C2aD Chemical Bonding: Ionic, Covalent and Metallic: Exam Drill

Total Marks

AQA 8464 · Calculator allowed · about 90 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question checks three key terms used throughout this topic.

(a) Define an 'ionic bond'. **(1)**

(b) Define a 'covalent bond'. **(1)**

(c) Define 'delocalised electrons'. **(1)**

(Total for Question 1 is 3 marks)

2 The formula of an ionic compound must balance the total positive charge with the total negative charge.

(a) Aluminium ions, Al^{3+}, and sulfide ions, S^{2-}, form the ionic compound aluminium sulfide. Deduce the formula of aluminium sulfide, showing that the charges balance. **(3)**

(b) Potassium ions, K^{+}, and oxide ions, O^{2-}, form the ionic compound potassium oxide. Deduce the formula of potassium oxide. **(2)**

(Total for Question 2 is 5 marks)

3 Potassium and fluorine react together to form the ionic compound potassium fluoride, KF. A potassium atom has the electronic structure 2,8,8,1. A fluorine atom has the electronic structure 2,7.

(a) Explain how a potassium atom forms a potassium ion, including the charge on the ion formed. **(2)**

(b) Explain how a fluorine atom forms a fluoride ion, including the charge on the ion formed. **(2)**

(Total for Question 3 is 4 marks)

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4 Required practical: Priya tests whether solid lead bromide, molten lead bromide, and an aqueous solution of sodium chloride conduct electricity, using a circuit containing a bulb and two graphite electrodes.

(a) State whether solid lead bromide would conduct electricity, and explain your answer in terms of its structure. **(2)**

(b) Explain why molten lead bromide does conduct electricity. **(2)**

(c) State one similarity in why molten lead bromide and aqueous sodium chloride solution both conduct electricity. **(1)**

(Total for Question 4 is 5 marks)

5 A student writes the following statement: 'Magnesium chloride, $MgCl_2$, has a low melting point because the covalent bonds between magnesium and chlorine atoms are weak.' This statement contains two errors.

(a) Identify and correct the error in the statement about the type of bonding in magnesium chloride. **(2)**

(b) Identify and correct the error in the statement about the melting point of magnesium chloride. **(2)**

(Total for Question 5 is 4 marks)

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6 Nitrogen reacts with hydrogen to form ammonia, NH_3, a simple covalent molecule. A nitrogen atom has 5 electrons in its outer shell.

(a) State how many more electrons a nitrogen atom needs to achieve a full outer shell. **(1)**

(b) Explain why a nitrogen atom forms three covalent bonds when it reacts with hydrogen to form ammonia. **(3)**

(Total for Question 6 is 4 marks)

7 An electrician notes that solid copper wire conducts electricity, but solid calcium oxide (also a giant lattice structure) does not conduct electricity unless it is melted.

(a) Explain why solid copper conducts electricity. **(2)**

(b) Explain why solid calcium oxide does not conduct electricity, even though it is also a giant lattice structure. **(2)**

(c) State what must happen to solid calcium oxide for it to be able to conduct electricity. **(1)**

(Total for Question 7 is 5 marks)

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8 A materials engineer is choosing a material for the heating element inside an electric kettle, which must conduct electricity and withstand high temperatures without melting or breaking. The choices are an ionic compound, a simple covalent (molecular) substance, or a metal. Evaluate which type of substance would be the most suitable material for the heating element, considering melting point, electrical conductivity as a solid, and structure.

(Total for Question 8 is 6 marks)

9 Magnesium oxide, MgO, has a melting point of 2852 degrees C. Sodium chloride, NaCl, has a melting point of 801 degrees C. Both are ionic compounds with giant lattice structures.

(a) State the type of structure both compounds have. **(1)**

(b) Higher tier only. Explain why magnesium oxide has a much higher melting point than sodium chloride. **(3)**

(Total for Question 9 is 4 marks)

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10 Compound R has the formula Ca3N2. A nitride ion has charge N3-.

