2.18 Chemical Bonding: Ionic, Covalent and Metallic: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

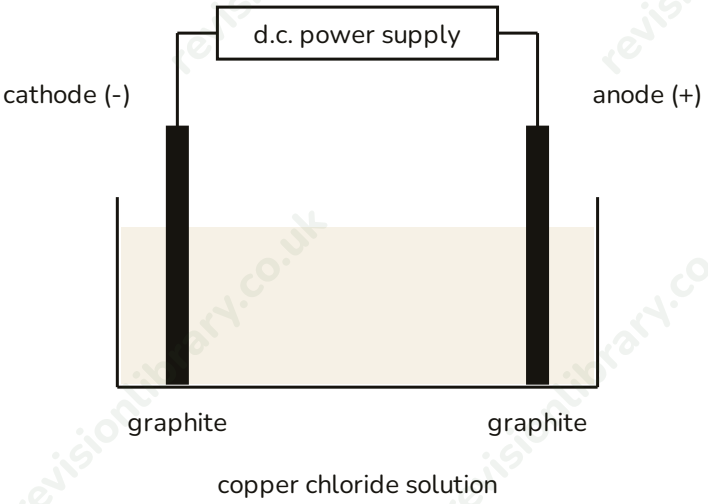
Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Required practical: a student electrolysed a solution of copper chloride using inert (graphite) electrodes connected to a d.c. power supply, as shown in Figure 4.

Figure 4



(a) State the type of bonding present in solid copper chloride. **(1)**

(b) Explain, in terms of structure and bonding, why solid copper chloride does not conduct electricity, but the copper chloride solution used in this practical does conduct electricity. **(4)**

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(c) Predict the product formed at the negative electrode (cathode) during this electrolysis, and explain your answer. **(2)**

(d) State the product formed at the positive electrode (anode). **(1)**

(e) Write the half equation for the reaction at the cathode. **(2)**

(f) Write the half equation for the reaction at the anode. **(2)**

(g) A second student repeated the electrolysis using a more concentrated copper chloride solution, passing the same current for the same length of time. State and explain the effect this has on the mass of copper deposited at the cathode. **(2)**

(h) State one safety precaution that should be taken when carrying out this practical. **(1)**

(Total for Question 1 is 15 marks)

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2 A student is asked to describe the bonding in methane, CH_4. The student writes: 'Methane contains ionic bonds between the carbon atom and each hydrogen atom, because the carbon atom transfers electrons to the hydrogen atoms.'

(a) Explain why the student's description is incorrect, and give the correct type of bonding present in methane. **(3)**

(Total for Question 2 is 3 marks)

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3 Sodium reacts with chlorine to form the ionic compound sodium chloride, NaCl.

(a) Complete the electron configurations of a sodium atom and a chlorine atom. **(2)**

(b) Describe, in terms of electron transfer, how a sodium atom and a chlorine atom form ions when they react. **(2)**

(c) State the ratio of Na^+ ions to Cl^- ions in sodium chloride, and name the type of bonding holding them together. **(1)**

(Total for Question 3 is 5 marks)

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4 Compare the type of bonding present in sodium chloride, iodine and magnesium, and use this to explain: why solid sodium chloride does not conduct electricity but molten sodium chloride does; why solid iodine does not conduct electricity in either the solid or liquid state; and why solid magnesium conducts electricity.

(Total for Question 4 is 6 marks)

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5 Ionic compounds form in fixed ratios that balance the total positive and negative charge on the ions.

(a) Magnesium ions, Mg^{2+}, and chloride ions, Cl^{-}, combine to form magnesium chloride. Use the charges on the ions to work out the formula of magnesium chloride. Show your reasoning. **(2)**

.....

(b) Aluminium ions, Al^{3+}, and oxide ions, O^{2-}, combine to form aluminium oxide. Use the charges on the ions to work out the formula of aluminium oxide. Show your reasoning. **(2)**

.....

(Total for Question 5 is 4 marks)

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6 Calcium reacts with oxygen to form the ionic compound calcium oxide, CaO.

