C2bD Structures, Properties and Nanoparticles: Exam Drill

AQA 8464 · Calculator allowed · about 95 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 Give two properties of ionic compounds that distinguish them from simple covalent molecules.

(a) Property 1 **(1)**

(b) Property 2 **(1)**

(Total for Question 1 is 2 marks)

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2 A piece of copper metal and a sample of silicon (a giant covalent solid) are compared.

(a) State which of the two is a better electrical conductor and give one reason. **(2)**

(b) State one physical property of silicon that is a result of its giant covalent structure. **(1)**

(Total for Question 2 is 3 marks)

3 Nanoparticles of silver are being considered for use as an antibacterial coating. A student is given two samples: sample A contains 1.5×10^{18} particles and sample B contains 1.5×10^{11} particles. Both samples contain the same total mass of silver.

(a) Explain which sample has the greater total surface area and why. **(2)**

(b) State one reason why a greater total surface area can make silver nanoparticles better antibacterial agents. **(1)**

(Total for Question 3 is 3 marks)

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4 Calculate the surface area to volume ratio (SA:V) of a spherical nanoparticle of diameter 8.0 nm. Use formulas: surface area = $4 \pi r^2$, volume = $4/3 \pi r^3$. Give the ratio in nm^{-1}, to 2 significant figures.

(a) Show the substitution into the formulas using radius in nm. **(2)**

(b) Calculate the numerical SA:V and give the final answer to 2 significant figures. **(2)**

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(Total for Question 4 is 4 marks)

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5 Describe the electrical conductivity of a solid ionic lattice and explain what happens to the ions when the compound is melted.

(a) Describe the conductivity of the solid ionic lattice. **(1)**

(b) Explain what happens when the ionic solid is melted and why it then conducts. **(2)**

(Total for Question 5 is 3 marks)

6 A student is investigating how particle size affects the rate of a reaction using powdered zinc and zinc lumps reacting with excess hydrochloric acid. The student records the time taken for hydrogen gas to stop being produced. The results are: powdered zinc average time 45 s; lump zinc average time 320 s.

(a) State why the powdered zinc reacts faster than the lumps. **(2)**

(b) Suggest one improvement to the method to make the comparison fairer between powder and lumps. **(2)**

(Total for Question 6 is 4 marks)

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7 Give the structure name for each of the following substances and state whether they are solids that conduct electricity when solid.
Substances: A sodium chloride, B diamond, C graphite.

(a) Sodium chloride: structure and conductivity as a solid? **(1)**

(b) Diamond: structure and conductivity as a solid? **(1)**

(c) Graphite: structure and conductivity as a solid? **(1)**

(Total for Question 7 is 3 marks)

8 A chemist measures the melting points of three compounds and obtains: compound X 801 degrees C, compound Y 134 degrees C, compound Z -10 degrees C. Use these data to identify the likely type of bonding for each compound and give a brief reason in each case.

(a) Compound X: type of bonding and reason. **(1)**

(b) Compound Y: type of bonding and reason. **(1)**

(c) Compound Z: type of bonding and reason. **(2)**

(Total for Question 8 is 4 marks)

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9 Fullerenes are forms of carbon with cage-like structures. State one potential use of fullerenes and explain briefly why their structure makes this use possible.

(a) Give one potential use. **(1)**

(b) Explain briefly how the cage-like structure helps in this use. **(2)**

(Total for Question 9 is 3 marks)

10 Glass is an amorphous solid formed from silica and other oxides. A student heats a sample and observes it softens gradually rather than having a sharp melting point. Which type of solid is glass: giant covalent, simple molecular, ionic, metallic or amorphous? Explain your choice referring to structure.

(a) Identify the type. **(1)**

(b) Explain why it softens gradually rather than having a sharp melting point, referring to structure. **(3)**

(Total for Question 10 is 4 marks)

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11 State what is meant by the term 'allotrope' and give one example of allotropy in carbon.

(a) Definition of allotrope. **(1)**

(b) Example in carbon. **(1)**

(Total for Question 11 is 2 marks)

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12 A sample of nanoparticles is used as a catalyst. Explain, using the concept of surface area to volume ratio, why nanoparticles can be more effective catalysts than the same material in bulk form.

(a) Explain why nanoparticles can be more effective catalysts. **(3)**

(Total for Question 12 is 3 marks)

13 A student makes 0.250 mol of a substance that crystallises as tiny particles. The student prepares a suspension of the substance by dissolving the crystals in 500 cm3 of water. Calculate the concentration in mol per litre (mol dm^{-3}) of the suspension.

