OCR A | Year 12 chemistry

Bonding

Questions & answers

49 original questions | 346 marks. Questions start on page 2. Work in the dotted spaces, then check the answers at the back. Use the values supplied in each question.

Ionic bonding & formulae Q1-Q11

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Ionic bonding & formulae

Question 1 | OCR A | 7 marks

Complete the table of OCR A ions. [7]

Ion name	Formula and charge
Nitrate	...
Carbonate	...
Sulfate	...
Hydroxide	...
Ammonium	...
Zinc	...
Silver	...

Question 2 | OCR A | 7 marks

Write the formula of each compound. Every formula must be neutral and in the smallest whole-number ratio. [6]

Part	Compound	Formula
a	Aluminium oxide	...
b	Calcium nitrate	...
c	Ammonium sulfate	...
d	Magnesium hydroxide	...
e	Zinc carbonate	...
f	Silver nitrate	...

(g) State when brackets are required around a compound ion. [1]

Question 3 | OCR A | 4 marks

(a) State the precise OCR A definition of ionic bonding. [2 marks]

(b) Explain why electron transfer is not itself the ionic bond. [2 marks]

Question 4 | OCR A | 5 marks

Draw a dot-and-cross diagram for magnesium chloride, $MgCl_2$. Show outer-shell electrons only, electron origin, square brackets, charges and complete outer shells. [5 marks]

Question 5 | OCR A | 7 marks

Sodium forms Na^{+} ions and oxygen forms O^{2-} ions.

(a) Deduce the formula of sodium oxide. [1 mark]

(b) Draw a complete electron-origin diagram for sodium oxide. Show all ions, brackets, charges and outer-shell electrons. [6 marks]

Question 6 | OCR A | 10 marks

Main-group elements X and Y form X^{3+} and Y^{2-} ions with complete octets. X has three outer-shell electrons and Y has six before ion formation.

(a) Deduce the formula of the compound formed. [2 marks]

(b) State the total number of electrons transferred when one formula unit forms. [2 marks]

(c) Draw a complete electron-origin diagram for one formula unit. Show the smallest ion ratio, complete outer shells, brackets and charges. [6 marks]

Question 7 | OCR A | 12 marks

Stretch note: This question connects Atomic Structure II electron configurations with ionic formulae, electron origin and conductivity. Atom X has electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^2$. Atom Y has electron configuration $1s^2\ 2s^2\ 2p^5$.

(a) Identify X and Y. [2 marks]

(b) State the ions formed by X and Y. [2 marks]

(c) Deduce the formula of the compound formed. [1 mark]

(d) Draw a complete electron-origin diagram for the compound. [5 marks]

(e) Explain why the compound does not conduct as a solid but does conduct when molten. [2 marks]

Question 8 | OCR A | 3 marks

Which has the higher melting point, CaO or KCl? Explain your answer. [3]

Question 9 | OCR A | 3 marks

NaF and NaCl have comparable lattice arrangements. Explain why NaF has a higher melting point than NaCl. [3]

Question 10 | OCR A | 7 marks

Sodium chloride forms a giant ionic lattice.

(a) Explain why sodium chloride has a high melting point. [2 marks]

(b) Explain why solid sodium chloride does not conduct electricity but molten sodium chloride does. [3 marks]

(c) Explain why aqueous sodium chloride conducts electricity. [1 mark]

(d) State whether all ionic compounds are soluble in water. [1 mark]

Question 11 | OCR A | 8 marks

Each statement contains a chemistry error. Identify the error and write a corrected statement.

(a) The ionic bond is the transfer of electrons from a metal atom to a non-metal atom. [2 marks]

(b) Molten sodium chloride conducts because its electrons become free to move. [2 marks]

(c) Iodine melts because the covalent bond inside each I_2 molecule is broken. [2 marks]

(d) All ionic compounds dissolve in water simply because their ions are charged. [2 marks]

Covalent, dative & bond strength

Question 12 | OCR A | 5 marks

(a) State the precise OCR A definition of a covalent bond. [3 marks]

(b) State the number of shared electron pairs in H_2, O_2 and N_2. [2 marks]

Question 13 | OCR A | 7 marks

Draw complete dot-and-cross diagrams for HCl, O_2 and N_2. Show all shared pairs and all lone pairs. [7 marks]

Question 14 | OCR A | 7 marks

Carbon dioxide, CO_2, contains two carbon-oxygen double bonds.

(a) State the total number of shared electron pairs in one CO_2 molecule. [1 mark]

(b) Draw a complete dot-and-cross diagram for CO_2. Show electron origin and all lone pairs. [6 marks]

Question 15 | OCR A | 6 marks

(a) State what is meant by a dative covalent bond. [2 marks]

(b) For $NH_3 + H^+ \rightarrow NH_4^+$, name the electron-pair donor and acceptor and state the arrow direction. [2 marks]

(c) Draw the ammonium ion, showing the origin of the electron pair in the newly formed bond, square brackets and overall charge. [2 marks]

Question 16 | OCR A | 6 marks

A water molecule reacts with H^+ to form H_3O^+.