(a) State the general rule that determines the ratio of ions in the formula of an ionic compound. **(1)**

(b) Use this rule and the formula Ca3N2 to calculate the charge on a calcium ion. Show your working. **(3)**

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(Total for Question 10 is 4 marks)

Mark scheme · C2aD Chemical Bonding: Ionic, Covalent and Metallic: Exam Drill

Question 1

- (a) **B1** the strong electrostatic force of attraction between oppositely charged ions, oe
- **(a) Answer: The strong electrostatic force of attraction between oppositely charged ions.**
- (b) **B1** a shared pair of electrons between two (non-metal) atoms, oe
- **(b) Answer: A shared pair of electrons between two atoms.**
- (c) **B1** outer-shell electrons from metal atoms that are free to move throughout the whole metallic structure, not fixed to one atom, oe
- **(c) Answer: Outer-shell electrons from metal atoms that are free to move throughout the whole structure.**

Question 2

- (a) **M1** identifies that 2 aluminium ions and 3 sulfide ions are needed
- (a) **M1** shows total charge balances: 2 x (3+) = 6+ and 3 x (2-) = 6-
- (a) **A1** Al2S3 cao
- **(a) Answer: Al2S3**
- (b) **M1** identifies that 2 potassium ions are needed to balance 1 oxide ion
- (b) **A1** K2O cao
- **(b) Answer: K2O**

Question 3

- (a) **M1** the potassium atom loses its 1 outer-shell electron, oe
- (a) **A1** forming a K+ ion with a full outer shell (electronic structure 2,8,8), oe
- **(a) Answer: The potassium atom loses its 1 outer-shell electron, forming a K+ ion with a full outer shell.**
- (b) **M1** the fluorine atom gains 1 electron (the electron lost by potassium), oe
- (b) **A1** forming an F- ion with a full outer shell (electronic structure 2,8), oe
- **(b) Answer: The fluorine atom gains 1 electron, forming an F- ion with a full outer shell.**

Question 4

- (a) **B1** does not conduct electricity
- (a) **B1** the ions are held in fixed positions in the giant ionic lattice and cannot move to carry charge, oe
- **(a) Answer: Solid lead bromide does not conduct electricity, because its ions are held in fixed positions in the lattice and cannot move to carry charge.**
- (b) **M1** when lead bromide melts, the giant ionic lattice breaks down and the ions are free to move, oe
- (b) **A1** the mobile (free-moving) ions can now carry electrical charge through the liquid, oe
- **(b) Answer: Melting breaks down the lattice, freeing the ions to move, and these mobile ions can carry electrical charge.**
- (c) **B1** both contain ions that are free to move (mobile) and can carry electrical charge, oe
- **(c) Answer: Both contain free-moving (mobile) ions that can carry electrical charge.**

Question 5

- (a) **M1** identifies that the bonding in magnesium chloride is ionic, not covalent, oe
- (a) **A1** explains that ionic bonding involves electron transfer to form oppositely charged ions held together by electrostatic attraction, unlike covalent bonding, which involves shared pairs of electrons, oe
- **(a) Answer: The bonding is ionic, not covalent: magnesium and chlorine atoms transfer electrons to form oppositely charged ions, which are held together by electrostatic attraction.**
- (b) **M1** identifies that magnesium chloride actually has a high melting point, not a low one, oe
- (b) **A1** explains this is because there are strong electrostatic forces of attraction between oppositely charged ions throughout the giant ionic lattice, which need a large amount of energy to overcome, oe
- **(b) Answer: Magnesium chloride actually has a high melting point, because there are strong electrostatic forces between oppositely charged ions throughout the giant lattice, which need a lot of energy to overcome.**

