1.12 The Digestive System and Enzymes: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 The small intestine is lined with villi, which increase the efficiency of absorption of digested food molecules into the blood.

(a) State four features of villi that adapt them for efficient absorption. **(4)**

(Total for Question 1 is 4 marks)

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2 Table 2 shows the results of four food tests (iodine test, Benedict's test, Biuret test and emulsion test) carried out on four unknown food samples, W, X, Y and Z (required practical).

Sample	Iodine test	Benedict's test (after heating)	Biuret test	Emulsion test
W	turns blue-black	remains blue	remains blue	remains clear, no layer
X	remains browny-orange	forms a brick-red precipitate	remains blue	remains clear, no layer
Y	remains browny-orange	remains blue	turns purple/lilac	remains clear, no layer
Z	remains browny-orange	remains blue	remains blue	forms a cloudy white emulsion layer

(a) Identify which biological molecule is present in each of samples W, X, Y and Z. **(4)**

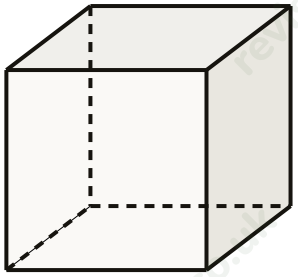
(b) State one safety precaution that should be taken when heating sample X with Benedict's solution, and explain why it is necessary. **(2)**

(Total for Question 2 is 6 marks)

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3 Bile emulsifies large lipid droplets into many smaller droplets. A student models a large lipid droplet as a cube of side length 8 mm.

Diagram NOT accurately drawn



(a) Calculate the volume of the large cube-shaped droplet. **(1)**

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(b) Bile breaks this large droplet into 8 smaller droplets of equal volume, also modelled as cubes. Calculate the side length of each smaller cube. **(2)**

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(c) Calculate the total surface area of the 8 smaller cubes, and compare this with the surface area of the original large cube. **(3)**

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(d) Use your answer to part (c) to explain why bile increases the rate of fat digestion by lipase. **(2)**

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(Total for Question 3 is 8 marks)

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4 A student measures the time taken for an amylase solution to break down starch using iodine. The student records the time taken at different temperatures and obtains these results:

Temperature 15°C: 220 s
Temperature 25°C: 130 s
Temperature 35°C: 80 s
Temperature 45°C: 240 s

Use the data to answer the following.

(a) State the temperature at which amylase activity appears to be highest. **(1)**

(b) Explain why the time increases again at 45°C. **(1)**

(Total for Question 4 is 2 marks)

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5 An experiment measures the initial rate of amylase by recording the time to decolourise iodine-starch. Two trials at 30°C give times 100 s and 105 s. At 40°C the times are 60 s and 58 s. Calculate the mean initial rate as 'starch decolourised per minute' for 30°C and 40°C. Show working.

(a) Calculate mean time for 30°C and convert to decolourisation events per minute (use 1 event per run). **(2)**

(b) Calculate mean time for 40°C and convert to decolourisation events per minute. **(2)**

(Total for Question 5 is 4 marks)

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6 A 1 m^2 section of small intestine wall lining, if it were completely flat and smooth, would have a surface area of 1 m^2. Folding of the wall into villi and microvilli increases the effective surface area of this section by a factor of 30.

(a) Calculate the effective surface area of this section of intestine wall after folding into villi and microvilli. **(1)**

.....

(b) For this mathematical model, assume a total folded surface area of 250 m^2. This is a model value, not an anatomical measurement. Using the factor of 30 given above, estimate the surface area of the model intestine wall if it were completely flat and unfolded. Give your answer to 2 significant figures. **(2)**

(Total for Question 6 is 3 marks)

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7 Aisha investigates how pH affects the rate of starch digestion by amylase (required practical), using a water bath at 35°C, amylase solution, starch solution, buffer solutions of different pH, a spotting tile and iodine solution.

(a) Describe a method Aisha could use to obtain reliable results for this investigation, and explain how she would use her results to determine the rate of reaction at each pH. **(6)**

(Total for Question 7 is 6 marks)

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8 Extended response (6 marks). A new enzyme called protease X is being tested for use in a laundry detergent to remove protein stains at 30°C. Describe and explain the scientific factors the manufacturer must consider when deciding whether protease X is suitable for the detergent. In your answer consider activity, stability and safety, and include any further tests you would recommend.

