1.1 Biological Molecules: 1-hour Pack

AQA 7402 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 The initial rate of an enzyme-catalysed reaction was measured at increasing substrate concentrations, with enzyme concentration and all other conditions kept constant. Results:
Substrate concentration (mmol dm^{-3}): 1, 2, 4, 8, 16, 32
Initial rate (arbitrary units): 5, 9, 15, 19, 20, 20

(a) Describe the relationship shown by the data between substrate concentration and initial rate of reaction. **(2)**

(b) Explain, in terms of enzyme action, why the rate of reaction reaches a maximum despite further increases in substrate concentration. **(3)**

(c) Calculate the percentage increase in rate of reaction between substrate concentration 2 mmol dm^{-3} and 4 mmol dm^{-3}. Show your working. **(3)**

(d) Predict, giving a reason, what would happen to the maximum (plateau) rate of reaction if the experiment were repeated with double the enzyme concentration, all other conditions unchanged. **(2)**

(Total for Question 1 is 10 marks)

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2 This question is about DNA structure and semi-conservative replication, investigated using density-gradient centrifugation. Bacteria were grown for many generations in a medium containing only the heavy nitrogen isotope 15N, so that all their DNA was 'heavy'. They were then transferred to a medium containing only the light isotope 14N and allowed to divide.

(a) State the number of hydrogen bonds that form between an adenine-thymine base pair, and between a cytosine-guanine base pair. **(2)**

(b) Explain what is meant by describing the two strands of the DNA double helix as antiparallel. **(1)**

(c) After one round of replication in the 14N medium, all the DNA formed a single band of intermediate ('hybrid') density on a density gradient. Using semi-conservative replication, explain why every DNA molecule after this first division is hybrid. **(2)**

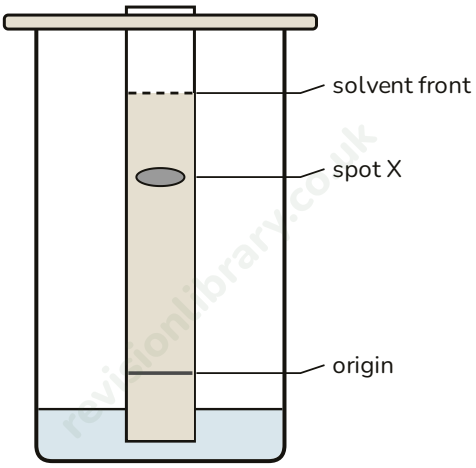
(d) The bacteria were allowed to divide for a second time in the 14N medium. If semi-conservative replication continues, calculate the fraction of the resulting DNA molecules that are hybrid density and the fraction that are light density. **(2)**

(e) Explain why this second-generation result is inconsistent with a conservative model of replication, in which the original double helix would remain completely intact. **(2)**

(Total for Question 2 is 9 marks)

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3 A student used paper chromatography to identify an unknown amino acid, X, present in a plant extract. The chromatogram was run in a single solvent, and the positions of the solvent front and of each spot were measured from the origin (the pencil line where samples were spotted). The solvent front had travelled 12.0 cm from the origin. Spot X had travelled 8.4 cm. Reference Rf values run under the same conditions were: leucine 0.73, valine 0.61, glycine 0.26.



(a) Calculate the Rf value of spot X. **(2)**

(b) Using the reference Rf values given, identify amino acid X and justify your choice. **(2)**

(c) Explain why the origin must be marked in pencil rather than pen. **(1)**

(d) Suggest one reason the Rf value obtained might differ from the literature value, and explain how the technique could be improved to reduce this source of error. **(2)**

(Total for Question 3 is 7 marks)

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4 Starch, glycogen and cellulose are all polysaccharides built from glucose monomers, but each has a structure suited to a different biological function. Discuss the relationship between the structure of starch (as amylose and amylopectin), glycogen and cellulose, and their functions in living organisms.

(Total for Question 4 is 6 marks)

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5 A student used a colorimeter to determine an unknown concentration of glucose using a calibration curve.

(a) A stock glucose solution has a concentration of 200 mmol dm^{-3}. The student needs to prepare 10 cm^3 of a 1 in 4 dilution of this stock. Calculate the volume of stock solution and the volume of distilled water required, and state the resulting glucose concentration. **(3)**

(b) The student's calibration line had the equation: absorbance = 0.004 x concentration (mmol dm^{-3}). Before measuring, the unknown sample was diluted 1 in 5 (since its absorbance was too high to read directly), and the diluted sample gave an absorbance reading of 0.52. Calculate the glucose concentration of the original (undiluted) unknown sample. **(3)**

(c) Explain why the student diluted the unknown sample before measuring its absorbance, and explain why extrapolating (reading a value beyond the range of) the calibration curve would reduce the validity of a result. **(3)**

(Total for Question 5 is 9 marks)

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6 The circular chromosome of a bacterium contains 4.6 x 10^6 base pairs. The average molar mass of one base pair (including the sugar-phosphate backbone on both strands) is 650 g/mol. Each base pair contributes a rise of 0.34 nm to the length of the double helix. Avogadro's constant is 6.02 x 10^{23} per mole.