Question 6

- (a) **B1** 3
- **(a) Answer: 3**
- (b) **M1** nitrogen needs 3 more electrons to achieve a full, stable outer shell of 8 electrons, oe
- (b) **M1** each covalent bond is a shared pair of electrons, formed by sharing one electron with each of 3 separate hydrogen atoms, oe
- (b) **A1** forming 3 covalent bonds gives the nitrogen atom a share in 8 outer-shell electrons (a full, stable outer shell), oe
- **(b) Answer: Nitrogen needs 3 more electrons for a full outer shell, so it shares one electron with each of 3 hydrogen atoms, forming 3 covalent bonds and giving it a share in 8 outer-shell electrons.**

Question 7

- (a) **M1** metallic bonding consists of a lattice of positive metal ions surrounded by a 'sea' of delocalised (free) electrons, oe
- (a) **A1** these delocalised electrons are free to move throughout the whole structure, carrying charge, even in the solid state, oe
- **(a) Answer: Copper has a lattice of positive ions surrounded by delocalised electrons, which are free to move throughout the solid and carry charge.**
- (b) **M1** in ionic calcium oxide, the ions are held in fixed positions by strong electrostatic forces and cannot move, oe
- (b) **A1** there are no delocalised (mobile) charged particles able to move through the solid lattice to carry a current, oe
- **(b) Answer: In calcium oxide the ions are held in fixed positions by strong electrostatic forces, so there are no mobile charged particles free to carry a current.**
- (c) **B1** it must be melted (or dissolved in water), so its ions become free to move, oe
- **(c) Answer: It must be melted, or dissolved in water, so the ions become free to move.**

Question 8

- **Level 3** (5-6): A balanced evaluation of all three types of substance, correctly linking structure to melting point and to electrical conductivity as a solid, with a justified recommendation of a metal.
- **Level 2** (3-4): Discussion of at least two of the three substance types with some correct linking of structure to properties, but the evaluation is not fully balanced or the conclusion not fully justified.
- **Level 1** (1-2): Simple, undeveloped statements about one substance type, with little reference to structure.
- **Indicative content:**
  - Ionic compounds have high melting points due to the strong electrostatic forces of attraction throughout the giant ionic lattice, but do not conduct electricity as solids because the ions are held in fixed positions
  - Simple covalent (molecular) substances usually have low melting points because only the weak intermolecular forces between molecules need to be overcome, not the strong covalent bonds within each molecule
  - Simple covalent substances do not conduct electricity in any state because there are no charged particles (ions or delocalised electrons) free to move
  - Metals have (often) high melting points and conduct electricity well as solids, because the delocalised electrons in the metallic structure are free to move and carry charge, even without melting
  - Metals are also malleable, so can be shaped into a wire or element, rather than being brittle and breaking under stress
  - A justified conclusion should recommend a metal, since it is the only one of the three that both conducts as a solid and can withstand high temperature, whereas ionic compounds fail on solid conductivity and simple covalent substances fail on both melting point and conductivity

Question 9

- (a) **B1** giant ionic lattice (structure)
- **(a) Answer: Giant ionic lattice.**
- (b) **M1** the ions in magnesium oxide (Mg2+ and O2-) have a greater charge than the ions in sodium chloride (Na+ and Cl-), oe
- (b) **M1** greater ionic charge produces stronger electrostatic forces of attraction between the oppositely charged ions in the lattice, oe
- (b) **A1** so more (thermal) energy is needed to overcome these stronger forces and melt magnesium oxide, giving it a higher melting point, oe
- **(b) Answer: Magnesium oxide's ions (Mg2+ and O2-) carry a greater charge than sodium chloride's (Na+ and Cl-),**

Question 10

- (a) **B1** the total positive charge must equal (balance) the total negative charge, oe
- **(a) Answer: The total positive charge must balance the total negative charge.**
- (b) **M1** total negative charge from 2 nitride ions: 2 x (3-) = 6-
- (b) **M1** total positive charge must also be 6+, shared equally between 3 calcium ions
- (b) **A1** charge on each calcium ion = 6 / 3 = 2+ (i.e. Ca2+) cao
- **(b) Answer: 2+ (Ca2+)**