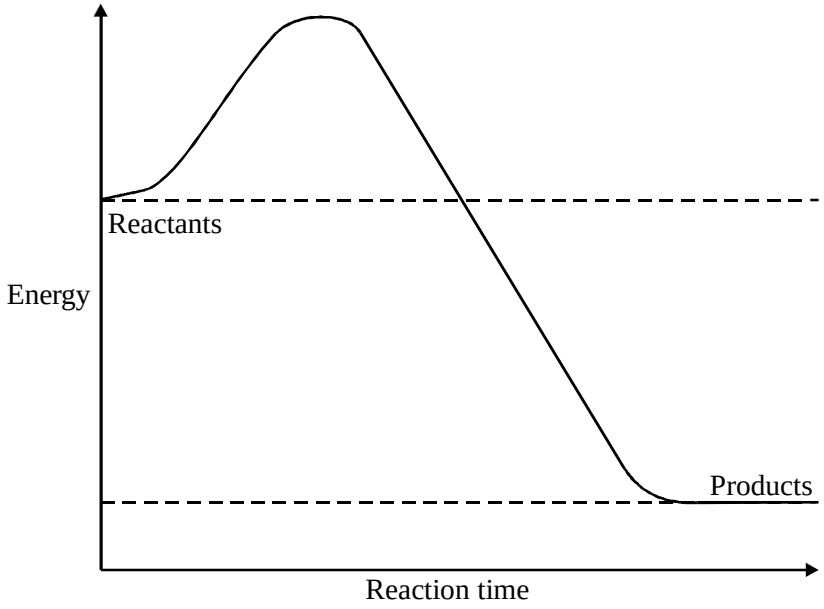
1. (a) The graph shows the energy changes which take place during a chemical reaction.



(i) Use the graph to explain what is meant by the term *activation energy*.

.....

.....

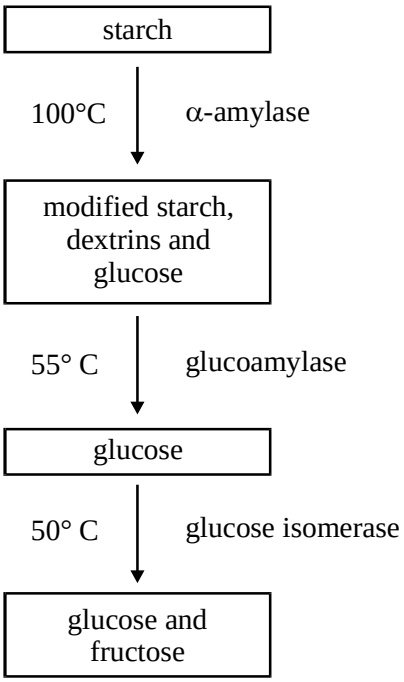
.....

(1)

(ii) Draw a curve on the graph to show the energy changes which would take place if the same chemical reaction were catalysed by an enzyme.

(2)

The flow chart shows the way in which fructose is produced from starch in the food industry.



(b) Describe a biochemical test which could be used to show that reducing sugars were produced in the first stage of this process.

.....

.....

.....

.....

(2)

(c) Acid could have been used in place of the α-amylase in the first stage of this process. Suggest why:

(i) acid could have been used;

.....

.....

(1)

(ii) acid was **not** used.

.....

.....

(1)

(d) In the laboratory, the optimal conditions for bacterial α-amylase are a pH of *7* and a temperature of 80°C.

In terms of your knowledge of the way in which enzymes work, explain why the rate of reaction would change if:

(i) the temperature fell by 10°C;

.....

.....

.....

.....

(2)

(ii) the pH changed substantially.

.....

.....

.....

.....

.....

.....

(3)
(Total 12 marks)

2. The *turnover number* of an enzyme is defined as the number of substrate molecules converted to product by one molecule of enzyme in one minute. In an experiment carried out at 20°C, the turnover number for an enzyme was found to be 2500 at the start of the experiment but dropped to 1000 after 5 minutes.

(a) (i) Suggest why the turnover number decreased after 5 minutes.

.....

.....

.....

.....

(2)

(ii) How would you expect the turnover number to differ from 2500 at the start of an identical experiment but carried out at 30°C? Explain your answer.

.....

.....

.....

.....

(2)

(b) Explain why it would be important to have a control in the experiment at 20°C and at 30°C.

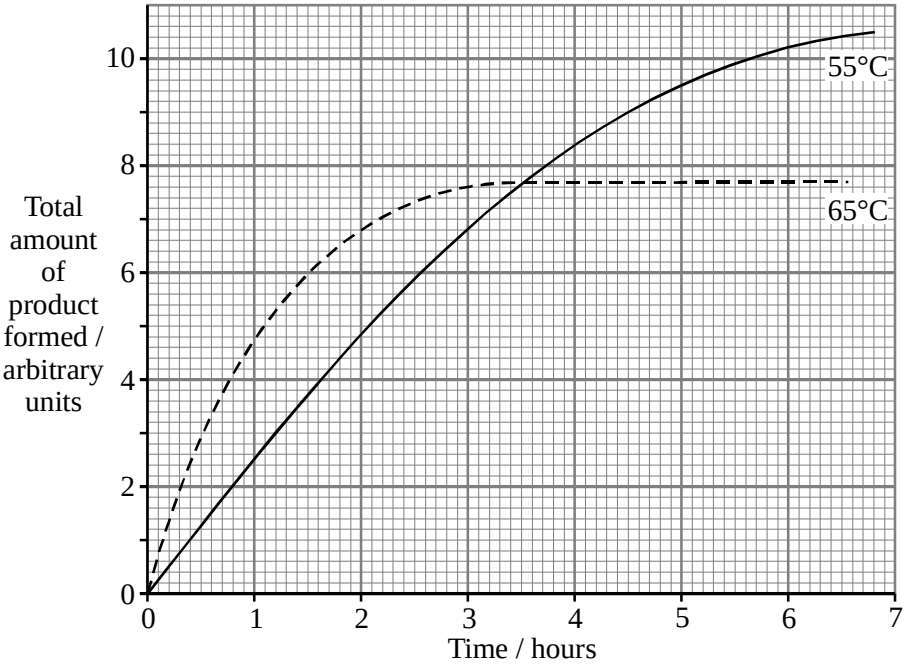
.....

