InkChemistry

ANSWER BOOK

Covalent, dative covalent and metallic bonding

Bonding and structure · Unit C03

AQA 3.1.3.2, 3.1.3.3 · OCR A 2.2.2, 3.1.1

21 questions · 64 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 CDC-Q1

B1 a shared pair of electrons between two atoms. **B1** the pair is attracted electrostatically to the nuclei of both atoms. [2]

A2 CDC-Q2

B1 a shared pair of electrons in which both electrons come from the same atom. **B1** it is drawn as an arrow from the atom that donates the pair to the atom that accepts it. [2]

A3 CDC-Q5

B1 H_2O: two bonding pairs and two lone pairs on oxygen. **B1** CO_2: four bonding pairs, as two double bonds, and no lone pairs on carbon. [2]

A4 CDC-Q8

B1 the two atoms are joined by a triple bond, three shared pairs of electrons. **B1** the triple bond is very strong, 945 kJ mol^{-1}, so a large amount of energy is needed to break it before N_2 can react. [2]

A5 CDC-Q20

B1 two σ bonds: the C–H bond and one of the three bonds in C≡N. **B1** two π bonds, both in the C≡N triple bond. [2]

SECTION B · Standard, 3 to 5 marks

B1 CDC-Q9

B1 magnesium forms Mg^{2+} ions, sodium forms Na^+ ions. **B1** magnesium releases two delocalised electrons per atom, sodium one. **B1** Mg^{2+} is smaller than Na^+. **B1** so the attraction between the positive ions and the delocalised electrons is stronger in magnesium, and more energy is needed to overcome it. [4]

B2 CDC-Q10

B1 a metal has delocalised electrons that are not attached to any one atom. **B1** the delocalised electrons move through the lattice when a potential difference is applied, carrying charge. **B1** metals are malleable because layers of positive ions can slide over one another. **B1** the delocalised electrons move with the ions, so the bonding is not broken and like charges are not forced together. [4]

B3 CDC-Q18

B1 each carbon mixes its 2s orbital with two 2p orbitals to form three sp^2 hybrid orbitals. **B1** the three sp^2 orbitals lie in a plane at 120° and form σ bonds to two hydrogen atoms and the other carbon. **B1** the unhybridised 2p orbital on each carbon lies at right angles to that plane, and the two overlap sideways to form a π bond. **B1** sideways overlap needs the two p orbitals to be parallel, so both CH_2 groups are held in the same plane. [4]

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B4 CDC-Q3 — **B1** three shared pairs between nitrogen and the three hydrogen atoms, each pair one dot and one cross. **B1** one lone pair on nitrogen, both electrons in nitrogen's symbol. **B1** nitrogen has eight electrons in its outer shell and each hydrogen has two. [3]

B5 CDC-Q4 — **B1** three shared pairs between the two nitrogen atoms, a triple bond, six electrons in the overlap. **B1** three of the shared electrons are dots and three are crosses, one from each atom in every pair. **B1** each nitrogen atom also has one lone pair, giving each atom eight outer electrons. [3]

B6 CDC-Q6 — **B1** the lone pair on the nitrogen of NH_3 is donated to the H^+, which has no electrons. **B1** this forms a dative covalent bond, both electrons of the shared pair coming from nitrogen. **B1** once formed, a dative bond is a shared pair like any other, so all four N–H bonds have the same length and strength. [3]

B7 CDC-Q7 — **B1** aluminium in $AlCl_3$ has only six outer electrons, so it can accept an electron pair. **B1** a chlorine atom in each $AlCl_3$ molecule has lone pairs. **B1** a lone pair on a chlorine of each molecule forms a dative bond to the aluminium of the other, so two dative bonds join the molecules and each aluminium has eight outer electrons. [3]

