2.19 Structures, Properties and Nanoparticles: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Priya carries out a practical investigation into four unlabelled solid substances, A, B, C and D, in order to classify the type of structure and bonding in each. For each substance she tests its melting point, and whether it conducts electricity as a solid and (separately) once it has been melted.

Table 1

Substance	Melting point	Conducts as a solid?	Conducts when molten?
A	High	No	Yes
B	High	No	No
C	Low	No	No
D	High	Yes	Yes

(a) Describe how Priya could safely test whether a solid substance conducts electricity. **(2)**

(b) Priya then needs to melt each solid to test whether it conducts electricity as a liquid. Suggest one safety precaution she should take when heating a solid until it melts. **(1)**

(c) State one variable that Priya should control to make her comparison of melting points a fair test. **(1)**

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(d) Using the results in Table 1, identify the most likely type of structure and bonding for each of substances A, B, C and D. **(4)**

(e) Explain why substance A only conducts electricity when molten, and not when solid. **(2)**

(f) Evaluate one limitation of using melting point alone to identify the type of bonding in an unknown solid, and suggest one improvement to Priya's method. **(2)**

(g) Explain why it would be dangerous for Priya to test the electrical conductivity of a substance while it is still molten by holding bare wires against it by hand. **(2)**

(h) State the independent variable in Priya's investigation. **(1)**

(Total for Question 1 is 15 marks)

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2 Silver nanoparticles are increasingly used as an antibacterial coating in wound dressings, replacing the traditional use of bulk silver metal.

(a) Explain, in terms of surface area to volume ratio, why silver nanoparticles are more effective antibacterial agents than the same mass of bulk silver. **(3)**

(b) Suggest one economic advantage to a manufacturer of using nanoparticle silver rather than bulk silver in a wound dressing, if the total mass of silver used stays the same. **(1)**

(c) Evaluate the risks that should be considered before using silver nanoparticles in medical products, compared with using bulk silver. **(3)**

(Total for Question 2 is 7 marks)

3 Magnesium oxide (MgO) is a giant ionic lattice made up of Mg^{2+} ions and O^{2-} ions.

(a) Describe the structure of a giant ionic lattice such as magnesium oxide. **(2)**

(b) Magnesium oxide has a much higher melting point than sodium chloride. Use the charges on the ions in each compound to explain why. **(2)**

(c) Explain why solid magnesium oxide does not conduct electricity, but molten magnesium oxide does. **(2)**

(Total for Question 3 is 6 marks)

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4 Compare the structures of diamond and graphite, and use these structures to explain the differences in their hardness and electrical conductivity.

(Total for Question 4 is 6 marks)

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5 Buckminsterfullerene and carbon nanotubes both belong to the fullerene family of carbon structures.

(a) Give the molecular formula of buckminsterfullerene, the first fullerene to be discovered. **(1)**

(b) State one use of carbon nanotubes, and explain how a property of nanotubes makes them suitable for this use. **(2)**

(c) Give one other use of fullerene molecules (other than the use given in part (b)). **(1)**

(Total for Question 5 is 4 marks)

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6 Poly(ethene) is an example of a thermosoftening polymer. Some other polymers are thermosetting.

(a) Describe, in terms of bonding between polymer chains, the structure of a thermosoftening polymer. **(2)**

(b) Explain why thermosoftening polymers can be melted and reshaped repeatedly, while thermosetting polymers cannot. **(2)**

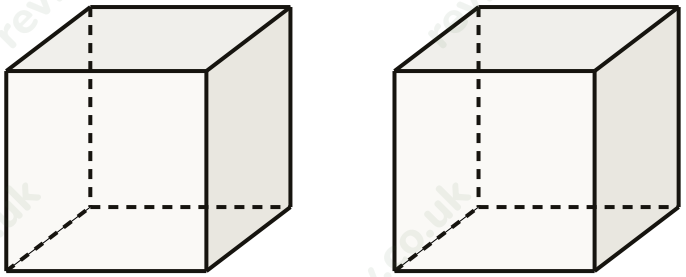
(c) State one factor, other than the presence of cross-links, that affects the properties (such as strength or melting point) of a polymer. **(1)**

(Total for Question 6 is 5 marks)

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7 A student compares two cube-shaped samples of the same material to investigate how particle size affects surface area to volume ratio.