(Total for Question 8 is 6 marks)

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9 Higher tier only. Enzymes are proteins with a specific tertiary structure.

(a) Explain, using ideas about bonds within the enzyme molecule, how an extreme pH can cause an enzyme to lose its catalytic function, and why activity may not recover when the pH is returned to the optimum. **(4)**

(Total for Question 9 is 4 marks)

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10 Stretch question: The small intestine has many villi which increase surface area. A student estimates that flattening all villi would reduce the absorptive surface area by 60%. Explain quantitatively how such a reduction in surface area would affect the rate of absorption of a simple sugar, assuming diffusion is the only limiting factor. State any assumptions you make.

(a) Explain quantitatively how a 60% reduction in surface area affects diffusion rate, assuming rate α surface area and all else equal. **(3)**

(b) State one biological assumption made in this quantitative argument. **(1)**

(Total for Question 10 is 4 marks)

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Mark scheme · 1.12 The Digestive System and Enzymes: 1-hour Pack

Question 1

(a) one correct feature of villi, from: a large surface area, due to their finger-like shape and folding, increasing the rate of diffusion; a single layer of epithelial cells, giving a short diffusion distance/thin wall; a good (dense) blood supply/network of capillaries, which maintains a steep concentration gradient by carrying absorbed molecules away quickly; microvilli on the surface of the epithelial cells, further increasing the surface area; a lacteal, for the absorption of fatty acids and glycerol into the lymphatic system, oe **B1**

(a) a second, different correct feature from the same list **B1**

(a) a third, different correct feature from the same list **B1**

(a) a fourth, different correct feature from the same list (any four from the five features, max 4 marks; do not credit the same feature twice) **B1**

(a) Answer: Any four from: large surface area (finger-like shape/folding); single layer of cells (short diffusion distance); good blood supply (capillary network) maintaining a steep concentration gradient; microvilli further increasing surface area; a lacteal for absorbing fatty acids and glycerol.

Question 2

(a) W: starch **B1**

(a) X: reducing sugar (e.g. glucose) **B1**

(a) Y: protein **B1**

(a) Z: lipid (fat/oil) **B1**

(a) Answer: W: starch. X: reducing sugar. Y: protein. Z: lipid.

(b) one suitable precaution, such as heating in a water bath rather than directly over a flame, wearing safety goggles, using a test-tube holder, or pointing the tube away from people; accept any other valid precaution, oe **B1**

(b) a reason linked to the chosen precaution: a water bath heats gently and evenly, reducing spitting or cracking; goggles protect eyes from splashes; a holder prevents burns from hot glass; pointing the tube away prevents hot liquid hitting people; accept any valid linked reason, oe **B1**

(b) Answer: Heat in a water bath, not directly over a flame, because this heats the mixture gently and evenly, reducing the risk of the liquid spitting or the tube cracking.

Question 3

(a) 512 mm^3 cao **B1**

(a) Answer: 512 mm^3.

(b) volume of each small cube = 512 / 8 = 64 mm^3, ft from (a), oe **M1**

(b) 4 mm cao (side = cube root of 64) **A1**

(b) Answer: 4 mm.

(c) surface area of large cube = 6 * 8^2 = 384 mm^2, oe **M1**

(c) surface area of one small cube = 6 * 4^2 = 96 mm^2, total for 8 cubes = 8 * 96 = 768 mm^2, ft from (b), oe **M1**

(c) comparison: 768 mm^2 is double (2 times) the original 384 mm^2 cao (ft from their two surface areas) **A1**

(c) Answer: Total surface area of the 8 small cubes = 768 mm^2, which is double the original large cube's surface area of 384 mm^2.

(d) breaking the large droplet into many smaller droplets increases the total surface area of the lipid, without changing its total volume/mass, oe **B1**

(d) this gives lipase a much greater surface area to act on (more lipid molecules exposed at a surface), increasing the rate of fat digestion, oe **B1**

(d) Answer: Emulsification increases the total surface area of the lipid (without changing its total volume), giving lipase a greater surface area to act on and so increasing the rate of digestion.

Question 4

(a) 35°C (shortest time so highest rate) cao **B1**

(a) Answer: 35°C

(b) enzyme denaturation at higher temperature reduces activity, oe **B1**

(b) Answer: Because the enzyme is denatured at the higher temperature, reducing its activity.

