IG.C5 Covalent Bonding: Simple Molecules and Giant Structures

Total Marks

EDEXCEL 4CH1 · Calculator allowed · about 40 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Define covalent bonding in terms of electrons, for the Edexcel 4CH1 covalent bonding topic.

(Total for Question 1 is 2 marks)

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2 Draw a dot-and-cross diagram showing the covalent bonding in a molecule of hydrogen chloride (HCl). Name which atom provides which electron(s) in the shared pair, and show lone pairs on chlorine.

(Total for Question 2 is 2 marks)

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3 Draw a dot-and-cross diagram for a water molecule (H2O) showing all bonding pairs and lone pairs on the oxygen atom. State how many lone pairs remain on oxygen after bonding.

(Total for Question 3 is 2 marks)

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4 Draw dot-and-cross diagrams showing the bonding in methane (CH4) and in ammonia (NH3). For each molecule state the number of covalent bonds and the number of lone pairs on the central atom.

(Total for Question 4 is 3 marks)

5 Draw dot-and-cross diagrams to show the double covalent bonding in a molecule of oxygen (O_2) and the bonding in carbon dioxide (CO_2). For each molecule indicate the total number of shared electron pairs.

(Total for Question 5 is 3 marks)

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6 Draw a dot-and-cross diagram for nitrogen gas, N_2, showing the triple bond between the two nitrogen atoms. State how many electrons are shared in total in the bond and how many lone pairs each nitrogen atom has after bonding.

(Total for Question 6 is 2 marks)

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7 Describe three general properties of simple molecular substances such as chlorine, methane and water that arise from their bonding and intermolecular forces. Give a brief explanation for each property in terms of bonds or intermolecular forces.

(Total for Question 7 is 3 marks)

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8 Explain why silicon dioxide (SiO_2) is a solid with a very high melting point and does not conduct electricity, whereas carbon dioxide (CO_2) is a gas at room temperature. Refer to bonding and structure for both substances in your answer.

(Total for Question 8 is 4 marks)

9 Describe the bonding and structure of graphite and explain two properties of graphite that arise from that structure, referring to the bonding and layers in your explanation.

(Total for Question 9 is 4 marks)

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10 State two similarities and two differences between simple molecular substances and giant covalent structures, in terms of bonding, melting points and electrical conductivity. Use specific reference to examples such as methane and diamond in your answer.

(Total for Question 10 is 3 marks)

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11 Compare diamond and graphite as examples of giant covalent forms of carbon. In your answer, describe their bonding and structure and explain how these lead to differences in properties such as hardness, electrical conductivity and thermal conductivity.

(Total for Question 11 is 6 marks)

Mark scheme · IG.C5 Covalent Bonding: Simple Molecules and Giant Structures

Question 1

- **B1** states that covalent bonding involves sharing of electrons
- **B1** mentions that it forms between non-metal atoms so each atom achieves a full outer shell or stable electron arrangement
- **Answer: Covalent bonding is the sharing of electrons between non-metal atoms so each atom attains a full outer shell or stable electron arrangement.**

Question 2

- **B1** shows H with 1 electron and Cl with 7 valence electrons in their separate shells
- **B1** shows one shared pair between H and Cl so H has a full shell and Cl shows eight electrons total, with three lone pairs on Cl
- **Answer: Diagram showing H (1 electron) and Cl (7 electrons) with one shared pair between them so H has 2 and Cl has 8 valence electrons; Cl has three lone pairs remaining.**

Question 3

- **B1** shows oxygen with 6 valence electrons and two hydrogens each with 1 electron
- **B1** shows two bonding pairs between O and each H and two lone pairs on O (states two lone pairs)
- **Answer: Oxygen with 6 electrons sharing one with each H to form two bonding pairs, and oxygen retains two lone pairs.**

Question 4

- **B1** methane diagram with C sharing four electrons with four H atoms
- **B1** ammonia diagram with N sharing three electrons with three H atoms and one lone pair on N
- **B1** states number of covalent bonds and lone pairs: CH4 has 4 bonds and 0 lone pairs on C; NH3 has 3 bonds and 1 lone pair on N
- **Answer: CH4: carbon shares four electrons with four H atoms (4 covalent bonds) and carbon has 0 lone pairs. NH3: nitrogen shares three electrons with three H atoms (3 covalent bonds) and has 1 lone pair.**