(a) Calculate the molar mass of this bacterial chromosome, in g/mol, to 3 significant figures. **(2)**

(b) Calculate the mass, in grams, of a single molecule of this chromosome. Give your answer in standard form to 3 significant figures. **(2)**

(c) Calculate the total length of this DNA molecule in micrometres, giving your answer to 3 significant figures, and state how this compares with the length of a typical bacterial cell (about 2 micrometres). **(3)**

(d) Explain briefly why this DNA molecule must be highly supercoiled and packaged within the bacterial cell. **(1)**

(Total for Question 6 is 8 marks)

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Mark scheme · 1.1 Biological Molecules: 1-hour Pack

Question 1

(a) as substrate concentration increases from 1 to 16 mmol dm^{-3}, the initial rate of reaction increases (rapidly at first) oe **M1**

(a) above 16 mmol dm^{-3} (up to 32) the rate levels off/plateaus, becoming independent of further increases in substrate concentration oe **A1**

(a) Answer: Rate rises with substrate concentration then plateaus above about 16 mmol dm^{-3}.

(b) at low substrate concentration there are more free/unoccupied active sites than substrate molecules, so rate is limited by substrate availability oe **M1**

(b) as substrate concentration rises, a greater proportion of active sites become occupied by substrate at any moment, forming more enzyme-substrate complexes oe **M1**

(b) at high substrate concentration nearly all active sites are occupied (saturated) at any one time, so enzyme (not substrate) concentration becomes the limiting factor and rate cannot increase further oe **A1**

(b) Answer: Active sites become saturated with substrate, so enzyme concentration becomes limiting.

(c) increase in rate = 15 - 9 = 6 **M1**

(c) percentage increase = (6 / 9) x 100 **M1**

(c) = 66.7% awrt 66.7 (allow 67%) **A1**

(c) Answer: 66.7% (awrt).

(d) the maximum (plateau) rate would be higher than 20 (arbitrary units) **B1**

(d) because doubling enzyme concentration provides more active sites available at any one time, so a higher substrate concentration (and higher rate) is needed before all active sites become saturated oe **B1**

(d) Answer: Plateau rate would increase, since more active sites are available before saturation occurs.

Question 2

(a) adenine-thymine: 2 hydrogen bonds **B1**

(a) cytosine-guanine: 3 hydrogen bonds **B1**

(a) Answer: A-T: 2 hydrogen bonds. C-G: 3 hydrogen bonds.

(b) the two strands run in opposite directions, one 5 prime to 3 prime and the other 3 prime to 5 prime oe **B1**

(b) Answer: The two strands run in opposite directions (one 5 prime to 3 prime, the other 3 prime to 5 prime).

(c) each original heavy strand acts as a template and stays intact, pairing with a newly synthesised light (14N) strand oe **B1**

(c) so every daughter molecule contains one original heavy strand and one new light strand, giving intermediate density oe **B1**

(c) Answer: Each daughter DNA molecule keeps one original heavy (15N) strand paired with one newly made light (14N) strand, so every molecule has the same intermediate density.

(d) recognise that of the two strands in each hybrid molecule, only the original heavy strand is again conserved intact, so half of the 4 resulting duplexes are hybrid and half are light **M1**

(d) 1/2 (50%) hybrid and 1/2 (50%) light, cao **A1**

(d) Answer: 1/2 (50%) of the molecules are hybrid density and 1/2 (50%) are light density.

(e) a conservative model predicts only fully heavy and fully light bands would ever appear, with no hybrid band at any generation oe **B1**

(e) since a hybrid band is observed (at generation 1, and persisting at generation 2), the conservative model is disproved oe **B1**

(e) Answer: Conservative replication predicts only fully heavy and fully light DNA, never hybrid; because hybrid DNA is observed, the conservative model must be wrong.

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Question 3

(a) Rf = distance moved by spot / distance moved by solvent front = 8.4 / 12.0 **M1**

(a) Rf = 0.70, cao **A1**

(a) Answer: 0.70

(b) leucine **B1**

(b) because its Rf value (0.70, ecf from (a)) is closest to the reference Rf for leucine (0.73), compared with valine (0.61) or glycine (0.26) oe **B1**

(b) Answer: Leucine, because its measured Rf (0.70) is closest to the reference value for leucine (0.73).

(c) pencil marks are insoluble in the solvent so they do not run/dissolve into the chromatogram and interfere with the results, unlike ink oe **B1**

(c) Answer: Pencil is insoluble in the solvent, so it will not dissolve and run up the paper, unlike ink.

(d) a valid reason, e.g. the solvent front was not marked immediately (it evaporates, so the measured distance is too small), or temperature differed from the reference run, oe **B1**

(d) a valid improvement matched to the reason given, e.g. mark the solvent front as soon as the chromatogram is removed from the tank, or run the chromatogram in a sealed tank at constant temperature, oe **B1**

(d) Answer: For example, the solvent front may have partly evaporated before being marked, giving a smaller measured distance; marking the front immediately on removal from the tank (or using a sealed tank at constant temperature) would reduce this error.