(a) Complete the electron configurations of a calcium atom and an oxygen atom. **(2)**

(b) Draw a dot-and-cross diagram for calcium oxide and explain, in terms of electron transfer, how the two ions are formed. **(3)**

(Total for Question 6 is 5 marks)

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7 Some elements bond by sharing pairs of electrons rather than transferring them completely.

(a) State what is meant by a covalent bond. **(1)**

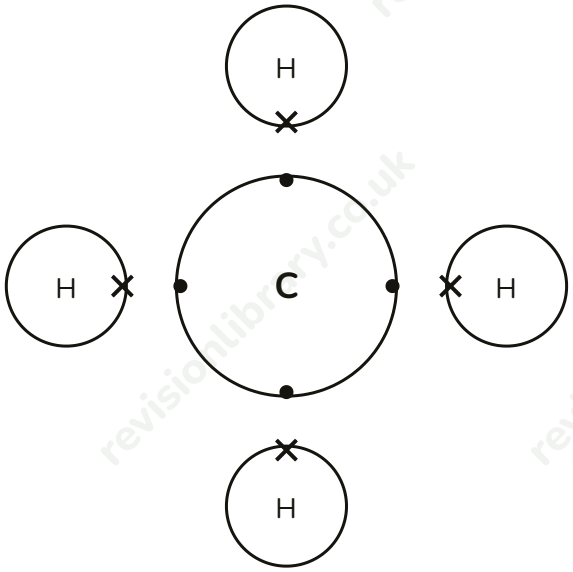
(b) Explain why two non-metal atoms share a pair of electrons instead of one atom transferring an electron completely to the other. **(2)**

(Total for Question 7 is 3 marks)

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8 Figure 2 shows the outline of a dot-and-cross diagram for methane, CH_4, before the covalent bonds have been added.

Figure 2: outline for the covalent bonding in methane, CH4



Complete the diagram to show all four shared pairs of electrons

(a) Complete the dot-and-cross diagram in Figure 2 to show the covalent bonding in a molecule of methane. Show outer-shell electrons only. **(3)**

(b) Explain how the carbon atom achieves a full outer shell in methane. **(2)**

(c) Give one limitation of the dot-and-cross diagram you completed in part (a) to represent the structure of a methane molecule. **(1)**

(Total for Question 8 is 6 marks)

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Mark scheme · 2.18 Chemical Bonding: Ionic, Covalent and Metallic: 1-hour Pack

Question 1

(a) ionic bonding cao **B1**

(a) Answer: Ionic bonding.

(b) copper chloride is ionic, held together by strong electrostatic forces of attraction in a giant lattice **B1**

(b) in the solid, the ions are held in fixed positions in the lattice and cannot move, so cannot carry charge **B1**

(b) when dissolved in water, the lattice breaks apart and the ions become free to move throughout the solution **B1**

(b) the free-moving ions can carry electrical charge between the electrodes, so the solution conducts oe **B1**

(b) Answer: In solid copper chloride, the Cu^{2+} and Cl^- ions are held in fixed positions in a giant ionic lattice by strong electrostatic forces, so they cannot move and cannot carry charge, and the solid does not conduct. When dissolved in water, the ions separate from the lattice and are free to move throughout the solution, so they can carry electrical charge between the electrodes, and the solution conducts.

(c) copper metal is deposited at the cathode **B1**

(c) because the positive Cu^{2+} ions are attracted to the negative electrode, where each ion gains electrons oe **B1**

(c) Answer: Copper metal is deposited at the cathode. The positively charged Cu^{2+} ions are attracted to the negative electrode, where each ion gains 2 electrons and is deposited as solid copper.

(d) chlorine gas, Cl_2 cao **B1**

(d) Answer: Chlorine gas, Cl_2.