(a) Identify the electron-pair donor and acceptor and state the direction of the dative-bond arrow. [3 marks]

(b) Draw the H_3O^+ ion, showing the origin of the electron pair in the dative bond, brackets and charge. [3 marks]

Question 17 | OCR A | 8 marks

A student writes calcium nitrate as $CaNO_3$ and ammonium sulfate as NH_4SO_4.

(a) Correct both formulae and explain the charge balance in each compound. [4]

The same student draws the following diagram for $NH_3 + H^+ \rightarrow NH_4^+$.

Student's dative-bond diagram



(b) Identify two errors in the diagram. [2]

(c) Draw a corrected model diagram. [2]

Question 18 | OCR A | 3 marks

(a) State the precise definition of metallic bonding. [2 marks]

(b) Bond X has an average bond enthalpy of 436 kJ mol^{-1} and bond Y has 598 kJ mol^{-1}. Identify the stronger bond and justify your choice. [1 mark]

Question 19 | OCR A | 4 marks

Average bond enthalpy data are shown: C–C 347 kJ mol^{-1}; H–H 436 kJ mol^{-1}; C=C 612 kJ mol^{-1}; N≡N 945 kJ mol^{-1}.

(a) Identify the strongest bond and explain your choice. [2 marks]

(b) Use the data to compare the strengths of a C–C bond and a C=C bond. [2 marks]

Metallic bonding

Question 20 | OCR A | 6 marks

Magnesium has a giant metallic lattice.

(a) Describe the particles and attraction in metallic magnesium. [2 marks]

(b) Explain why magnesium conducts electricity as both a solid and a liquid. [2 marks]

(c) Explain why magnesium has a relatively high melting point. [2 marks]

Structures & properties

Question 21 | OCR A | 8 marks

Diamond and graphite are giant covalent forms of carbon.

(a) Explain why diamond has a very high melting point. [2 marks]

(b) Explain why diamond does not conduct electricity. [2 marks]

(c) Explain why graphite conducts electricity. [2 marks]

(d) Explain why the layers in graphite can slide over one another. [2 marks]

Question 22 | OCR A | 8 marks

Graphite is used as an electrode. Diamond is used on cutting tools.

(a) Explain why graphite is suitable for use as an electrode. [3 marks]

(b) Explain why diamond is suitable for use on a cutting tool. [3 marks]

(c) Explain why graphite is softer than diamond. [2 marks]

Question 23 | OCR A | 6 marks

Iodine is a simple molecular substance made from I_2 molecules.

(a) Describe the particles and attractions in solid iodine. [2 marks]

(b) Explain why iodine has a much lower melting point than diamond. [2 marks]

(c) State what is overcome when iodine melts and what remains intact. [1 mark]

(d) Explain why iodine does not conduct electricity in the solid or liquid state. [1 mark]

Question 24 | OCR A | 8 marks

The properties of four substances are shown.

Substance	Melting point / °C	Conducts as solid?	Conducts as liquid?
A	801	No	Yes
B	650	Yes	Yes
C	3550	No	No
D	114	No	No

(a) Identify the most likely structure type for A–D. [4]

(b) For each substance, use the conductivity evidence together with its melting point to justify the identification. [4]

Question 25 | OCR A | 9 marks

Four unfamiliar substances have the following properties.

Substance	Melting point / °C	Solid conductivity	Liquid conductivity
P	80	None	None
Q	1414	None	None
R	770	None	Good
S	1085	Good	Good

(a) Identify the most likely structure type for P–S. [4]

(b) Explain the change in conductivity when R melts. [3]

(c) Explain why Q has a much higher melting point than P. [2]

Question 26 | OCR A | 8 marks

A student compares barium fluoride, BaF_2, potassium metal and iodine.

(a) State the structure type of each substance. [3]

(b) Explain why solid potassium conducts electricity but solid barium fluoride and solid iodine do not. [3]

(c) Explain why barium fluoride has a much higher melting point than iodine. [2]

Shapes & bond angles

Question 27 | OCR A | 6 marks

(a) State the electron-pair repulsion principle used to predict molecular shape. [2 marks]

(b) Place these repulsions in decreasing order of strength: bond pair-bond pair, lone pair-bond pair, lone pair-lone pair. [3 marks]

(c) Explain why replacing a bonded pair with a lone pair usually decreases a bond angle. [1 mark]

Question 28 | OCR A | 12 marks

Complete the table by giving the molecular shape and bond angle(s). Names and angles only; diagrams are not required. [12]

Species	Bonding pairs	Lone pairs	Shape	Bond angle(s)
$BeCl_2$	2	0	...	...
BF_3	3	0	...	...
CH_4	4	0	...	...
NH_3	3	1	...	...
H_2O	2	2	...	...
SF_6	6	0	...	...