Question 5

(a) correct mean time for 30 C = (100 + 105)/2 = 102.5 s and converts to per minute: 60 / 102.5 **M1**

(a) 0.585 events per minute (to 3 s.f.) cao **A1**

(a) Answer: 0.585 per minute

(b) mean time = (60 + 58)/2 = 59 s and rate = 60 / 59 **M1**

(b) 1.02 events per minute (to 3 s.f.) cao **A1**

(b) Answer: 1.02 per minute

Question 6

(a) 30 m^2 cao **B1**

(a) Answer: 30 m^2.

(b) 250 / 30, oe **M1**

(b) 8.3 m^2 awrt cao (2 s.f.) **A1**

(b) Answer: 8.3 m^2.

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Question 7

(a) set up a water bath at a constant temperature (e.g. 35°C) to control this variable **B1**

(a) mix a set volume of starch solution with a set volume of amylase solution and a chosen pH buffer solution, and start a timer immediately **B1**

(a) at regular time intervals (e.g. every 30 s), remove a drop of the reaction mixture and add it to a fresh well of iodine solution on the spotting tile **B1**

(a) continue sampling until the iodine solution no longer changes from browny-orange to blue-black, and record this time as the end-point **B1**

(a) repeat at each pH, keeping temperature, volumes and concentrations the same, and repeat each pH at least twice more to calculate a mean time and improve reliability **B1**

(a) calculate the rate of reaction at each pH using rate = 1 / time, and use these values to identify the pH giving the fastest rate (the optimum pH), oe **B1**

(a) Answer: Mix starch, amylase and a buffer at a controlled temperature; sample onto iodine at regular intervals until the colour no longer changes, recording the end-point time; repeat at each pH (repeating each pH for a mean); calculate rate = 1/time at each pH to find the optimum.

Question 8

Level 3 Detailed response that links multiple relevant factors: explains optimum activity at 30°C, pH range in detergents, stability to surfactants and oxidising agents, safety (allergenic potential), and recommends appropriate tests. Uses scientific reasoning and gives examples. **5-6**

Level 2 Clear response that describes some factors such as activity at 30°C and basic stability concerns, with some explanation and at least one recommended test. **3-4**

Level 1 Simple statements about activity or safety with little or no explanation; limited or no suggestions for tests. **1-2**

Indicative content:

- state that enzyme must be active at 30°C and explain how activity is measured (rate of stain removal at that temperature)
- consider pH of detergent and required pH range for activity; explain that many detergents are alkaline so enzyme must be active and stable at higher pH
- discuss stability to surfactants, oxidising agents (bleach) and high ionic strength; explain that protease may be inactivated by these components
- consider thermal stability during manufacturing and storage; explain importance of shelf life
- consider safety: potential for allergic reactions or degradation products; tests for toxicity and allergenicity
- recommend lab tests: activity assays at 30°C across pH range, stability tests with detergent ingredients, wash-cycle trials on stained fabrics, and safety testing

Question 9

(a) an extreme pH can disrupt bonds or interactions holding the tertiary structure (3D shape) together, such as ionic bonds or hydrogen bonds, oe **B1**

(a) this can change the shape of the active site so it is no longer complementary to the substrate, oe **B1**

(a) the enzyme may become denatured, so fewer or no enzyme-substrate complexes form and catalytic activity is reduced or lost; a small departure from optimum pH does not necessarily cause denaturation or zero activity, oe **B1**

(a) activity may not recover if the original bonds and tertiary structure do not reform when the pH is restored; pH effects are not always irreversible, oe **B1**

(a) Answer: An extreme pH can disrupt bonds holding the tertiary structure together and change the active site so the substrate no longer fits. This denaturation reduces or prevents enzyme-substrate complex formation. Activity may not recover if the original bonds and shape do not reform when the pH is restored. Smaller pH changes can reduce activity without denaturation, and their effects may be reversible.

Question 10

(a) states proportionality: rate is proportional to surface area (rate α area) **M1**

(a) calculates new area = 40% of original so rate becomes 0.40 x original **M1**

(a) concludes rate would be 40% of original (ie a 60% decrease) cao **A1**

(a) Answer: The absorption rate would fall to 40% of its former value (a 60% decrease), assuming diffusion rate is directly proportional to surface area.

(b) assumes diffusion is sole limiting factor and concentration gradient, diffusion distance and transporter density remain constant, oe **B1**

(b) Answer: Assumes diffusion is the only limiting factor and concentration gradient and diffusion distance stay the same.

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