(e) correct species with electrons shown on the correct side, $Cu^{2+} + 2e^-$ **M1**

(e) fully balanced equation with correct state symbols cao **A1**

(e) Answer: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

(f) correct species with electrons lost, $2Cl^- \rightarrow Cl_2 + 2e^-$ (or equivalent using 1 Cl^-) **M1**

(f) fully balanced equation with correct state symbols cao **A1**

(f) Answer: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

(g) no significant change to the mass of copper deposited (provided enough Cu^{2+} ions are present in both solutions) **B1**

(g) because the same current for the same time means the same quantity of charge (and the same number of moles of electrons) is passed, which determines the mass of copper deposited, not the concentration oe **B1**

(g) Answer: There is no significant effect on the mass of copper deposited (assuming there are enough Cu^{2+} ions available in both solutions). The mass deposited depends on the total charge passed (current x time), which is the same in both cases, not on the concentration of the solution.

(h) any valid precaution matched to the hazard, e.g. work in a well-ventilated area/fume cupboard because chlorine gas is toxic/irritant; OR wear eye protection in case of splashes **B1**

(h) Answer: Work in a well-ventilated area (or use a fume cupboard), because the chlorine gas produced is toxic and irritant; also wear eye protection in case of splashes.

Question 2

(a) methane contains covalent bonds, not ionic bonds **B1**

(a) carbon and hydrogen are both non-metals, and non-metal atoms share electrons (they do not transfer them completely) to gain full outer shells oe **B1**

(a) in methane, carbon shares one electron with each of the 4 hydrogen atoms (4 shared pairs), rather than any electrons being fully transferred oe **B1**

(a) Answer: The student is incorrect. Methane contains covalent bonds, not ionic bonds. Carbon and hydrogen are both non-metals, and when non-metal atoms bond together they share pairs of electrons rather than transferring them completely. In methane, the carbon atom shares one electron with each of the 4 hydrogen atoms, forming 4 covalent bonds, so no ions are formed and no electrons are fully transferred.

Question 3

(a) sodium: 2,8,1 **B1**

(a) chlorine: 2,8,7 **B1**

(a) Answer: Sodium: 2,8,1. Chlorine: 2,8,7.

(b) the sodium atom loses (transfers) its 1 outer-shell electron to become Na^+ (allow ft from (a)) **B1**

(b) the chlorine atom gains that electron directly to become Cl^- (allow ft from (a)) **B1**

(b) Answer: Na loses 1 outer-shell electron to form Na^+ (2,8); Cl gains that 1 electron to form Cl^- (2,8,8). The electron transfers directly from the sodium atom to the chlorine atom.

(c) 1:1 ratio; ionic bonding cao **B1**

(c) Answer: 1:1 ratio; ionic bonding, held together by strong electrostatic forces of attraction between the oppositely charged ions.

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Question 4

Level 3 A clear, accurate and logically structured explanation for all three substances, correctly linking bonding and structure (ions, delocalised electrons or molecules) to the presence or absence of free-moving charged particles able to carry electrical charge. **5-6**

Level 2 A mostly correct explanation for at least two of the three substances, linking bonding/structure to electrical conductivity, but the explanation for the third substance is missing, incomplete or contains an inaccuracy. Some scientific terms used correctly. **3-4**

Level 1 The type of bonding is identified for one or more of the substances, with limited or no linked explanation of electrical conductivity. The answer may be a list of isolated, unlinked statements. **1-2**

Level 0 No relevant content. **0**

Indicative content:

- Sodium chloride has ionic bonding; in the solid, the Na^+ and Cl^- ions are held in fixed positions in the giant lattice by strong electrostatic forces, so they cannot move and cannot carry charge, so solid sodium chloride does not conduct.
- When molten, the ionic lattice breaks down and the ions become free to move, so they can carry charge between the electrodes, so molten sodium chloride does conduct.
- Iodine is a simple molecular (covalent) substance made of individual I_2 molecules held together by weak intermolecular forces.
- Iodine has no ions and no delocalised electrons available in either the solid or liquid state, so there are no free-moving charged particles to carry charge; iodine does not conduct electricity as a solid or a liquid.
- Magnesium has metallic bonding: a lattice of positive Mg^{2+} ions surrounded by a sea of delocalised electrons.
- The delocalised electrons in magnesium are free to move throughout the structure even while it is solid, so they can carry charge, so solid magnesium conducts electricity.
- Correct identification of all three bonding types (ionic, covalent/molecular, metallic) supports access to the higher levels.

