{-1};

1 mark for related unit

2

(c) 1. Initial rate of reaction faster at 37 °C;

2. Because more kinetic energy;

3. So more E–S collisions / more E–S complexes formed;

4. Graph reaches plateau at 37 °C;

5. Because all substrate used up;

Allow converse for correct descriptions and explanations for curve at 25 °C

5

[8]

M2. (a) Any **two** of the following;

Concentration of enzyme

Volume of substrate solution

pH

Allow same concentration of substrate

1

(b) Ratio between 4:1 and 5:1;;

Initial rates incorrect but correctly used = 1 mark

2

(c) At 60 °C:

1. More kinetic energy;

2. More E–S complexes formed;

Allow converse for 37 °C

2

(d) Different times:

1. Higher temperature / 60 °C causes denaturation of all of enzyme;
Accept converse for 37 °C

2. Reaction stops (sooner) because shape of active site changed;
Reject if active site on substrate

Different concentrations of product (at 60 °C)

3. Substrate still available (when enzyme denatured);

4. But not converted to product;

4

[9]

M3. (a) (Rennet) has less / variable amount of chymosin;

Limited supply (of rennet) available;

Pepsin may digest curd / protein / has another

protein- digesting enzyme;

(Animal) rennet unacceptable by vegetarians / vegans / against religious beliefs / harms animals;
Accept use of figures e.g. 80-90% for first mark point.

2 max

(b) Both contain chymosin / both derived from animal gene;

1

(c) (i) (Coagulation time) is reduced / is more active;

1

(ii) 2 marks for correct answer of 27% / 27.3%;;

1 mark for incorrect answer in which candidate has shown fall in coagulation time as 3 (minutes) or 11 -8;

2 max

(d) 1. (Enzyme) denatured / loss of tertiary structure / hydrogen bonds broken;

2. Shape of active site changes / no longer complementary;

3. Less / no substrate binds / fewer / no enzyme-substrate complexes formed;

3

[9]

M4. (a) pH goes down and levels out;
after 30 min / pH 6.5;

2

(b) Enzyme not used up in reaction;

1

(c) Curve will be less steep:

*Only accept answers relating to curve **not** rate of reaction*

1

[4]

M5. (a) (i) 150;

1

(ii) 27;

1

(b) 100;
number of peptide bond hydrolysed = total number present / all peptide bonds have been hydrolysed;

accept calculation showing same number top and bottom.

2

(c) curve rising to peak at pH 2 and falling to zero by pH 6;

1

(d) (change in pH) leads to breaking of bonds holding tertiary structure / changes charge on amino acids;
enzyme / protein / active site loses shape / denatured; substrate will not bind with / fit active site / fewer / no ES complexes formed;

3

(e) more resistant to changes in pH and washing conditions variable / works in alkaline pH and washing powders alkaline;

mark awarded for indicating aspect of effect of pH and advantage of this in terms of washing powder and conditions in wash.

1

(f) maximum of three marks for specificity, points 1 - 3. Can only be given credit in context of specificity

1 each enzyme / protein has specific primary structure / amino acid sequence;

2 folds in a particular way / has particular tertiary structure giving an active site with a unique structure;

3 shape of active site complementary to / will only fit that of substrate;
maximum of three marks for inhibition, points 5 – 8

4 inhibitor fits at site on the enzyme other than active site;

5 distorts active site;

6 so substrate will no longer fit / form enzyme-substrate complex

6

[15]

M6. (a) (i) 150;

1

(ii) 27;

1

(b) 100;
number of peptide bond hydrolysed = total number present / all peptide bonds have been hydrolysed;

accept calculation showing same number top and bottom.

2

(c) curve rising to peak at pH 2 and falling to zero by pH 6;

1

(d) (change in pH) leads to breaking of bonds holding tertiary structure / changes charge on amino acids;
enzyme / protein / active site loses shape / denatured; substrate will not bind with / fit active site / fewer / no ES complexes formed;

3

(e) more resistant to changes in pH and washing conditions variable / works in alkaline pH and washing powders alkaline;

mark awarded for indicating aspect of effect of pH and advantage of this in terms of washing powder and conditions in wash.

1

(f) maximum of three marks for specificity, points 1 - 3. Can only be given credit in context of specificity

1 each enzyme / protein has specific primary structure / amino acid sequence;

2 folds in a particular way / has particular tertiary structure giving an active site with a unique structure;

3 shape of active site complementary to / will only fit that of substrate;
maximum of three marks for inhibition, points 5 – 8

4 inhibitor fits at site on the enzyme other than active site;

5 distorts active site;

6 so substrate will no longer fit / form enzyme-substrate complex

6

[15]

M7. (a) (i) Active site / enzyme not complementary;

Active site changes (shape) / is flexible;

(Change in enzyme allows) substrate to fit / E-S complex to form;

Active site becomes complementary / wraps around substrate = 2 marks

For mark point 2. allow 'binding site' but not 'enzyme'