.....

(1)

(Total 5 marks)

3. The total amount of product formed in an enzyme-controlled reaction was investigated at two different temperatures, 55 °C and 65 °C. The results are shown in the graph.



(a) (i) Explain how you would calculate the rate of the reaction at 55 °C over the first 2 hours of the investigation.

.....

.....

.....

.....

(1)

(ii) Explain why the initial rate of this reaction was faster at 65 °C than it was at 55 °C.

.....

.....

.....

.....

.....

.....

(3)

(b) Use your knowledge of enzymes to explain the difference in the two curves between 4 and 6 hours.

.....

.....

.....

(1)

(c) In this investigation, the enzyme and its substrate were mixed in a buffer solution. What was the purpose of the buffer solution?

.....

.....

(1)

(Total 6 marks)

4. Meat is the muscle tissue of an animal. When animals are slaughtered, biochemical changes occur in the muscle which result in the meat becoming tough. There are several ways of making the meat tender again. These involve partly breaking down the proteins which make up muscle tissue.

(a) One way is to add a protein-digesting enzyme called papain just before freezing the meat. As the meat is thawed and cooked, this enzyme digests the protein. Use your knowledge of enzymes to explain why:

(i) the rate at which the protein is digested increases as the meat warms up in the early stages of cooking;

.....

.....

.....

.....

.....

.....

(3)

(ii) protein digestion stops once the meat has been heated to 90 °C.

.....

.....

.....

.....

.....

.....

(3)

(b) Another way is to leave the meat for 10 days before freezing. Explain how lysosomes in muscle cells make the meat tender before it is frozen.

.....

.....

.....

.....

(2)
(Total 8 marks)

5. (a) A protein is formed from 300 amino acids. The diagrams show the primary, secondary and tertiary structures of this protein.

Primary structure. Length = 300 nm

Secondary structure. Length = 45 nm

Tertiary structure. Length = 8.6 nm

(i) Explain what causes the secondary structure to differ in length from the primary structure.

.....

.....

(1)

(ii) Explain what is meant by the tertiary structure of a protein.

.....

.....

(1)

(iii) Heating may affect the tertiary structure of a protein. Explain how.

.....

.....

.....

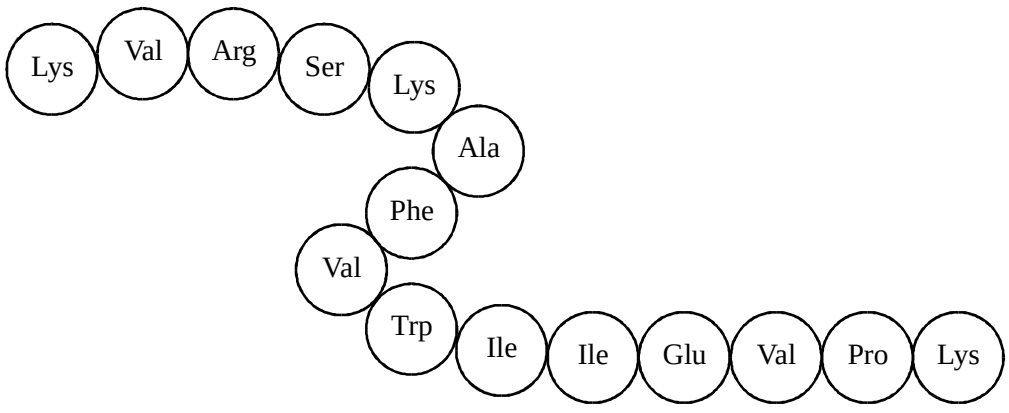
.....

(2)

(b) The first step in investigating the primary structure of a protein is to break it into shorter lengths with enzymes. The table shows some of the enzymes used and the position of the peptide bonds they break.

Enzyme	**Position of peptide bond that enzyme breaks**	
	First amino acid	**Second amino acid**
Trypsin	Lys or Arg	any
Chymotrypsin	Phe, Trp or Tyr	any
V8 protease	Glu	any

The diagram shows a polypeptide chain. The sequence of amino acids should be read from left to right.



(i) How many amino acid fragments will be produced from this polypeptide if it is incubated with a mixture of trypsin and V8 protease?

.....

(1)

(ii) Explain why trypsin and chymotrypsin break peptide bonds between different amino acids.

.....

.....

.....

.....

(3)

(Total 8 marks)

6. Lactose is a sugar which is found in milk. It can spoil milk products such as ice cream by producing an unpleasant sandy texture. Lactase is an enzyme which is used in making ice cream. It breaks down lactose to glucose and galactose. When ice cream is made, lactase is added to milk and left for about a day at 5 °C. The reaction is very slow.

(a) Use your knowledge of enzymes to explain why the rate of this reaction is very slow at 5 °C.

