B1cD Transport in and out of Cells: Exam Drill

AQA 8464 · Calculator allowed · about 90 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Diffusion is the passive movement of particles from an area of higher concentration to an area of lower concentration.

(a) State the name of the process described above. **(1)**

(Total for Question 1 is 1 mark)

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2 A student places two pieces of potato tissue of equal mass into two beakers. Beaker A contains pure water. Beaker B contains a 0.5 mol per litre sugar solution. Both are left for 30 minutes at room temperature.

(a) Predict what will happen to the mass of the potato in Beaker A and give a brief reason. **(1)**

(b) Predict what will happen to the mass of the potato in Beaker B and give a brief reason. **(1)**

(Total for Question 2 is 2 marks)

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3 Explain how active transport in root hair cells differs from diffusion, and give one biological example of active transport in plants.

(a) Explain one difference between active transport and diffusion. **(2)**

(b) Give one example of active transport in plants. **(1)**

(Total for Question 3 is 3 marks)

4 A student investigates the effect of surface area to volume ratio on diffusion using cubes of agar jelly containing a pH indicator. Cubes of side 1.0 cm and 3.0 cm are placed in dilute acid. After a fixed time the outer 1.0 mm layer of each cube has changed colour. Assume cubes are perfect and only the outer 1.0 mm layer changes colour in the fixed time.

(a) Calculate the surface area to volume ratio (surface area : volume) of the 1.0 cm cube. Give your answer as a ratio in simplest whole numbers. **(2)**

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(b) Calculate the surface area to volume ratio of the 3.0 cm cube and state which cube would show a faster relative change due to diffusion and why. **(2)**

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(Total for Question 4 is 4 marks)

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5 A student measures water uptake by a leafy shoot in a simple potometer. The apparatus records that 0.60 cm^3 of water is taken up in 15 minutes. Use density of water = 1.00 g per cm^3.

(a) Calculate the mass of water taken up in 15 minutes. **(1)**

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(b) Calculate the rate of water uptake in cm^3 per minute. **(2)**

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(c) Suggest one source of experimental error in this potometer measurement and one improvement the student could make. **(1)**

(Total for Question 5 is 4 marks)

6 Required practical style: A student tests the effect of sucrose concentration on the mass change of potato cylinders. They prepare sucrose solutions of concentrations 0.0 mol per litre, 0.2 mol per litre, 0.4 mol per litre and 0.8 mol per litre. Cylinders of equal length and diameter are placed in each solution for 40 minutes and then reweighed. Outline a control variable the student must keep and explain why, then state one improvement to increase the reliability of the results.

(a) Give one control variable the student must keep the same and explain why it must be controlled. **(2)**

(b) State one improvement to increase the reliability of the results. **(1)**

(c) Give one safety precaution the student should follow when preparing and handling the solutions. **(1)**

(Total for Question 6 is 4 marks)

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7 Levels question (6 marks). The kidney filters blood and then returns useful substances to the blood and removes waste substances into the urine. Explain how diffusion, osmosis and active transport are involved in the processes that occur in the nephron. You should make clear how each process contributes to reabsorption or filtration.

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(Total for Question 7 is 6 marks)

8 Data analysis: A student measures percentage mass change of potato cylinders after 40 minutes in different sucrose concentrations. The recorded mean percentage mass changes are: 0.0 mol per litre -> +12.0%; 0.1 mol per litre -> +6.0%; 0.2 mol per litre -> +1.0%; 0.4 mol per litre -> -8.0%; 0.6 mol per litre -> -14.0%.

(a) Plotting these points would show a line crossing the x axis where percentage change is zero. Estimate the approximate sucrose concentration of the solution that is isotonic with the potato cells (percentage change = 0%). Explain how you made your estimate. **(3)**

(b) State one limitation of using mean percentage mass change and one way to improve the experimental design to reduce the effect of that limitation. **(3)**

(Total for Question 8 is 6 marks)

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9 Error analysis: In the sucrose experiment a student reports a mean percentage change of +1.0% at 0.2 mol per litre. On inspecting raw data they find one replicate was recorded as +10.0% due to forgetting to blot excess solution from the cylinder before reweighing. Explain how this error affects the mean and suggest how the student should treat the outlier in their analysis.