Question 5

- **B1** O2 diagram showing two bonding pairs between the two O atoms (a double bond) and two lone pairs on each O
- **B1** CO2 diagram linear O=C=O with two double bonds, each O with two lone pairs
- **B1** states total shared pairs: O2 has 2 shared pairs, CO2 has 4 shared pairs (two per C=O)
- **Answer: O2: two shared pairs between O atoms (double bond), total 2 shared pairs. CO2: O=C=O with two double bonds, total 4 shared pairs (2 for each C=O).**

Question 6

- **B1** diagram shows three bonding pairs between the two N atoms (a triple bond)
- **B1** states that 6 electrons are shared in the triple bond and that each N has one lone pair remaining
- **Answer: N2: three shared pairs (6 electrons) between the two N atoms; each nitrogen retains one lone pair.**

Question 7

- **B1** states a property, for example: low melting and boiling points
- **B1** explains that this is because weak intermolecular forces require little energy to overcome while covalent bonds within molecules remain intact
- **B1** states another property and explains it, for example poor electrical conductivity in solid and liquid forms because there are no mobile charged particles to carry charge
- **Answer: Properties include low melting and boiling points because weak intermolecular forces are easily overcome, and poor electrical conductivity because molecules are neutral with no mobile ions or electrons to carry charge. Many simple molecular substances are gases or liquids at room temperature for these reasons.**

Question 8

- **B1** states that SiO2 has a giant covalent structure where each Si is bonded to four O atoms in a continuous network
- **B1** explains that strong covalent bonds throughout the giant lattice require large energy to break, giving a very high melting point
- **B1** states that SiO2 has no free charged particles to move so it does not conduct electricity
- **B1** contrasts CO2 as simple molecular with discrete CO2 molecules with weak intermolecular forces so it is a gas at room temperature
- **Answer: SiO2 is giant covalent: a continuous network of strong Si-O covalent bonds which need a lot of energy to break, so it is a hard solid with a very high melting point and it does not conduct because there are no mobile charged particles. CO2 is made of separate linear molecules held by weak intermolecular forces, so little energy is needed to separate them and CO2 is a gas at room temperature.**

Question 9

- **B1** describes graphite as layers of hexagonally arranged carbon atoms with strong covalent bonds within layers
- **B1** states that each carbon has three bonds and there is a delocalised electron per carbon
- **B1** explains that layers can slide over each other because of weak forces between layers, accounting for graphite being slippery and useful as a lubricant or pencil lead
- **B1** explains that delocalised electrons allow graphite to conduct electricity along the layers
- **Answer: Graphite consists of layers of carbon atoms bonded covalently in hexagons; each carbon is bonded to three others and there are delocalised electrons. Weak forces between layers allow them to slide, making graphite slippery, and the delocalised electrons make graphite a good conductor of electricity along the layers.**

Question 10

- **B1** one similarity: both have covalent bonding within molecules or between atoms
- **B1** second similarity: both are composed of non-metal elements (carbon, silicon, etc.)
- **B1** one difference or two differences: simple molecular substances have weak intermolecular forces and low melting points and usually do not conduct electricity, whereas giant covalent structures have strong covalent bonds throughout, very high melting points and usually do not conduct electricity except where delocalised electrons exist (graphite)
- **Answer: Similarities: both involve covalent bonds and are made from non-metal atoms. Differences: simple molecular substances like methane have weak intermolecular forces, low melting points and do not conduct electricity, while giant covalent structures like diamond have a continuous network of strong covalent bonds, very high melting points and do not conduct electricity; graphite is an exception because of delocalised electrons.**

Question 11

- **Level 1** (1-2): Basic statements about either diamond or graphite with limited linking to properties.
- **Level 2** (3-4): Describes bonding and structure of both forms and gives at least one linked explanation of a property for each, showing how structure leads to property.
- **Level 3** (5-6): Detailed comparison covering bonding and structure of diamond and graphite, with clear, linked explanations for multiple properties such as hardness, electrical conductivity and thermal conductivity, and a coherent conclusion contrasting the two forms.
- **Indicative content:**
  - Diamond: each carbon atom is bonded to four others in a tetrahedral lattice, strong covalent bonds throughout, no delocalised electrons
  - Diamond properties: extremely hard because bonds held in three dimensions; high melting point due to strong covalent bonds; does not conduct electricity because no mobile electrons, good thermal conductor because strong bonds transmit vibrations
  - Graphite: each carbon bonded to three others in planar hexagonal layers, with one delocalised electron per carbon and weak forces between layers
  - Graphite properties: layers can slide causing softness and lubrication and use in pencils; conducts electricity along layers because of delocalised electrons but not between layers; good thermal conductor along layers
  - Compare and conclude: relate how 3D rigid network gives hardness in diamond whereas layered structure and delocalised electrons give conductivity and lubricity in graphite