.....

.....

.....

.....

.....

.....

(3)

(b) Adult cats are unable to digest lactose. Lactase is used to reduce the amount of lactose in milk for cats. The milk is heated to sterilise it. It is then cooled and the lactase added before packaging. Explain why lactase is added after cooling the milk rather than before heating it.

.....

.....

.....

.....

(2)
(Total 5 marks)

7. (a) An enzyme was dissolved in water. A biuret test was carried out on the solution. Describe and explain the result you would expect.

.....

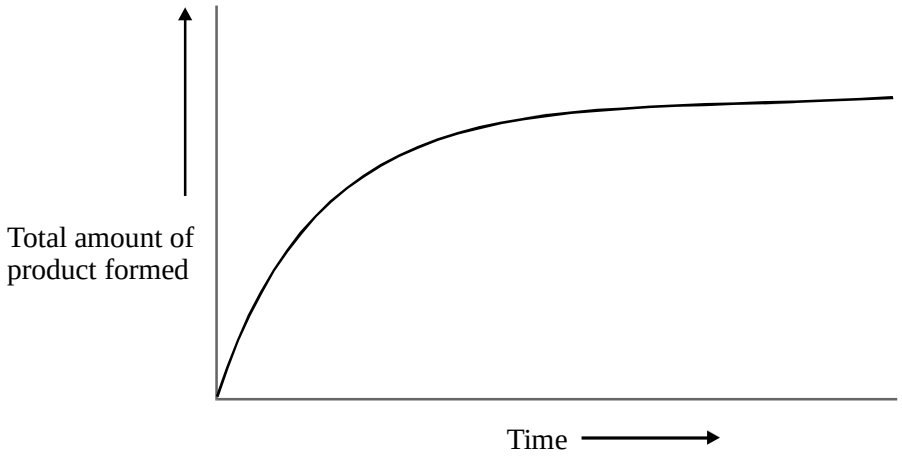
.....

.....

.....

(2)

(b) The graph shows the total amount of product formed during an enzyme-controlled reaction.



(i) Describe and explain what happened to the total amount of substrate present as the reaction progressed.

.....

.....

(1)

(ii) Use your knowledge of how an enzyme works to explain why the rate of reaction decreased with time.

.....

.....

.....

.....

(2)

(iii) This reaction was carried out at a temperature of 30°C. Sketch a curve on the graph to show the total amount of product formed at 20°C.

(2)

(c) Catalase is an enzyme which breaks down hydrogen peroxide to produce water and oxygen. The effect of substrate concentration on the rate of this reaction was investigated. Explain why the initial rate of reaction was measured at each substrate concentration.

.....

.....

.....

.....

(2)

(Total 9 marks)

8. Read the following passage.

In spite of the ability of animals to eat them, green plants dominate the landscape. Part of the reason for this is that most plants, not just the ones we regard as poisonous, contain toxins. These toxins are found in different amounts in different parts of the plant.

Many different substances act as toxins. The simplest are the non-protein amino acids. These substances are chemically similar to the twenty amino acids normally found. in proteins. Thus β-cyanoalanine, $NCCH_2CHNH_2COOH$, is clearly similar to alanine, CH_3CHNH_2COOH. When non-protein amino acids are eaten, they are incorporated into proteins. This results in the formation of unnatural enzymes that do not function properly. Plants which make these non-protein amino acids, however, do not synthesise faulty enzymes. Investigations with lily of the valley have shown why. This plant produces large amounts of azetidine 2-carboxylic acid (ACA). This substance is a non-protein amino acid very similar to the amino acid proline. In the lily of the valley, the enzyme which links proline to tRNA does not bind to azetidine 2-carboxylic acid.

Another group of toxins has been called the "sugar-shaped weapons of plants" and they inhibit enzymes involved in carbohydrate metabolism. One of these is a substance called swainsonine. It is toxic to cattle and affects the nervous system. This effect results from the build-up of mannose-based sugars because the animal's mannosidase enzymes cannot break them down.

Fortunately, many toxic compounds can be made harmless. In mammals, the liver plays an important part in this. Poisonous substances are converted into products which are relatively harmless. These products are excreted either in bile or urine. Molecular size is often the factor determining the final route of elimination from the body. Only the smaller molecules are removed in the urine. The selective ability of primary consumers to overcome the chemical defences of plants is reflected in the pattern of feeding we see today.

Use information in the passage and your own knowledge to answer the following questions.

(a) β-cyanoalanine (line 6) is a non-protein amino acid. Explain why β-cyanoalanine is

(i) an amino acid;

.....

.....

.....

.....

(2)

(ii) called a non-protein amino acid.

.....

.....

(1)

(b) (i) Explain why enzymes which contain non-protein amino acids cannot function properly.

.....

.....

.....

.....

.....

.....

(3)

(ii) Explain why enzymes which do not function properly are not synthesised in lily of the valley.

.....

.....

.....

.....

(2)

(c) Would you expect swainsonine (line 16) to be a competitive or a non-competitive inhibitor? Explain the evidence from the passage which supports your answer.

.....

.....

.....

.....

(2)

(d) Explain **one** way in which the information in the passage can help to explain why different species of primary consumer have different ecological niches.

.....

.....

.....