(a) Explain the likely effect of the +10.0% erroneous replicate on the mean percentage change. **(3)**

(b) Suggest how the student should treat this outlier when reporting their results and justify your suggestion. **(3)**

(Total for Question 9 is 6 marks)

10 A model cell has an internal sodium ion concentration of 120 mmol per litre and the external solution has 30 mmol per litre. Transport proteins pump sodium ions out of the cell at a rate of 2.0×10^{-6} mol per minute. Calculate the number of moles of sodium in the internal volume of the cell if the internal volume is 0.50 microlitres. Use 1 microlitre = 1.00×10^{-6} litres.

(a) Calculate the number of moles of sodium ions inside the cell. **(3)**

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(b) If sodium ions are being pumped out at 2.0×10^{-6} mol per minute, how many minutes would it take to pump out an amount of sodium equal to the internal amount you just calculated? State whether this pumping rate is realistic relative to the internal amount and explain briefly. **(3)**

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(Total for Question 10 is 6 marks)

11 Exam-style multi-part: The plasma membrane of a cell is selectively permeable. Fick's law states that the rate of diffusion across a membrane can be estimated using: rate of diffusion = (surface area x concentration difference) / thickness of membrane. A cell has a section of membrane with surface area 4.0 mm^2, a concentration difference of glucose across it of 8.0 arbitrary concentration units, and a thickness of 2.0 micrometres.

(a) Use Fick's law to calculate the initial rate of diffusion. Show your substitution. **(2)**

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(b) The cell then increases the surface area of this section of membrane to 12.0 mm^2 (a threefold increase) and the membrane becomes thinner, decreasing to 1.0 micrometre (half as thick), while the concentration difference stays the same. Calculate the new rate of diffusion, and state the factor by which the rate has increased compared with part (a). **(4)**

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(c) Using Fick's law, explain why both increasing the surface area and decreasing the membrane thickness increase the rate of diffusion. **(2)**

(Total for Question 11 is 8 marks)

12 Extended answer 10 marks. Evaluate the statement: "Cells maintain water balance primarily by osmosis alone." In your answer consider the roles of membrane structure, transport proteins, active transport and hormonal control where relevant. Use evidence and reasoning to support your conclusion.

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(Total for Question 12 is 10 marks)

Mark scheme · B1cD Transport in and out of Cells: Exam Drill

Question 1

- (a) **B1** diffusion cao
- **(a) Answer: Diffusion.**

Question 2

- (a) **B1** mass increases because water moves into the cells by osmosis (water potential higher outside than inside) oe
- **(a) Answer: Mass increases because water enters the potato cells by osmosis.**
- (b) **B1** mass decreases because water moves out of the cells by osmosis (water potential lower outside than inside) oe
- **(b) Answer: Mass decreases because water leaves the potato cells by osmosis.**

Question 3

- (a) **M1** states that active transport uses metabolic energy (ATP) whereas diffusion does not (passive)
- (a) **A1** explains consequence: active transport can move ions against a concentration gradient, diffusion moves substances down a concentration gradient cao
- **(a) Answer: Active transport uses energy (ATP) to move substances, allowing movement against a concentration gradient, whereas diffusion is passive and only moves substances down a concentration gradient.**
- (b) **B1** absorption of mineral ions by root hair cells cao
- **(b) Answer: Absorption of mineral ions by root hair cells.**

Question 4

- (a) **M1** calculates surface area = 6 x 1.0^2 = 6.0 cm^2 and volume = 1.0^3 = 1.0 cm^3 or equivalent
- (a) **A1** gives ratio 6:1 = 6:1 cao
- **(a) Answer: 6:1**
- (b) **M1** calculates surface area = 6 x 3.0^2 = 54.0 cm^2 and volume = 3.0^3 = 27.0 cm^3 giving ratio 54:27 = 2:1
- (b) **A1** states the 1.0 cm cube changes faster because it has the larger surface area to volume ratio (6:1 vs 2:1) cao
- **(b) Answer: 2:1; the 1.0 cm cube changes faster because it has the larger surface area to volume ratio (6:1 vs 2:1).**

