IG.C4 Ionic Bonding and Properties of Ionic Compounds

EDEXCEL 4CH1 · Calculator allowed · about 60 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 Describe how a sodium atom forms a sodium ion when reacting with a chlorine atom in the formation of sodium chloride.

(Total for Question 1 is 2 marks)

2 Draw a dot-and-cross diagram showing the electron transfer between magnesium and oxygen to form magnesium oxide, including the final ions and their charges.

(Total for Question 2 is 3 marks)

3 State the type of bonding and the type of structure present in solid sodium chloride as taught in ionic bonding in Edexcel 4CH1.

(Total for Question 3 is 1 mark)

4 Explain why ionic compounds such as sodium chloride have high melting and boiling points, referring to the lattice and the forces involved.

(Total for Question 4 is 2 marks)

5 Deduce the formula of the ionic compound formed between aluminium ions and oxide ions. Include the charges used to deduce the formula.

(Total for Question 5 is 2 marks)

6 State two electrical conductivity observations for a typical ionic compound, for the solid state and when it is molten or dissolved in water, in the context of Edexcel 4CH1.

(Total for Question 6 is 2 marks)

7 Deduce the formula for the ionic compound formed between calcium ions and carbonate ions (CO3 2-). Show the ionic charges used to deduce the formula.

(Total for Question 7 is 2 marks)

8 Draw a dot-and-cross diagram to show the electron transfer between sodium and chlorine to form sodium chloride, showing the outer electrons, the transfer and the final ions with their charges.

(Total for Question 8 is 3 marks)

9 Deduce the formula of the ionic compound formed between ammonium ions (NH4+) and sulfate ions (SO4 2-). Show how the charges lead to the formula.

(Total for Question 9 is 3 marks)

10 Explain why ionic solids are brittle: describe what happens at the atomic level in a giant ionic lattice when a shear force is applied.

(Total for Question 10 is 3 marks)

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11 Deduce the formula of the ionic compound formed between magnesium ions and hydroxide ions (OH-). Show the charges used to deduce the formula.

(Total for Question 11 is 2 marks)

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12 Explain how ionic charge and ionic radius affect the strength of the electrostatic attraction in an ionic lattice, and therefore the melting point, using examples of ions with different charges or sizes.

(Total for Question 12 is 4 marks)

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13 Explain, using the giant ionic lattice model, why ionic compounds have the following properties: high melting point, do not conduct electricity when solid but do when molten or dissolved, and are brittle. In your answer link each property to features of the structure and bonding.

6-mark levels question: explain how the structure and bonding in ionic compounds account for the three stated properties.

(Total for Question 13 is 6 marks)

Mark scheme · IG.C4 Ionic Bonding and Properties of Ionic Compounds

Question 1

- **B1** sodium loses one electron from its outer shell
- **B1** forms a Na^+ ion and chlorine gains that electron to form Cl^- (electron transfer)
- **Answer: Sodium loses one outer electron to become Na^+; chlorine gains that electron to become Cl^-, so electron transfer forms ions.**

Question 2

- **B1** shows Mg losing two electrons and O gaining two electrons (electron transfer arrows or equivalent)
- **B1** shows Mg^{2+} ion and O^{2-} ion with square brackets and correct charges
- **B1** shows outer shells of ions complete (no extra unpaired electrons shown)
- **Answer: Diagram showing Mg -> Mg^{2+} (loses 2 e-) and O -> O^{2-} (gains 2 e-), ions in brackets with charges.**

Question 3

- **B1** ionic bonding and a giant ionic lattice (or giant ionic structure)
- **Answer: Ionic bonding; giant ionic lattice (giant ionic structure).**

Question 4

- **B1** strong electrostatic attraction between oppositely charged ions in the lattice
- **B1** a lot of energy is required to overcome these attractions, so melting and boiling points are high
- **Answer: Strong electrostatic attraction between many oppositely charged ions in the giant lattice; large energy required to overcome these attractions, so high melting and boiling points.**