Diagram NOT accurately drawn



(a) Calculate the surface area to volume ratio of a cube with a side length of 1 cm. Give your answer in the form n : 1. **(2)**

.....

(b) Calculate the surface area to volume ratio of a cube of the same material with a side length of 0.1 cm. **(1)**

.....

(c) State how the surface area to volume ratio of a cube changes as its side length gets smaller. **(1)**

(Total for Question 7 is 4 marks)

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Mark scheme · 2.19 Structures, Properties and Nanoparticles: 1-hour Pack

Question 1

(a) connect the solid sample into a circuit with a low-voltage power supply and a bulb or ammeter, using electrodes/crocodile clips that touch the sample (oe) **M1**

(a) observe whether the bulb lights (or the ammeter shows a current), and only handle the circuit using the insulated wires/clips, not the electrodes directly (oe) **A1**

(a) Answer: Connect the solid into a circuit with a low-voltage power supply and a bulb or ammeter, using electrodes that touch the sample; observe whether the bulb lights (or a current is shown), handling the circuit only by its insulated parts

(b) any valid precaution, e.g. wear eye protection/heat-resistant gloves, use tongs/a heatproof stand rather than holding the container, heat gently and do not overheat, or work in a fume cupboard if the substance may give off fumes (any one) oe **B1**

(b) Answer: For example: wear eye protection and use tongs or a heatproof mat/stand rather than holding the heated container directly

(c) any valid controlled variable, e.g. the mass/amount of each sample used, the rate of heating, or the type/purity of each sample (any one) oe **B1**

(c) Answer: For example: the mass of each sample used should be the same

(d) A: giant ionic (lattice) - high melting point, and only conducts once the ions are free to move (i.e. when molten) oe **B1**

(d) B: giant covalent (e.g. diamond or silicon dioxide) - high melting point, but no ions or delocalised electrons free to move, so it never conducts oe **B1**

(d) C: simple molecular - low melting point (only weak intermolecular forces to overcome), and no charged particles free to move, so it never conducts oe **B1**

(d) D: metallic - high melting point, and conducts as both a solid and a liquid because delocalised electrons are free to move in both states oe **B1**

(d) Answer: A = giant ionic lattice; B = giant covalent structure; C = simple molecular substance; D = metal (metallic structure)

(e) in the solid, the ions in A are held in fixed positions in the lattice and cannot move to carry charge, ft from (d) oe **M1**

(e) once molten, the ions are free to move throughout the liquid and can carry electrical charge, so it conducts, ft from (d) oe **A1**

(e) Answer: As a solid, A's ions are fixed in the lattice and cannot move; once molten, the ions are free to move and carry charge, so molten A conducts electricity

(f) limitation, e.g. both giant ionic and giant covalent substances can have similarly high melting points, so melting point alone cannot always distinguish between them (oe) **B1**

(f) improvement, e.g. also test electrical conductivity in the solid and molten states (as Priya did), or test solubility in water, to help distinguish between structures with similar melting points (oe) **B1**

(f) Answer: Limitation: giant ionic and giant covalent substances can both have very high melting points, so melting point alone cannot reliably tell them apart. Improvement: also test electrical conductivity as a solid and when molten, since this can distinguish ionic (conducts only when molten) from covalent (never conducts) structures

(g) the molten substance is likely to be extremely hot, so touching it or bare wires near it risks severe burns (oe) **M1**

(g) if the molten substance conducts electricity, holding bare wires by hand also risks an electric shock; suitable insulated apparatus (e.g. electrodes held in a stand, not by hand) should be used instead (oe) **A1**

(g) Answer: The molten substance will be very hot, so holding bare wires near it risks serious burns; if it conducts electricity, there is also a risk of electric shock, so insulated electrodes held in a stand, not by hand, should be used instead

(h) the substance/sample being tested (A, B, C or D) oe **B1**

(h) Answer: The identity of the substance being tested (A, B, C or D)

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Question 2

(a) for the same total mass of silver, nanoparticles have a much greater total surface area to volume ratio than bulk silver (oe) **M1**