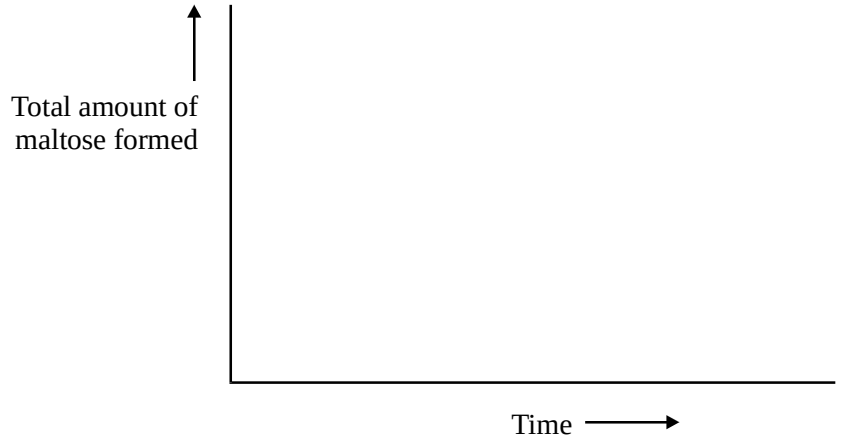
.....

(2)

(Total 12 marks)

9. (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.

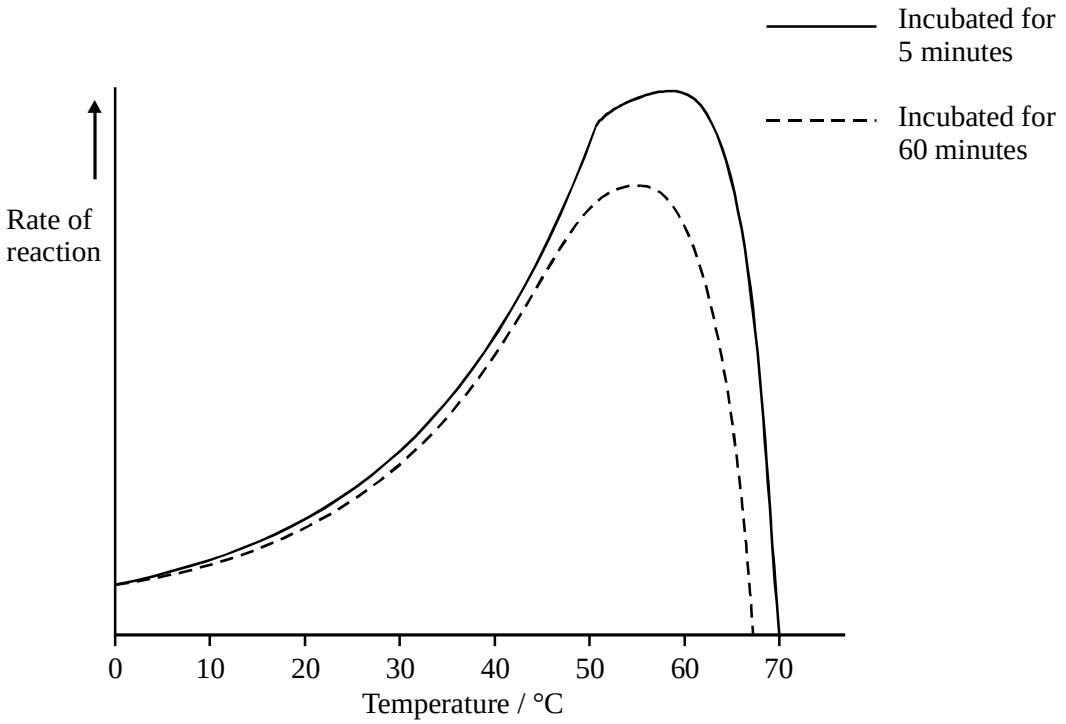
.....

.....

.....

(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.

.....

.....

(1)

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

.....

.....

.....

.....

(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.

.....

.....

.....

.....

.....

.....

(3)

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

.....

.....

.....

.....

.....

.....

.....

.....

.....

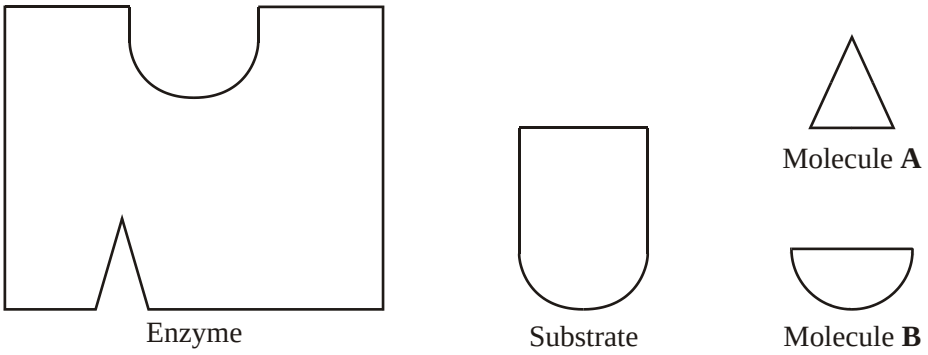
.....

.....

(6)

(Total 15 marks)

10. (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.

.....

.....

.....

.....

(2)

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

.....

.....

.....

.....

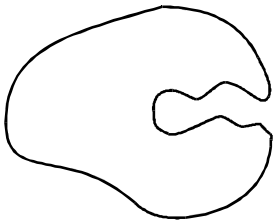
.....

.....

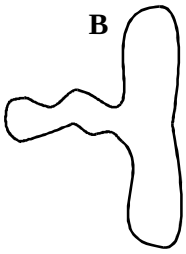
(3)
(Total 7 marks)

11. (a) Diagram **A** shows an enzyme, and **B** is the substrate of this enzyme.