Question 5

- **B1** states charges: Al^{3+} and O^{2-}
- **B1** deduces formula Al_2O_3 (cross-over or lowest whole-number ratio)
- **Answer: Al^{3+} and O^{2-} combine to give Al_2O_3.**

Question 6

- **B1** solid ionic compound does not conduct electricity
- **B1** molten or aqueous ionic compound conducts electricity
- **Answer: Solids do not conduct; molten or dissolved ionic compounds conduct electricity.**

Question 7

- **B1** states charges: Ca^{2+} and CO_3^{2-}
- **B1** deduces formula $CaCO_3$ (charges balance 2+ and 2-)
- **Answer: Ca^{2+} and CO_3^{2-} combine to give $CaCO_3$.**

Question 8

- **B1** shows Na losing one electron and Cl gaining one electron (electron transfer indicated)
- **B1** shows Na^+ and Cl^- in brackets with correct charges
- **B1** shows that both ions have full outer shells after transfer
- **Answer: Diagram showing Na -> Na^+ (loses 1 e-) and Cl -> Cl^- (gains 1 e-), ions in brackets with charges and filled outer shells.**

Question 9

- **B1** states charges: NH_4^+ and SO_4^{2-}
- **B1** uses charges to find ratio: two NH_4^+ needed for one SO_4^{2-}
- **B1** gives formula $(NH_4)_2SO_4$
- **Answer: Two NH_4^+ ions balance one SO_4^{2-} to give $(NH_4)_2SO_4$.**

Question 10

- **B1** states that layers of ions shift when a force is applied
- **B1** states that like-charged ions can be brought next to each other by the shift
- **B1** states that strong repulsion between like charges causes the crystal to cleave or shatter
- **Answer: A shear shifts layers of ions so that like-charged ions are adjacent; strong repulsion between these like charges breaks the lattice, causing brittle fracture.**

Question 11

- **B1** states charges: Mg^{2+} and OH^-
- **B1** deduces formula $Mg(OH)_2$ (one Mg^{2+} balances two OH^-)
- **Answer: Mg^{2+} and OH^- combine to give $Mg(OH)_2$.**

Question 12

- **B1** states that greater ionic charge increases attraction between ions
- **B1** states that smaller ionic radius increases attraction because ions are closer together
- **B1** links stronger attraction to higher melting point
- **B1** gives an example, e.g. MgO (Mg^{2+} and O^{2-}) has a higher melting point than NaCl (Na^+ and Cl^-) because charges are larger and ions are smaller, so attractions are stronger
- **Answer: Higher ionic charges and smaller ionic radii increase electrostatic attraction, raising melting points; for example MgO with Mg^{2+} and O^{2-} has stronger attractions and a higher melting point than NaCl with Na^+ and Cl^-.**

Question 13

- **Level 1** (1-2): Simple statements about one or two properties with little or no linkage to structure. Limited use of technical terms.
- **Level 2** (3-4): Clear statements about two properties with some explanation linking structure to property, using relevant technical terms such as ions, lattice and electrostatic attraction.
- **Level 3** (5-6): Detailed, coherent explanations for all three properties linking each to the ionic lattice and electrostatic forces. Uses correct technical terms and gives consequences for particle movement where relevant.
- **Indicative content:**
  - High melting point: many strong electrostatic attractions between oppositely charged ions throughout a giant lattice require large energy to overcome
  - Electrical conductivity: in solid state ions are fixed in place so cannot move and do not carry charge; when molten or in solution ions are free to move and so conduct electricity
  - Brittleness: applying a force shifts layers so like-charged ions line up and repel each other, causing the lattice to split
  - Use of terms: ions, giant ionic lattice, electrostatic attraction, ions free to move when molten/dissolved, fixed positions in solid
  - Clear linkage between particle-level behaviour and macroscopic property, e.g. movement of ions explains conductivity, breaking ionic attractions explains melting