Question 5

- (a) **B1** 0.60 g (since density 1.00 g per cm^3 so mass = volume x density)
- **(a) Answer: 0.60 g**
- (b) **M1** substitutes and calculates rate = 0.60 cm^3 / 15 min
- (b) **A1** gives 0.040 cm^3 per minute cao
- **(b) Answer: 0.040 cm^3 per minute**
- (c) **B1** one valid error and improvement: e.g. error - temperature change affecting transpiration; improvement - carry out at constant temperature or use a temperature-controlled room, oe
- **(c) Answer: Error: room temperature changed, affecting transpiration. Improvement: repeat experiment at a controlled temperature or use a water bath to keep conditions constant.**

Question 6

- (a) **M1** identifies a valid control variable e.g. length or diameter of potato cylinders, temperature, or time in solution
- (a) **A1** explains why: to ensure mass change is only due to sucrose concentration differences, not size or temperature effects cao
- **(a) Answer: Control variable: temperature (or cylinder size). This must be controlled so that differences in mass change are due to sucrose concentration and not to differences in diffusion rate caused by temperature or surface area.**
- (b) **B1** use replicates and calculate a mean, oe
- **(b) Answer: Use at least three replicates for each concentration and calculate the mean mass change.**
- (c) **B1** wear goggles and gloves when handling solutions to avoid eye or skin contact, or clean up spills immediately, oe
- **(c) Answer: Wear safety goggles and gloves when preparing and handling the sucrose solutions.**

Question 7

- **Level 3** (5-6): Detailed explanation. Candidate explains how diffusion, osmosis and active transport each operate in the nephron, links these processes to reabsorption or filtration, and uses appropriate biological terms accurately.
- **Level 2** (3-4): Developed explanation. Candidate describes two of the processes with some link to nephron function, or gives a basic explanation of all three with limited detail.
- **Level 1** (1-2): Simple statements. Candidate gives one or two relevant facts about the processes but with little or no linkage to how they act in the nephron.
- **Indicative content:**
  - Filtration at the glomerulus: blood pressure forces water and small solutes out of capillaries into Bowman's capsule; large proteins and blood cells remain in blood.
  - Diffusion: small molecules such as urea and some ions move by diffusion down concentration gradients across nephron membranes contributing to selective reabsorption or waste movement.
  - Osmosis: water is reabsorbed from the filtrate into blood in the loop of Henle and collecting duct where differences in solute concentration create osmotic gradients; antidiuretic hormone alters permeability.
  - Active transport: useful substances such as glucose and amino acids are moved from the filtrate back into epithelial cells and then into blood using carrier proteins and ATP, allowing reabsorption against a concentration gradient.
  - How each contributes: filtration produces the filtrate; diffusion and active transport move solutes between filtrate and blood; osmosis moves water following solute reabsorption, concentrating urine.

Question 8

- (a) **M1** identifies two points to interpolate across the zero crossing e.g. between 0.1 mol per litre (+6.0%) and 0.2 mol per litre (+1.0%) or between 0.2 and 0.4 accounting sign change
- (a) **M1** performs linear interpolation or describes method
- (a) **A1** gives approximate isotonic concentration 0.22 mol per litre (or 0.20 to 0.24 mol per litre) with explanation
- **(a) Answer: Approximately 0.22 mol per litre (about 0.20 to 0.24 mol per litre). Estimated by linear interpolation between 0.2 mol per litre (+1.0%) and 0.4 mol per litre (-8.0%), or between 0.1 and 0.2 and finding where percentage change crosses zero.**
- (b) **M1** states limitation: variation between biological samples or measurement precision affecting means, oe
- (b) **M1** gives improvement: use more replicates and report standard deviation or error bars
- (b) **A1** links improvement to limitation: more replicates reduces random variation and gives a more reliable mean
- **(b) Answer: Limitation: biological variation between potato cylinders affects the mean. Improvement: use more replicates and calculate standard deviation or error bars so the mean is more reliable.**