Question 4

Level 3 A detailed and accurate account covering the structure and function of at least two of starch, glycogen and cellulose, with clear, logically linked explanations connecting structural features (e.g. branching, alpha/beta-glycosidic bonds, coiling, hydrogen bonding) to biological function (storage compactness, rapid hydrolysis, structural strength). Relevant scientific terminology is used accurately and consistently throughout. **5-6**

Level 2 A generally accurate account of the structure and function of the polysaccharides, but coverage may be less detailed, may focus mainly on one polysaccharide, or the links between structure and function are only partially explained. Scientific terminology is mostly appropriate with some minor inaccuracies. **3-4**

Level 1 Basic or isolated statements are made about the structure or the function of one or more polysaccharides, with little or no linkage made between structure and function. Limited use of scientific terminology. **1-2**

Level 0 No relevant content is provided. **0**

Indicative content:

- Starch is a mixture of amylose (unbranched chain of alpha-glucose joined by 1,4-glycosidic bonds, coiled/helical shape) and amylopectin (branched, with 1,4 and 1,6-glycosidic bonds).
- Amylose's coiled, compact shape makes it well suited to storage, taking up little space.
- Amylopectin's branching gives many terminal ends, allowing enzymes to hydrolyse it rapidly, releasing glucose quickly when energy is needed.
- Starch is large and insoluble, so it does not affect the water potential of the cell (osmotically inactive), unlike free glucose.
- Glycogen has a structure similar to amylopectin but is even more highly branched, giving more ends for even faster hydrolysis, suited to the higher metabolic/respiratory demand of animal cells.
- Glycogen is the main storage polysaccharide in animals (e.g. stored as granules in liver and muscle cells).
- Cellulose is made of beta-glucose monomers joined by 1,4-glycosidic bonds, with alternate glucose molecules rotated 180 degrees, producing long, straight, unbranched chains.
- Many hydrogen bonds cross-link adjacent parallel cellulose chains into bundles called microfibrils.
- Microfibrils are arranged in bundles/fibres within the plant cell wall, giving it high tensile strength, providing structural support and preventing the cell bursting under turgor pressure.

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Question 5

(a) volume of stock solution = 10 / 4 = 2.5 cm^3 **M1**

(a) volume of distilled water = 10 - 2.5 = 7.5 cm^3 **M1**

(a) resulting concentration = 200 / 4 = 50 mmol dm^{-3} cao **A1**

(a) Answer: 2.5 cm^3 stock + 7.5 cm^3 water; concentration = 50 mmol dm^{-3}.

(b) concentration of diluted sample = 0.52 / 0.004 **M1**

(b) = 130 mmol dm^{-3}, then multiply by the dilution factor of 5 to find the original concentration **M1**

(b) = 650 mmol dm^{-3} awrt 650 **A1**

(b) Answer: 650 mmol dm^{-3}.

(c) the undiluted sample's absorbance was too high/outside the range of the calibration standards to be measured accurately, so it was diluted to bring the reading within the calibrated range oe **M1**

(c) extrapolating the calibration curve assumes the same directly proportional relationship between absorbance and concentration continues beyond the highest standard tested oe **M1**

(c) but this relationship may not remain linear at higher concentrations (e.g. due to saturation of the colour reaction), so a concentration read from an extrapolated curve may be inaccurate/less valid oe **A1**

(c) Answer: Dilution keeps the reading within the calibrated range; extrapolation assumes the proportional relationship holds beyond tested values, which may not be valid.

Question 6

(a) correct substitution: 4.6 x 10^6 x 650 **M1**

(a) 2.99 x 10^9 g/mol, cao **A1**

(a) Answer: 2.99 x 10^9 g/mol

(b) mass of one molecule = molar mass / Avogadro's constant = 2.99 x 10^9 / 6.02 x 10^{23}, ft from (a) **M1**

(b) 4.97 x 10^{-15} g, cao **A1**

(b) Answer: 4.97 x 10^{-15} g

(c) length = 4.6 x 10^6 x 0.34 nm = 1.564 x 10^6 nm **M1**

(c) convert to micrometres: 1.56 x 10^3 micrometres (1560 micrometres), cao **A1**

(c) valid comparison, e.g. this is roughly 800 times longer than a 2 micrometre bacterial cell oe **B1**

(c) Answer: Approximately 1.56 x 10^3 micrometres (1560 micrometres), roughly 800 times the length of the bacterial cell itself.

(d) the DNA molecule is far longer than the cell itself, so it must be tightly coiled/supercoiled and looped (e.g. around associated proteins) to fit inside the small volume of the cell oe **B1**

(d) Answer: Because the DNA is hundreds of times longer than the cell, it must be tightly supercoiled and looped to fit within the cell's small volume.

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