(a) Show the conversion of volume to dm3 and substitution into concentration = moles / volume. **(2)**

(b) Give the final concentration with units. **(2)**

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(Total for Question 13 is 4 marks)

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14 Required practical style question: A student investigates how the amount of product formed in reaction between calcium carbonate and hydrochloric acid depends on the surface area of the calcium carbonate. Calcium carbonate chips are broken into three size ranges: large chips, small chips and powdered. The student uses the same mass of calcium carbonate and same concentration and volume of acid for each test and measures the volume of carbon dioxide produced every 30 seconds until production stops. The student finds the powdered sample produces the greatest total volume of CO2 and does so fastest. Using the data summary below, evaluate the student's conclusion and suggest two improvements to the experimental design.

Data summary (results):
Powder: total CO2 125 cm3; reaction finished in 60 s.
Small chips: total CO2 118 cm3; reaction finished in 220 s.
Large chips: total CO2 116 cm3; reaction finished in 360 s.

(Total for Question 14 is 6 marks)

15 A metal sample has a density of 8.96 g cm^{-3} and a volume of 12.5 cm3. Calculate the mass of the sample in grams. Show substitution and give the answer to three significant figures.

(a) Show the substitution into mass = density x volume. **(2)**

(b) Give the final answer to three significant figures with units. **(2)**

(Total for Question 15 is 4 marks)

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16 Explain why metals generally have high melting points and are malleable, making reference to structure and bonding.

(a) Explain high melting points. **(1)**

(b) Explain malleability. **(2)**

(Total for Question 16 is 3 marks)

Mark scheme · C2bD Structures, Properties and Nanoparticles: Exam Drill

Question 1

- (a) **B1** high melting or boiling point (strong ionic lattice with strong electrostatic attraction) cao
- **(a) Answer: High melting or boiling point**
- (b) **B1** conducts electricity when molten or dissolved (ions are mobile) cao
- **(b) Answer: Conducts electricity when molten or dissolved**

Question 2

- (a) **B1** copper is the better conductor
- (a) **B1** because copper has delocalised electrons that can move and carry charge (silicon does not have free electrons in the same way) oe
- **(a) Answer: Copper, because it has delocalised electrons that move and carry charge.**
- (b) **B1** very high melting point (strong covalent bonds throughout the giant lattice) cao
- **(b) Answer: Very high melting point**

Question 3

- (a) **B1** sample A (1.5×10^{18} particles) has more particles
- (a) **B1** more particles means greater total surface area for the same mass, so sample A has the greater total surface area oe
- **(a) Answer: Sample A, because it has far more particles so the combined surface area is greater for the same mass.**
- (b) **B1** greater total surface area increases contact with bacteria, increasing reaction or ion release rate, causing more antibacterial activity, oe
- **(b) Answer: Greater surface area increases contact with bacteria, so more silver ions or reactive surface area affect bacteria.**

Question 4

- (a) **M1** correct substitution: r = 4.0 nm so $SA = 4 \pi (4.0)^2$ and $V = 4/3 \pi (4.0)^3$
- (a) **M1** cancelling π and showing ratio $SA/V = (4 \pi r^2) / (4/3 \pi r^3) = 3/r$
- (b) **M1** calculates 3 / 4.0 = 0.75
- (b) **A1** 0.75 nm^{-1} cao
- **(b) Answer: 0.75 nm^{-1}**

Question 5

- (a) **B1** solid ionic lattice does not conduct electricity (ions fixed in place) cao
- **(a) Answer: A solid ionic lattice does not conduct electricity because the ions are fixed in place.**
- (b) **B1** on melting, ions are free to move (ions become mobile) or ions dissociate in molten state
- (b) **B1** mobile ions carry charge so the molten ionic liquid conducts electricity cao
- **(b) Answer: On melting the ions become mobile and can move; these mobile ions carry charge so the molten compound conducts electricity.**

Question 6

- (a) **B1** powder has larger total surface area exposed to acid per unit mass
- (a) **B1** more frequent collisions between acid particles and zinc surface increases reaction rate, oe
- **(a) Answer: Powdered zinc has a much larger total surface area for the same mass so there are more frequent collisions with acid, increasing the reaction rate.**
- (b) **B1** use the same mass of zinc in both tests, or same concentration and volume of acid, or control temperature
- (b) **B1** ensure the same stirring or mixing so results are comparable, oe
- **(b) Answer: Use the same mass of zinc and the same concentration and volume of acid, and keep temperature and stirring the same.**

Question 7

- (a) **B1** giant ionic lattice; does not conduct as a solid (ions fixed)
- **(a) Answer: Giant ionic lattice; does not conduct as a solid**
- (b) **B1** giant covalent lattice; does not conduct as a solid (all electrons are used in bonds)
- **(b) Answer: Giant covalent lattice; does not conduct as a solid**
- (c) **B1** layered covalent structure; conducts as a solid (delocalised electrons between layers) cao
- **(c) Answer: Layered covalent structure; conducts as a solid**