A



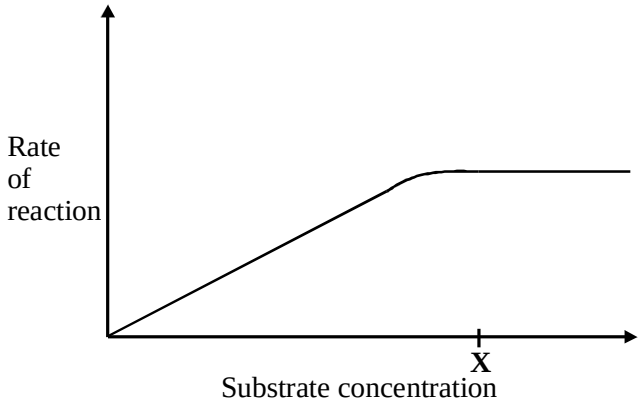
B



By drawing on this diagram, show how a competitive inhibitor would affect the activity of the enzyme.

(2)

(b)



The graph shows the effect of changing substrate concentration on the rate of an enzyme controlled reaction. Explain why increasing substrate concentration above the value shown as **X** fails to increase the rate of the reaction further.

.....

.....

.....

.....

.....

(2)

(c) Explain how adding excess substrate could overcome the effect of a competitive inhibitor.

.....

.....

.....

(1)

(d) Explain what happens to an enzyme molecule when it is denatured by high temperature.

.....

.....

.....

.....

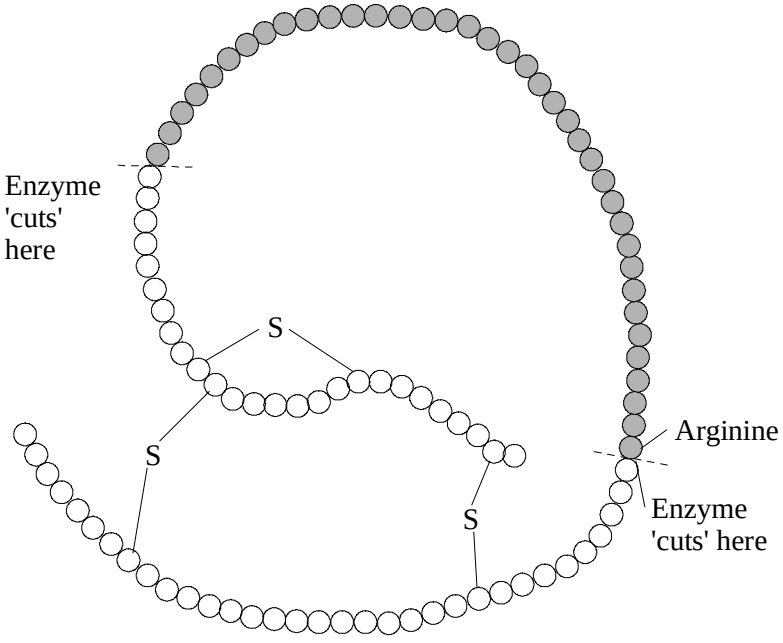
.....

.....

(3)

(Total 8 marks)

12. Insulin is a protein. It is made in the cells of the pancreas from a larger molecule called pro-insulin. An enzyme breaks the pro-insulin into insulin and a short polypeptide. This is shown in the diagram.



(a) Name the type of monomer which forms insulin.

.....

(1)

(b) Describe the result you would expect if the enzyme were tested with biuret reagent.

.....

.....

(1)

(c) If the amino acid arginine is replaced by glycine in a molecule of pro-insulin, insulin will not be produced. Explain why the enzyme will no longer break down pro-insulin.

.....

.....

.....

.....

.....

.....

(3)
(Total 5 marks)

13. (a) Starch molecules do not break down in boiling water. In the body starch is digested by amylase.

(i) Name the product of the digestion of starch by amylase.

.....

(1)

(ii) Explain how amylase makes it possible for starch to be digested at body temperature.

.....

.....

.....

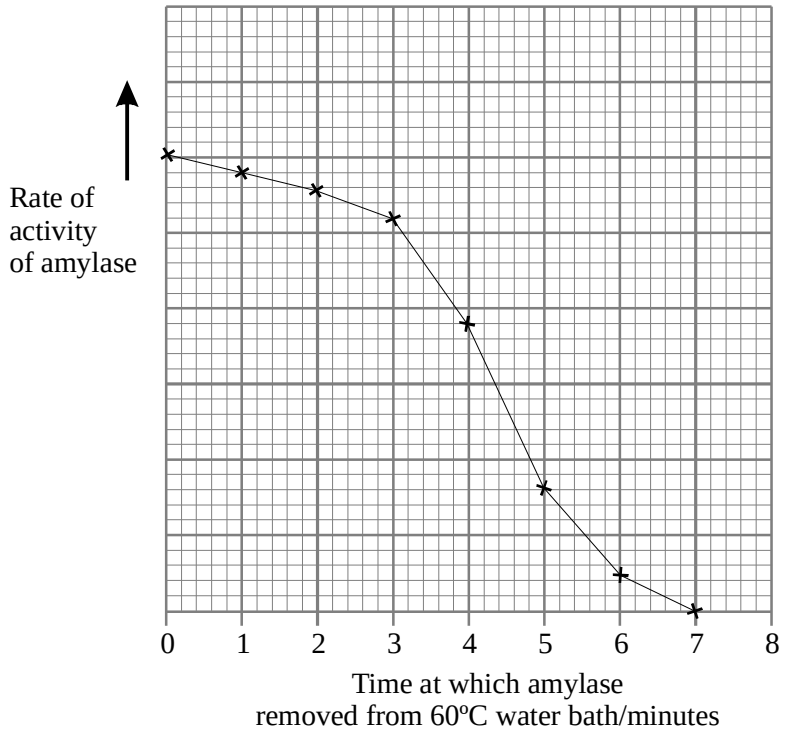
.....

