7.1 The covalent model

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS covalent bond • electronegativity • hydrogen bond • London forces • giant covalent structure • resonance

Objective

Build the skills to answer exam questions on **the covalent model** : Lewis formulas, molecular shape, polarity, giant covalent structures, intermolecular forces and chromatography.

You must be able to:

- draw Lewis formulas and use VSEPR theory to predict shapes and bond angles
- decide whether bonds and molecules are polar from electronegativity and shape
- compare boiling points using London forces, dipole–dipole forces and hydrogen bonds
- describe diamond, graphite, graphene and silicon dioxide, and calculate R_F values
- explain resonance, sigma and pi bonds, and hybridization

1 Key knowledge and worked examples

Covalent bonds and shapes

A **covalent bond** is the attraction of two nuclei to a shared pair of electrons. In a **coordination bond** both electrons come from one atom (as in NH_4^+).

electron domains	lone pairs	shape	angle	example
2	0	linear	180°	CO_2
3	0	trigonal planar	120°	BF_3
4	0	tetrahedral	109.5°	CH_4
4	1	trigonal pyramidal	107°	NH_3
4	2	bent	104.5°	H_2O

Lone pairs repel more than bonding pairs, so they squeeze the angles. A bond is **polar** when the atoms differ in electronegativity; a molecule is polar only if the bond dipoles do **not** cancel.

intermolecular force	between	strength
London (dispersion)	all molecules; larger with more electrons	weakest
dipole–dipole	polar molecules	stronger
hydrogen bond	H bonded to N, O or F, and a lone pair on N, O or F	strongest

Giant covalent: diamond (each C bonded to four, very hard), graphite (layers, delocalized electrons, conducts), graphene (one layer), SiO_2 (each Si bonded to four O). **Chromatography:** $R_F = \dfrac{\text{distance moved by spot}}{\text{distance moved by solvent}}$.

HL: resonance spreads (delocalizes) π electrons over several bonds. A σ bond is head-on overlap; a π bond is sideways overlap. sp^3, sp^2, sp hybrids match 4, 3, 2 domains.

Worked example 1: shape. SO_2: S has 3 domains with 1 lone pair, so **bent**, a little under 120°.

Worked example 2: boiling points. CH_4 (−162 °C) and C_3H_8 (−42 °C): propane has more electrons, so **stronger London forces**.

Answer shapes: domains, then lone pairs, then shape and angle.

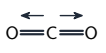
2 Practice

2.1 Deduce the shape and bond angle of an ammonia molecule, NH_3, and of a carbon dioxide molecule, CO_2. [2]





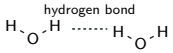
2.2 Both C=O and O−H bonds are polar. Explain why carbon dioxide is a non-polar molecule but water is polar. [3]





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2.3 Water boils at 100 °C, but hydrogen sulfide, H_2S, boils at −60 °C. Explain the difference. [3]



2.4 State the number of σ and π bonds in an ethene molecule, C_2H_4, and the hybridization of the carbon atoms. [2]



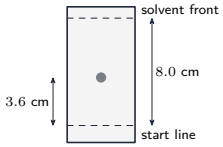
2.5 All three C–O bonds in the carbonate ion, CO_3^{2-}, have the same length. Explain this using resonance, and compare the bond length with C–O and C=O. [3]



3 Exam-style questions

3.1 A student uses paper chromatography to analyse a food dye.

(a) Calculate the R_F value of the spot. [2]

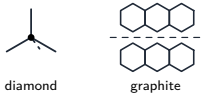


(b) Explain how the components of a mixture are separated. [2]

(c) Explain why the start line is drawn in pencil, not ink. [1]

3.2 Diamond and graphite are both forms of carbon.

(a) Describe the structure of graphite. [2]



(b) Explain why graphite conducts electricity but diamond does not. [2]

(c) Explain why both have very high melting points. [1]

(d) Silicon dioxide also has a very high melting point. Describe its structure. [2]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

NH_3: trigonal pyramidal, 107°; CO_2: linear, 180°

2.2

oxygen is more electronegative than C and H, so each bond is polar; CO_2 is linear, so the two bond dipoles cancel; H_2O is bent, so the dipoles do not cancel

2.3

water molecules form hydrogen bonds (H bonded to O, the very electronegative O with lone pairs); H_2S has only dipole–dipole and London forces; hydrogen bonds are stronger, so more energy is needed to separate water molecules

2.4

5 σ and 1 π; sp^2

2.5

three resonance structures can be drawn with the double bond in different places; the π electrons are delocalized over all three bonds, so they are identical (bond order $1\frac{1}{3}$); the length is between that of a C–O single bond and a C=O double bond

3.1

(a) $R_F = \dfrac{3.6}{8.0} = \mathbf{0.45}$

(b) components have different attractions to the paper (stationary phase) and the solvent (mobile phase); so they move up the paper at different rates and separate

(c) ink would dissolve in the solvent and move up the paper / pencil (graphite) is insoluble

3.2

(a) layers of carbon atoms in hexagons, each carbon covalently bonded to three others; weak London forces between the layers

(b) in graphite one electron per carbon is delocalized and can move along the layers; in diamond all four outer electrons are in covalent bonds, so none are free

(c) many strong covalent bonds must be broken

(d) a giant covalent lattice; each Si bonded to four O, and each O bonded to two Si

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