(a) this means a much greater proportion of the silver atoms are exposed on a surface, able to come into contact with (and act on) bacteria (oe) **M1**

(a) so nanoparticle silver is more effective at killing/inhibiting bacteria than the same mass of bulk silver, and/or a smaller mass of nanoparticle silver can achieve the same antibacterial effect (oe) **A1**

(a) Answer: For the same mass of silver, nanoparticles have a far greater surface area to volume ratio, so a much greater proportion of silver atoms are exposed and able to act on bacteria; this makes nanoparticle silver more effective, so less material is needed for the same antibacterial effect

(b) because nanoparticle silver is more effective per gram, a smaller mass of (expensive) silver could be used to achieve the same antibacterial effect, reducing material costs (oe) **B1**

(b) Answer: Since nanoparticle silver is more effective per gram, the manufacturer could use less (expensive) silver to achieve the same antibacterial effect, lowering material costs

(c) nanoparticles may be small enough to pass through cell membranes or skin, which bulk silver particles cannot do, potentially entering the bloodstream or affecting healthy cells (oe) **B1**

(c) nanotechnology is a relatively new field, so the long-term effects of silver nanoparticles on human health and on the environment (e.g. if washed away and entering water systems) are not yet fully researched/understood (oe) **B1**

(c) any other valid evaluative point, e.g. the greater reactivity of nanoparticles (due to their high surface area to volume ratio) could make them more likely to cause unwanted reactions/toxicity than the same mass of bulk silver, so the benefits (improved wound healing) must be weighed against these currently unknown risks (oe); accept any three distinct valid points from this list for full marks **B1**

(c) Answer: Any three of: nanoparticles may cross cell membranes or skin more easily than bulk particles, potentially entering the bloodstream; the long-term health and environmental effects of nanoparticles are not yet fully understood, as nanotechnology is relatively new; their high surface area to volume ratio makes them more reactive, which could increase the risk of unwanted toxic effects, so these unknowns must be weighed against the benefit of improved wound healing

Question 3

(a) a regular, repeating (three-dimensional) arrangement of oppositely charged ions (oe) **B1**

(a) held together by strong electrostatic forces of attraction between the oppositely charged ions, acting in all directions (ionic bonds) (oe) **B1**

(a) Answer: A regular, repeating 3D arrangement of oppositely charged ions, held together by strong electrostatic forces of attraction (ionic bonds) acting in all directions

(b) magnesium oxide contains Mg^{2+} and O^{2-} ions (2+ and 2- charges), whereas sodium chloride contains Na^{+} and Cl^{-} ions (1+ and 1- charges) (oe) **M1**

(b) the higher ionic charges in magnesium oxide give stronger electrostatic forces of attraction between the ions, so more energy is needed to overcome them and separate the lattice, giving a much higher melting point (oe) **A1**

(b) Answer: Mg^{2+} and O^{2-} have higher charges than Na^{+} and Cl^{-}, so the electrostatic forces of attraction between the ions in magnesium oxide are stronger; more energy is needed to overcome these stronger forces, giving magnesium oxide a much higher melting point (MgO approximately 2852°C compared with NaCl approximately 801°C)

(c) in the solid, the ions are held in fixed positions in the lattice and cannot move, so there are no charge carriers free to move (oe) **M1**

(c) when molten, the ions are free to move (throughout the liquid) and can carry electrical charge, so the liquid conducts (oe) **A1**

(c) Answer: In the solid, ions are fixed in place in the lattice and cannot move to carry charge; when molten, the ions are free to move and can carry electrical charge, so molten magnesium oxide conducts

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Question 4

Level 3 A clear, detailed and accurate comparison of both structures, correctly linked to both hardness and electrical conductivity. Reference is made to the number of covalent bonds per carbon atom, the three-dimensional rigid lattice of diamond versus the layered structure of graphite, the presence or absence of delocalised electrons, and the weak forces between graphite's layers. **5-6**

Level 2 Structural detail is given for at least one of diamond or graphite, and this is used to explain at least one property (hardness or conductivity). The explanation may be one-sided or only partly linked to the structure. **3-4**