Question 8

- (a) **B1** giant covalent (e.g. network) because very high melting point
- **(a) Answer: Giant covalent; very high melting point indicates strong covalent bonds throughout lattice.**
- (b) **B1** ionic or metallic possible; moderately high melting point suggests strong ionic or metallic bonding
- **(b) Answer: Ionic or metallic; moderately high melting point suggests strong electrostatic or metallic bonding between particles.**
- (c) **B1** simple molecular
- (c) **B1** low melting point indicates weak intermolecular forces between molecules cao
- **(c) Answer: Simple molecular; low melting point because only weak intermolecular forces need to be overcome.**

Question 9

- (a) **B1** drug delivery, lubricants, catalysts or in electronics (any one)
- **(a) Answer: Drug delivery**
- (b) **B1** cage can trap or carry small molecules or atoms inside, allowing encapsulation or controlled release
- (b) **B1** large surface area and stability allow interactions useful in catalysis or electronics, oe
- **(b) Answer: The cage can trap or carry small molecules inside, enabling encapsulation and controlled release; fullerenes also have large surface areas useful for catalysis or electronic interactions.**

Question 10

- (a) **B1** amorphous solid
- **(a) Answer: Amorphous solid**
- (b) **B1** structure lacks long-range regular order (no regular lattice)
- (b) **B1** different regions require different energies to move so softening occurs over a range of temperatures
- (b) **B1** not a giant covalent crystalline lattice with one sharp melting point, oe
- **(b) Answer: Glass is amorphous, lacking long-range order; different parts of the structure require different energies to move so it softens gradually over a range of temperatures rather than melting at a sharp point.**

Question 11

- (a) **B1** different forms of the same element with different structures and properties cao
- **(a) Answer: Different forms of the same element with different structures and properties.**
- (b) **B1** diamond, graphite, graphene or fullerenes (any one)
- **(b) Answer: Diamond**

Question 12

- (a) **B1** nanoparticles have a much larger surface area to volume ratio than bulk material
- (a) **B1** more surface area provides more active sites for reactant molecules to adsorb
- (a) **B1** so rate increases and less material is needed to achieve the same catalytic effect, oe
- **(a) Answer: Nanoparticles have a much larger surface area to volume ratio than bulk material, giving more active sites for reactants to adsorb, increasing reaction rate and making them more effective catalysts.**

Question 13

- (a) **M1** converts 500 cm3 to 0.500 dm3 and substitutes: concentration = 0.250 / 0.500
- (a) **M1** evaluates the division to reach the numeric value
- (b) **M1** calculates 0.250 / 0.500 = 0.50
- (b) **A1** 0.50 mol dm^{-3} cao
- **(b) Answer: 0.50 mol dm^{-3}**

Question 14

- **Level 3** (5-6): Detailed evaluation: correctly assesses the validity of the student's conclusion using the data, refers to both rate and total yield differences, recognises possible sources of systematic or random error, and gives two valid, practical improvements with justification.
- **Level 2** (3-4): Some evaluation: makes correct points about rate differences and notices small differences in total CO2; suggests one reasonable improvement or two basic improvements without full justification.
- **Level 1** (1-2): Limited evaluation: repeats the conclusion or notes one simple observation from the data with little or no justification and no practical improvements.
- **Indicative content:**
  - The student's conclusion that powdered sample reacts fastest is supported by times: 60 s vs 220 s and 360 s, showing a clear rate increase.
  - Total CO2 values are similar (125, 118, 116 cm3) so the powder giving slightly more product could be due to measurement error rather than true increase in yield; the difference between 116 and 125 cm3 is small and may not be significant.
  - Possible sources of error: not all CO2 collected due to leakage, measuring cylinder accuracy, timing resolution, incomplete reaction for larger chips if surface inside chips not exposed, or loss of acid concentration.
  - Improvements: use gas syringe with finer resolution to reduce measurement error; ensure apparatus is gas-tight (use stoppered flask and tubing) and repeat trials to calculate mean and standard deviation; dry and weigh remaining solid to check mass change; crush chips to measure particle size distribution rather than nominal categories; control temperature and stir the mixture for consistent mixing.

Question 15

- (a) **M1** substitutes: mass = 8.96 x 12.5
- (a) **M1** evaluates the product to get a numerical value
- (b) **M1** correct rounding or presentation to three significant figures
- (b) **A1** 112 g cao
- **(b) Answer: 112 g**

Question 16

- (a) **B1** strong metallic bonds between positive ions and delocalised electrons require a lot of energy to overcome
- **(a) Answer: Strong metallic bonds between positive ions and delocalised electrons require a lot of energy to break, giving high melting points.**
- (b) **B1** metal ions are in layers that can slide over each other
- (b) **B1** delocalised electrons maintain bonding when layers slide so the metal does not shatter, oe
- **(b) Answer: Metal ions are arranged in layers that can slide over each other while delocalised electrons continue to hold the lattice together, so the metal is malleable.**