.....

.....

(3)

(b) In an investigation, a sample of amylase was placed in a water bath at 60°C. Each minute, a small amount of the amylase was removed and mixed with starch solution at 35°C. The rate of activity of the amylase was measured. The results are shown in the graph.



Use your knowledge of enzymes to explain why the activity of the amalyse decreased.

.....

.....

.....

.....

.....

.....

.....

.....

(4)
(Total 8 marks)

14. Cyanide is a poison. It combines non-competitively with an enzyme found in mitochondria. This enzyme, called cytochrome oxidase, is essential for ATP production in respiration. ATP is the substance that transfers energy for use in other processes in the cell.

(a) Use your knowledge of enzymes to explain how cyanide stops the activity of cytochrome oxidase.

.....

.....

.....

.....

(2)

(b) It has been suggested that it might be possible to use cyanide to kill cancer cells. Cassava plants make a substance called linamarin and also an enzyme that breaks down linamarin to release cyanide. The idea is to use an antibody that attaches only to the cell surface membrane of cancer cells. The enzyme from the cassava plants would be combined with this antibody. Linamarin would then be injected into the person with cancer,

(i) Suggest what type of substance would cause the antibody to attach only to cancer cells.

.....

(1)

(ii) Explain how this method would kill the cancer cells, but not other cells.

.....

.....

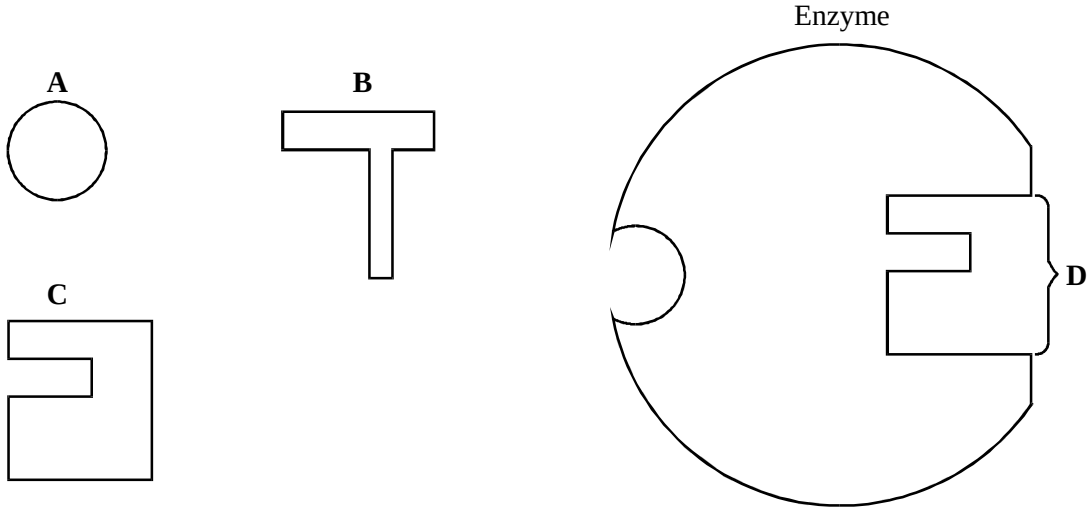
.....

.....

.....

(3)
(Total 6 marks)

15. The diagrams represent an enzyme and three molecules that could combine with it.



(a) Name the part of the enzyme labelled **D**.

.....

(1)

(b) Explain how substrate **C** is broken down by the enzyme.

.....

.....

.....

.....

.....

.....

.....

.....

(4)

(c) Molecules **A** and **B** inhibit the enzyme in different ways.
Explain how each molecule inhibits the enzyme.

Molecule **A** .....

.....

.....

.....

Molecule **B** .....

.....

.....

.....

(4)

(d) A student carried out an investigation using amylase from a saprophytic fungus. Six wells (holes) of the same size were cut in a starch agar plate. Each well was filled with the same concentration and volume of amylase solution. An equal volume of buffer solution was added to produce a different pH in each well. The plates were incubated at 25°C for 4 hours and then covered with iodine solution. It was observed that there were clear rings around each well. The width of these clear rings is shown in the table.

pH	**Width of clear ring / mm**
4	1
5	2
6	6
7	11
8	9
9	3

(i) What conclusion can be drawn from the results?

.....

.....

(1)

(ii) Use an appropriate method to estimate the maximum rate of reaction that was observed in this investigation. Show your working.

Maximum rate of reaction .....

(2)

(Total 12 marks)

16. Read the following passage.

Proteins have many different functions. These include catalysing chemical reactions and transporting substances across membranes. Many of these functions rely on the specific shape of their molecules. Molecules of a particular protein always fold into the same shape.

Although different proteins have different shapes, they share a number of structural features. They are formed from 20 different types of amino acid, each containing the same four chemical elements. Unlike triglycerides, proteins are polymers. Their chains are linear and never branched. The primary structure is the term used to refer to the sequence of amino acids which makes up a particular protein. These amino acids are linked by peptide bonds. The side-chains or R-groups of different amino acids may form chemical bonds with each other. It is these bonds which allow the formation of protein molecules with specific tertiary shapes.