Question 5

(a) recognises that 2 Cl^- ions (2 x 1- = 2-) are needed to balance the 2+ charge on 1 Mg^{2+} ion oe **M1**

(a) correct formula $MgCl_2$ cao **A1**

(a) Answer: $MgCl_2$

(b) finds the lowest common multiple of the charges (6), or shows an equivalent correct method, e.g. 2 Al^{3+} ions balance 3 O^{2-} ions oe **M1**

(b) correct formula Al_2O_3 cao **A1**

(b) Answer: Al_2O_3

Question 6

(a) calcium: 2,8,8,2 **B1**

(a) oxygen: 2,6 **B1**

(a) Answer: Calcium: 2,8,8,2. Oxygen: 2,6.

(b) diagram shows $[Ca]^{2+}$ with an empty outer shell **B1**

(b) diagram shows $[O]^{2-}$ surrounded by 8 outer-shell electrons (6 original electrons plus 2 transferred, shown as a different symbol so they are distinguishable) **B1**

(b) explanation that the calcium atom transfers (loses) both of its outer electrons to the oxygen atom, so the oxygen atom gains 2 electrons (allow ft from (a)) **B1**

(b) Answer: Ca loses its 2 outer electrons to form Ca^{2+} (2,8,8); O gains those 2 electrons to form O^{2-} (2,8). Diagram: $[Ca]^{2+}$ with no outer electrons shown, and $[O]^{2-}$ with 8 outer electrons shown (6 dots plus 2 crosses), each ion in square brackets with its charge marked.

Question 7

(a) a shared pair of electrons between two (non-metal) atoms oe **B1**

(a) Answer: A covalent bond is a shared pair of electrons between two atoms.

(b) both atoms need to gain electrons to achieve a full outer shell (both are non-metals wanting to gain, not lose, electrons) oe **B1**

(b) the shared pair of electrons is attracted to (the nuclei of) both atoms, holding the atoms together oe **B1**

(b) Answer: Both atoms need to gain electrons to complete their outer shells, so neither can fully transfer electrons to the other; instead they share a pair of electrons, which is attracted to both positive nuclei, holding the atoms together as a covalent bond.

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Question 8

(a) 4 hydrogen atoms shown, each bonded to the central carbon atom **B1**

(a) each C-H bond shown as one correctly placed shared pair of electrons (one dot from carbon, one cross from hydrogen) **B1**

(a) carbon shown with a full outer shell of 8 electrons (an octet) and each hydrogen shown with a full outer shell of 2 (a duplet) **B1**

(a) Answer: Carbon (4 outer electrons) shares one electron with each of 4 separate hydrogen atoms, forming 4 single covalent bonds (4 shared pairs); each shared pair is shown as one dot (from C) and one cross (from H); carbon ends with 8 outer electrons and each H ends with 2.

(b) carbon starts with 4 electrons in its outer shell and needs 4 more electrons to reach a full outer shell of 8 **B1**

(b) by forming 4 single covalent bonds, one with each hydrogen atom, carbon shares 4 more electrons, giving it a full outer shell of 8 electrons oe **B1**

(b) Answer: Carbon has 4 outer electrons and needs 4 more for a full shell of 8. By forming 4 single covalent bonds, one with each hydrogen atom, carbon shares 4 more electrons, giving it a full outer shell (octet).

(c) any one valid limitation, e.g. it does not show the true 3D (tetrahedral) shape of the molecule / it shows the molecule as flat and does not show the bond angles oe **B1**

(c) Answer: It does not show the true 3D shape of the molecule (methane is actually tetrahedral); the 2D diagram makes it look flat and does not show the bond angles.

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