Question 9

- (a) **M1** states that the outlier increases the mean above the true central value
- (a) **M1** explains why: outlier is much larger so it biases the mean upward
- (a) **A1** may quantify effect if candidate calculates new mean without outlier or describes magnitude qualitatively cao
- **(a) Answer: The +10.0% replicate will raise the mean above the true value, biasing the result upward because the outlier is much larger than the other replicates.**
- (b) **M1** suggests either discard the outlier after justification or keep it but report median and explain anomaly
- (b) **M1** justifies with reason: e.g. outlier due to procedural error (not blotting) so not representative
- (b) **A1** adds recommendation to repeat the replicate or increase sample number to check consistency
- **(b) Answer: The student should justify excluding the outlier because it is due to a known procedural error (not blotting). They should repeat the measurement or increase replicates and report the mean both with and without the outlier or report the median to show the effect.**

Question 10

- (a) **M1** converts concentration to mol per litre: 120 mmol per litre = 0.120 mol per litre
- (a) **M1** converts volume: 0.50 microlitres = 0.50 x 10^{-6} L = 5.0 x 10^{-7} L and multiplies: moles = 0.120 x 5.0 x 10^{-7}
- (a) **A1** gives final value 6.0 x 10^{-8} mol cao
- **(a) Answer: 6.0 x 10^{-8} mol**
- (b) **M1** divides: time = 6.0 x 10^{-8} mol / 2.0 x 10^{-6} mol per min
- (b) **M1** calculates time = 0.03 min (or 1.8 seconds) shown
- (b) **A1** comments that this is unrealistically fast compared to typical biological pumping rates or notes that such a high pump rate would rapidly deplete ions, so either pump rate or volume is unrealistic
- **(b) Answer: 0.03 minutes (1.8 seconds); this is unrealistically fast for biological pumping over whole cells and suggests the given pump rate is not realistic for this small internal amount.**

Question 11

- (a) **M1** substitutes into rate = (surface area x concentration difference) / thickness = (4.0 x 8.0) / 2.0
- (a) **A1** 16 (arbitrary units) cao
- **(a) Answer: 16 arbitrary units**
- (b) **M1** substitutes new values into rate = (12.0 x 8.0) / 1.0
- (b) **M1** evaluates numerator 12.0 x 8.0 = 96
- (b) **A1** new rate = 96 (arbitrary units) cao
- (b) **A1** states the rate has increased by a factor of 6 (96 / 16 = 6) cao
- **(b) Answer: New rate = 96 (arbitrary units), which is 6 times the rate found in part (a).**
- (c) **P1** rate of diffusion is directly proportional to surface area, so a larger surface area allows more particles to cross the membrane per second
- (c) **C1** rate of diffusion is inversely proportional to membrane thickness, so a thinner membrane gives a shorter diffusion distance/pathway, so particles cross faster
- **(c) Answer: Rate of diffusion is directly proportional to surface area, so a bigger surface area lets more particles cross per second. Rate of diffusion is inversely proportional to thickness, so a thinner membrane means a shorter diffusion distance, so diffusion happens faster.**

Question 12

- **Level 3** (8-10): Comprehensive evaluation. Candidate considers multiple mechanisms (osmosis, membrane structure, transport proteins, active transport, hormonal regulation), weighs evidence for and against the statement, and reaches a justified conclusion supported by biological reasoning.
- **Level 2** (4-7): Balanced discussion. Candidate describes several relevant mechanisms and provides some evaluation but lacks full breadth or depth of reasoning and conclusion is partially supported.
- **Level 1** (1-3): Limited statements. Candidate gives simple facts about osmosis or mentions one other mechanism with little or no evaluation or conclusion.
- **Indicative content:**
  - For the statement: osmosis is a major passive mechanism moving water across membranes following solute gradients; membrane permeability to water (aquaporins) and solute concentrations determine net water movement.
  - Against the statement: membrane structure and transport proteins (aquaporins) regulate water flow; active transport of solutes changes osmotic gradients so active transport indirectly controls water balance; hormonal control such as antidiuretic hormone alters aquaporin insertion in membranes affecting water reabsorption in kidneys; cell walls in plants and turgor pressure resist water influx so osmosis alone does not determine balance.
  - Consider evidence: examples from kidney nephron where active transport of Na+ creates osmotic gradients leading to water reabsorption; in plant cells cell wall and vacuole volume limit water uptake; experimental controls that show water movement depends on solute transport.
  - Conclusion should weigh whether osmosis is the primary direct mechanism but often regulated and controlled by other processes so the statement is an oversimplification; provide a supported judgement.