The amino acid sequences of over 100000 proteins are known but, so far, we only know the tertiary structure of about 5000 of these. We have recently discovered that the folding of polypeptide chains is controlled by a group of proteins called chaperones. Chaperones bind to unfolded regions of polypeptide chains as they are being synthesised and prevent them from binding to other proteins. Once folded, the protein and chaperone separate allowing the chaperone to affect the folding of more polypeptide chains.

Use information from the passage and your own knowledge to answer the following questions.

(a) (i) What are the “same four chemical elements” found in all amino acids (line 7)?

.....

(1)

(ii) Explain why “unlike triglycerides, proteins are polymers” (lines 7 – 8).

.....

.....

.....

.....

(2)

(iii) Glycogen is also a polymer. Explain how many different sorts of protein can be produced but only one sort of glycogen.

.....

.....

.....

.....

(2)

(b) Describe **two** ways in which chaperones (line 17) are similar to enzymes.

1.....

.....

2.....

.....

(2)

(c) (i) Explain what causes molecules of a particular protein always to fold into the same shape.

.....

.....

.....

.....

(2)

(ii) Describe how molecular shape is important in explaining the way in which enzymes may be affected by inhibitors.

.....

.....

.....

.....

.....

(6)
(Total 15 marks)

17. Read the following passage.

Many different processes essential to life depend on proteins. These include enzyme controlled reactions, transport across plasma membranes and the binding of hormones to receptor molecules on their target cells. Every protein molecule has a tertiary structure which gives it a precise three-dimensional shape. The function of the protein depends on this shape, and the shape depends on the pH of the surrounding solution.

Changes in pH affect different proteins in different ways. This is because the amino acid molecules from which they are built have different structures. Some of these amino acids have different charges at different pH values. Unless they have the correct charges, the protein molecule will not have its correct three-dimensional shape.

If hydrogen or hydroxyl ions are added to a solution, its pH will normally change. A buffer solution is one which maintains a constant pH when hydrogen or hydroxyl ions are added to it. Buffers also occur naturally and play an important role in keeping conditions inside living organisms constant.

Use information from the passage and your own knowledge to answer the following questions.

(a) The receptor molecules to which hormones bind are proteins. Glucagon is a hormone.

(i) Use the information in the first paragraph to explain why glucagon will only bind to one particular type of receptor molecule.

.....

.....

.....

.....

(2)

(ii) Suggest why glucagon is able to bind to liver cells but not to cells in other parts of the body.

.....

.....

(1)

(b) Explain how the amino acids from which proteins are built (lines 6–7) differ in structure from each other.

.....

.....

(1)

(c) Amylase is an enzyme, found in saliva, which breaks down starch. It works best at a pH of 8. Explain why amylase does not function in the stomach where the pH is approximately 3.

.....

.....

.....

.....

.....

.....

(3)

(d) When a suspension of mitochondria is prepared from liver, the tissue is ground in a buffer solution, then centrifuged. Explain why a buffer solution is used.

.....

.....

.....

.....

(2)

(e) Describe how proteins are arranged in a plasma membrane and the part they play in transporting substances into and out of cells.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(6)

(Total 15 marks)

18. (a) Describe how you would use a biochemical test to show that a solution contained protein.

.....

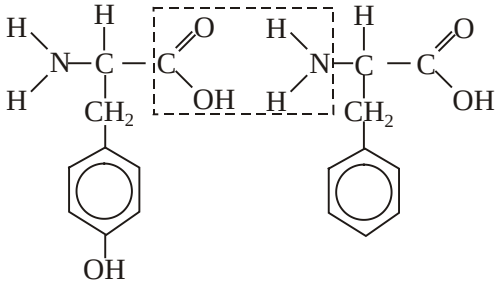
.....

.....

.....

(2)

The diagram shows the structure of two amino acid molecules, tyrosine and phenylalanine.



Tyrosine Phenylalanine

(b) Copy from the diagram the R group in the phenylalanine molecule.

(1)

(c) (i) In the space below, draw the chemical bond formed when these two amino acids are joined by condensation. You need only draw the parts of the molecules shown in the box.

(2)

(ii) Name this bond.

.....

(1)

(d) Tyrosine can be made in the body by hydroxylating phenylalanine. Use the diagram to explain the meaning of *hydroxylating*.

.....

.....

(1)

(Total 7 marks)

19. Read the following passage.

During the course of a day, we come into contact with many poisonous substances. These include industrial and household chemicals. The skin acts as a barrier and prevents many of these substances entering and harming the body.

The skin is one of the largest organs in the body. It is composed of several layers of tissue. The outer layer consists of dead cells packed with keratins. Keratins are a group of proteins that differ from each other in their primary structure. Each keratin molecule consists of several polypeptide chains, each individual chain wound into a spiral or helix. The polypeptide chains include many sulphur-containing amino acids and these help to give the keratin molecules their characteristic strength.

Use information from the passage and your own knowledge to answer the questions.

(a) What is the evidence from the passage that keratin molecules have a quaternary structure?

.....

.....

(1)

(b) Explain how sulphur-containing amino acids help to give keratin molecules their characteristic strength (lines 8–9).

.....

.....

.....

.....

(2)

(c) Explain why differences in primary structure result in keratins with different properties (line 6).

.....

.....

.....

.....

(2)

(d) The skin prevents poisonous substances entering and harming the body (line 3). Explain why these substances are unable to pass through the outer layer of skin cells by active transport.