For mark point 2. can only have enzyme changes (shape) if active site has been mentioned earlier

Final mark point must have context

Reject: active site on substrate for second marking point only

Accept: diagrams only if suitably labelled or annotated

2 max

(ii) Active site does not change (shape) / is fixed (shape) / is rigid / does not wrap around substrate / (already) fits the substrate / is complementary (before binding);

Assume that 'it' refers to lock and key

1

(b) Similar structure / shape (to PABA) / both complementary;

Competes for / binds to active site / competitive inhibitor;

Less PABA binds / less E-S complexes;

OR

Specific reference to different structure / shape (to PABA) using the diagram;

Binds to position other than active site / binds to allosteric site / binds to inhibitor site / non-competitive inhibitor;

Changes the active site so substrate cannot bind / less PABA binds / less E-S complexes;

Q *Reject: same structure / shape*

Note: competitive inhibitor binds to active site = 1 mark (same mark point)

Assume that 'it' refers to sulfanilamide

Accept: PABA / substrate cannot bind

Neutral: less product produced as in question stem

Neutral: different structure / shape to PABA

Reject: active site on substrate for second marking point only

3 max

[6]

M8. (a) diagram showing molecule **A** fitting in inhibition site; distortion of active site;

2

(b) molecules moving less / slower; reduces chance of collision (between enzyme and substrate) / of enzyme-substrate complexes being formed; *(reject converse)*

2

(c) these bonds hold / maintain tertiary / globular structure (of enzyme);
enzyme denatured / tertiary structures destroyed; (shape of) active site distorted / changes;
substrate no longer fits / enzyme-substrate complex not formed;

3 max

[7]

M9. (a) (i) (Grinding) breaks open cells / increases surface area (of liver);
Releases catalase / enzyme / more catalase / allows more hydrogen peroxide into liver;

2

(ii) Heating causes bonds (maintaining tertiary structure) to break;
Denatures / changes tertiary structure so active site changed;
Substrate no longer fits / ES complex not formed;

3

(b) (Control) to show that sand did not affect reaction (with ground liver);

1

(c) (i) Lower activation energy / less energy required to bring about reaction;

1

(ii) Energy in products / water and oxygen less than energy in substrate / reactants / hydrogen peroxide;
(Difference) given out as heat / exothermic;

2

[9]

M10. (a) (i) Curve rising and levelling out;

1

(ii) Substrate becomes limiting / falls / gets less;
Fewer collisions / complexes formed;

2

(b) To keep pH the same / optimum pH / so change in pH does not affect reaction;

1

(c) (i) For temperature up to 40 – 50 °C has no effect;
Over temperature (of 40 – 50 °C) reduces rate of reaction;

Note. Award one mark for general statement about the longer the incubation time, the slower the rate of reaction.

2

(ii) Bonds (holding tertiary structure) broken;
More enzyme denatured / tertiary structure destroyed / active sites lose shape / no longer fit;
Fewer enzyme-substrate complexes formed;

Note. Award marks if clearly in the context of more denaturation.
Allow credit here for converse relating to exposure for 5 minutes.

3

(d) Competitive
2 Similarity of shape of inhibitor and substrate;
3 Inhibitor can enter / bind with active site (of enzyme);

Non-competitive
4 Affect / bind to enzyme other than at active site;
5 Distorts shape of active site;

Inhibitors
6 Prevent entry of / binding of substrate to active site;
7 Therefore fewer / no enzyme-substrate complexes formed;

6

[15]

M11. (a) colour results from starch-iodine reaction;
decrease due to breakdown of starch by carbohydrase / enzyme;

2

(b) (i) curve drawn below curve on graph and starting at same point;

1

(ii) curve drawn above curve on graph and starting at same point but finishing above;

(allow curve or horizontal line)

(allow alternative curve for pH if explanation in (ii) is consistent)

1

(c) (i) 1. increase in temperature increases kinetic energy;
2. increases collisions (between enzyme / active site and substrate) / increases formation of enzyme / substrate complexes;
3. increases rate of breakdown of starch / rate of reaction / carbohydrase activity;

(ii) 4. (decrease in pH) increases H^+ ions / protons which attach / attracted to amino acids;
5. hydrogen / ionic bonds disrupted / broken which denatures enzyme / changes tertiary structure;
6. changes shape / charge of active site so active site / enzyme unable to combine / fit with starch / enzyme-substrate complex no longer able to form;
7. decreases rate of breakdown of starch / rate of reaction / carbohydrase activity;

(allow alternative explanation for pH if consistent with line drawn in (ii))

7

[11]

M12. (a) specific 3D tertiary structure / shape;
substrate complementary shape;

(reject same shape)

substrate (can bind) to active site / can fit into each active site;

3

(b) (bacterial) active site / enzymes / proteins denatured /
tertiary 3D structure disrupted / changed;
(ionic) bonds broken;

(reject peptide bonds)
(ignore other bonds)

no enzyme substrate complex formed / substrate no longer fits;

3

[6]