B8 CDC-Q11 — **B1** two of the shared pairs are ordinary covalent bonds, each with one electron from carbon and one from oxygen. **B1** the third shared pair is a dative bond, both electrons coming from a lone pair on oxygen, drawn as O→C. **B1** carbon then has six shared electrons plus one lone pair, and oxygen six shared electrons plus one lone pair, eight each. [3]

B9 CDC-Q12 — **B1** tin atoms are a different size from copper atoms. **B1** they disrupt the regular layers of ions in the metal lattice. **B1** so the layers cannot slide over each other as easily when a force is applied. [3]

B10 CDC-Q13 — **B1** nitrogen is in Period 2, so its outer shell can hold at most eight electrons. **B1** phosphorus is in Period 3, so its outer shell has room for more than eight electrons. **B1** in PCl_5 phosphorus shares all five outer electrons, giving it ten; nitrogen cannot share all five. [3]

B11 CDC-Q14 — **M1** amount of Mg = 1.00 ÷ 24.3 = 0.04115 mol. **M1** each atom releases two electrons, so electrons = $2 \times 0.04115 \times 6.022 \times 10^{23}$. **A1** 4.96×10^{22} delocalised electrons, to three significant figures. [3]

B12 CDC-Q15 — **M1** amount of N_2 = 2.40 ÷ 24.0 = 0.100 mol. **M1** one N≡N bond per molecule, so energy = 0.100 × 945. **A1** 94.5 kJ, to three significant figures. [3]

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B13 CDC-Q17 **B1** the claim is wrong: the dative bond differs only in where both electrons came from when it formed. **B1** once formed it is a shared pair attracted to both nuclei, like the other three bonds. **B1** all four N–H bonds have the same length and strength and the ion is a regular tetrahedron, so no bond can be identified. [3]

B14 CDC-Q19 **M1** N≡N is one σ and two π bonds, so the two π bonds together are worth 945 − 163 = 782 kJ mol⁻¹. **M1** amount of nitrogen = 5.60 ÷ 28.0 = 0.200 mol, so energy = 0.200 × 782; error carried forward from the π value. **A1** 156 kJ, to three significant figures; reject 78.2 kJ, which counts only one of the two π bonds. [3]

B15 CDC-Q21 **B1** an iodine atom is larger than a chlorine atom, so the H–I bond is longer. **B1** the shared pair is further from the iodine nucleus, so the H–I bond is weaker, 298 against 432 kJ mol⁻¹. **B1** the hot wire supplies enough energy to break H–I bonds, giving hydrogen and iodine, but not enough to break H–Cl bonds. [3]

SECTION C · Long, 6 marks or more

C1 CDC-Q16 **Indicative content** [6]

B1 both are giant lattices containing Na^+ ions, held by electrostatic attraction acting in all directions through the whole structure. **B1** in sodium the Na^+ ions are attracted to a sea of delocalised electrons, one released by each atom, which belong to no single ion. **B1** in sodium chloride each Na^+ ion is attracted to the oppositely charged Cl^- ions around it, and there are no delocalised electrons at all. **B1** sodium conducts as a solid because its delocalised electrons move through the lattice and carry charge when a potential difference is applied. **B1** solid sodium chloride does not conduct because its ions are fixed in place; it conducts only when molten or dissolved, with ions carrying the charge. **B1** sodium bends because layers of ions slide while the electrons move with them, but sodium chloride shatters because a shifted layer brings like charges together.

Levels

Level 3 (5–6 marks) both structures are compared point for point: the delocalised electrons of sodium against the Na^+ and Cl^- ions of the salt, conductivity in the solid explained for both, and the sliding of metal layers against the shattering of the ionic lattice; every point names both substances.

Level 2 (3–4 marks) metallic and ionic bonding are described and the conductivity difference explained; the hammer blow is answered without the layer argument, or some points speak of one substance only.

Level 1 (1–2 marks) sodium is said to have delocalised electrons or sodium chloride to be ionic; solid sodium chloride is often said to conduct, or both solids to bend under the hammer.

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