Level 1 Simple, largely unlinked statements about diamond and/or graphite are given, such as 'diamond is hard' or 'graphite conducts electricity', with little or no reference to structure or bonding. **1-2**

Level 0 No relevant content. **0**

Indicative content:

- In diamond, each carbon atom forms four covalent bonds to four other carbon atoms, arranged in a rigid, three-dimensional tetrahedral lattice.
- This rigid lattice of strong covalent bonds, extending throughout the structure in all directions, means a large number of strong bonds must be broken to break or scratch diamond, so diamond is extremely hard.
- All four outer electrons of each carbon atom in diamond are used in covalent bonding, so there are no free or delocalised electrons and no ions; diamond does not conduct electricity.
- In graphite, each carbon atom forms three covalent bonds to three other carbon atoms, arranged in flat hexagonal layers (sheets).
- Only three of each carbon atom's four outer electrons are used in covalent bonding, so one electron per carbon atom is delocalised and free to move within a layer.
- These delocalised electrons can move and carry charge, so graphite conducts electricity (unlike diamond).
- The layers in graphite are held together only by weak intermolecular forces between layers, with no covalent bonds between them.
- Because these forces between layers are weak, the layers can slide over each other easily, so graphite is soft and slippery, and is used as a lubricant and in pencils.
- Diamond's hardness makes it useful in cutting tools and drill tips, whereas graphite's softness and electrical conductivity make it useful for very different applications, such as electrodes.

Question 5

(a) C_{60} cao **B1**

(a) Answer: C_{60}

(b) a valid use, e.g. reinforcing materials/composites (such as tennis racket frames or bicycle frames), or as tiny electrical wires/components in nanotechnology, or as industrial catalysts (any one) oe **B1**

(b) a linked property, e.g. high tensile strength for their very low mass/density makes them good for reinforcing composites without adding much weight; or their ability to conduct electricity makes them useful in tiny electrical circuits; or their very large surface area to volume ratio makes them effective catalysts (must match the use given) oe **B1**

(b) Answer: For example: reinforcing composite materials (e.g. sports equipment), because nanotubes have a very high tensile strength for their low mass, making the material strong without adding much weight

(c) any valid use, e.g. delivering drugs into the body (drug delivery), acting as lubricants, or acting as catalysts (any one, must differ from the use given in (b)) oe **B1**

(c) Answer: For example: delivering drug molecules to specific cells in the body (drug delivery)

Question 6

(a) thermosoftening polymers consist of individual, tangled polymer chains (oe) **B1**

(a) only weak intermolecular forces act between the separate chains, with no covalent bonds (cross-links) joining one chain to another (oe) **B1**

(a) Answer: Thermosoftening polymers are made of individual, tangled chains held together only by weak intermolecular forces between chains, with no covalent cross-links between them

(b) on heating a thermosoftening polymer, the weak intermolecular forces between chains are overcome, allowing the chains to move/slide past each other so the polymer softens and can be remoulded, then this can be repeated (oe) **M1**

(b) thermosetting polymers have covalent cross-links (strong covalent bonds) between chains, forming a rigid giant covalent network; these strong cross-links do not break on heating, so the polymer does not melt/soften and cannot be reshaped (oe) **A1**

(b) Answer: Heating overcomes the weak forces between the separate chains of a thermosoftening polymer, letting the chains slide and the polymer be reshaped repeatedly; thermosetting polymers have strong covalent cross-links between chains that do not break on heating, so they cannot be melted or reshaped

(c) the length of the polymer chains (or the degree of branching of the chains) oe **B1**

(c) Answer: The average length of the polymer chains (or the amount of branching in the chains)

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Question 7

(a) correct surface area and volume found: surface area = 6 x 1^2 = 6 cm^2, volume = 1^3 = 1 cm^3 (oe) **M1**

(a) ratio = 6 : 1 (accept 6 cm^{-1}) cao **A1**

(a) Answer: 6 : 1 (6 cm^{-1})

(b) 60 : 1 (60 cm^{-1}) cao **B1**

(b) Answer: 60 : 1 (60 cm^{-1})

(c) the surface area to volume ratio increases as the side length (particle size) decreases, ft consistent with (a) and (b) oe **B1**

(c) Answer: The surface area to volume ratio increases as the cube gets smaller

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