.....

.....

.....

.....

.....

.....

(3)

(e) Skin cells may be studied with a transmission electron microscope or an optical microscope. Explain the advantages and limitations of using a transmission electron microscope to study cells.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(6)
(Total 14 marks)

20. (a) Describe a biochemical test to find out if a substance contains a protein.

.....

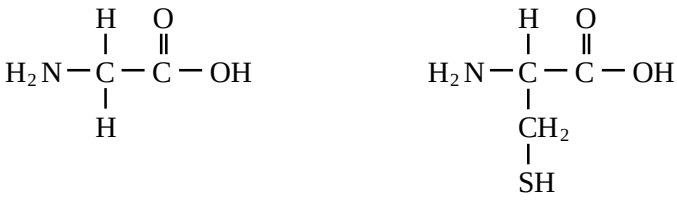
.....

.....

.....

(2)

(b) The diagram shows the structural formulae of two amino acids.



(i) Name **one** chemical element found in all amino acids, but **not** in monosaccharides.

.....

(1)

(ii) What type of chemical reaction occurs to form a dipeptide?

.....

(1)

(iii) Draw the structural formula of the dipeptide formed when these two amino acids combine.

(1)
(Total 5 marks)

21. A test for glucose relies on two enzyme-controlled reactions.

glucose + oxygen + water $\xrightarrow{\text{glucose oxidase}}$ gluconic acid + hydrogen peroxide

hydrogen peroxide + colourless substance $\xrightarrow{\text{peroxidase}}$ water + coloured substance

(a) Describe how you could use Benedict's reagent to test a urine sample for the presence of glucose.

.....

.....

.....

.....

(2)

(b) Suggest **two** reasons why a test for glucose in urine based on glucose oxidase and peroxidase might be preferred to one using Benedict's reagent.

1 .....

.....

2 .....

.....

(2)
(Total 4 marks)

22. Read the following passage.

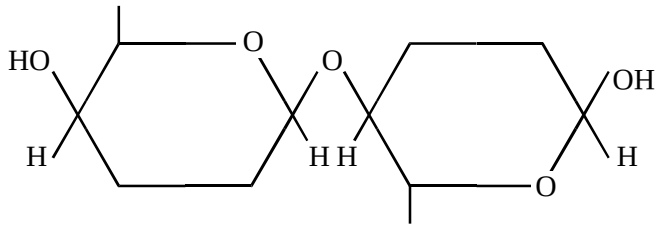
If you are lactose intolerant, drinking cow's milk will make you ill. This is the case for about half of the world's adult human population. These people lack an enzyme called lactase.

Lactase is a digestive enzyme normally found on the plasma membranes of epithelial cells in the small intestine. The enzyme hydrolyses lactose, the sugar found in milk, breaking it down to the two six-carbon sugars, galactose and β-glucose. These separate sugars are then absorbed from the intestine, a process which involves active transport.

In people who are lactose intolerant, lactose is not digested. Instead it stays in the intestine where it affects the water potential of the intestinal contents. This results in diarrhoea. Bacteria in the intestine ferment the lactose, producing carbon dioxide, methane and other gases. It is the build up of these gases which produce the other embarrassing symptoms of lactose intolerance - loud abdominal rumblings and lots of wind.

Use information from the passage and your own knowledge to answer the following questions.

(a) The diagram shows a lactose molecule.



(i) Use the diagram to explain why lactose is described as a disaccharide

.....

.....

(1)

(ii) On the diagram, draw a ring round the chemical bond which is hydrolysed by lactase

(1)

(iii) The molecular formula of galactose is $C_6H_{12}O_6$. What is the molecular formula of lactose

.....

(2)

(b) Galactose and glucose are absorbed by epithelial cells lining the small intestine but some other monosaccharides are not. Use your knowledge of active transport to explain this difference

.....

.....

.....

.....

(2)

(c) Diarrhoea involves the production of large amounts of watery faeces. Explain the link between the presence of lactose in the intestine and diarrhoea.

.....

.....

.....

.....

.....

.....

(3)

(d) The bacteria in the intestine are prokaryotic cells. The epithelial cells which line the small intestine are eukaryotic cells. Describe the ways in which prokaryotic cells and eukaryotic cells differ

.....

.....

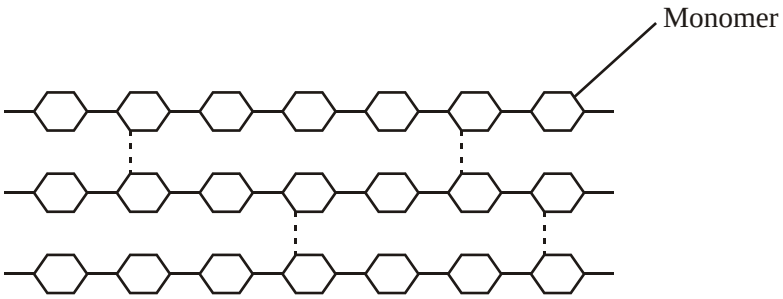
.....

.....

.....

(6)
(Total 15 marks)

23. Cellulose is made from one type of monomer. The monomers are held together by bonds. The diagram shows parts of three cellulose molecules in a cell wall.



(a) Name the monomer present in cellulose.

.....

(1)

(b) Name the type of reaction that converts cellulose to its monomers.

.....

(1)

(c) Cotton is a plant fibre used to make cloth. Explain how cellulose gives cotton its strength.

.....

.....

.....

.....

.....

.....

(3)

(Total 5 marks)