Question 29 | OCR A | 8 marks

(a) State the numbers of bonding pairs and lone pairs around the central atom in NH_3 and H_2O. [2 marks]

(b) For each molecule, state the shape name and draw a clear 3-D diagram. Also state its bond angle. [4 marks]

(c) Explain why the H-O-H angle is smaller than the H-N-H angle. [2 marks]

Question 30 | OCR A | 8 marks

(a) PCl_5 has five bonding pairs and no lone pairs around P. SF_6 has six bonding pairs and no lone pairs around S. State the name of the shape and the bond angle(s) for each molecule. [6 marks]

(b) Draw a clear 3-D diagram of each molecule to match the shape names in part (a). Use wedge-and-dash bonds where needed and keep equivalent bonds similar in length. [2 marks]

Electronegativity & polarity

Question 31 | OCR A | 7 marks

(a) Define electronegativity using precise OCR A wording. [2 marks]

(b) State which element is the most electronegative and describe the general direction in which electronegativity increases in the periodic table. [2 marks]

(c) Pauling electronegativities are H 2.1, C 2.5, O 3.5 and F 4.0. Calculate the electronegativity difference for C-H and O-H, then identify the more polar bond. [3 marks]

Question 32 | OCR A | 6 marks

(a) Explain what is meant by a polar covalent bond and a permanent dipole. [2 marks]

(b) Use δ+ and δ- to show the permanent dipole in H-Cl. Add a bond-dipole arrow pointing in the correct direction. [2 marks]

(c) Distinguish bond polarity from the polarity of a whole molecule. [2 marks]

Question 33 | OCR A | 8 marks

Selected Pauling electronegativities are Mg 1.2, H 2.1, C 2.5, Cl 3.0, O 3.5 and F 4.0.

(a) Calculate the electronegativity difference for Mg-Cl, C-Cl and O-H. [3 marks]

(b) Rank these three bonds from least polar to most polar. [2 marks]

(c) Use the values to suggest why $MgCl_2$ has mainly ionic bonding whereas CCl_4 has covalent bonding. [2 marks]

(d) State which atom is δ- in a C=O bond. [1 mark]

Question 34 | OCR A | 8 marks

(a) For each molecule, state whether it is polar or non-polar. [5]

Molecule	Polar / non-polar
CO_2	...
BF_3	...
H_2O	...
NH_3	...
CCl_4	...

(b) Choose one non-polar molecule from part (a) that contains polar bonds. State its shape, then explain why it has no overall dipole. A drawing is not required. [3]

Question 35 | OCR A | 8 marks

Carbon dioxide, O=C=O, and hydrogen cyanide, H-C≡N, are both linear. Pauling electronegativities are H 2.1, C 2.5, N 3.0 and O 3.5.

(a) State the shape name and bond angle around carbon in each molecule. Names and angles only; diagrams are not required in part (a). [4 marks]

(b) Add bond-dipole arrows to both molecules. Include partial charges at the terminal atoms. [2 marks]

(c) Explain why CO_2 is non-polar but HCN is polar. [2 marks]

Intermolecular forces

Question 36 | OCR A | 6 marks

(a) Define an induced dipole-dipole interaction. You may also use the term London dispersion force. [2 marks]

(b) Define a permanent dipole-dipole interaction. [2 marks]

(c) Define hydrogen bonding, including the atoms involved and the role of a lone pair. [2 marks]

Question 37 | OCR A | 7 marks

(a) State the strongest intermolecular force present between molecules or atoms of each substance. Use the most specific OCR A term. [5]

Substance	Strongest force
Ne	...
HCl	...
NH_3	...
CH_3OH	...
CO_2	...

(b) Explain why HCl molecules also experience induced dipole-dipole interactions. [2]

Question 38 | OCR A | 7 marks

The boiling points of three halogens are shown.

Substance	Boiling point / °C
Cl_2	−34.0
Br_2	58.8
I_2	184.3

(a) State the strongest intermolecular force between molecules of each halogen. [1]

(b) Explain the boiling-point trend from Cl_2 to I_2. [4]

(c) Predict whether F_2 boils above or below −34.0 °C. Justify your answer. [2]

Question 39 | OCR A | 7 marks

(a) Draw two HCl molecules to show a permanent dipole-dipole attraction. Use solid lines for H-Cl bonds, a dotted line for the intermolecular attraction and correct partial charges. [4 marks]

(b) Name the dotted attraction. [1 mark]

(c) A student calls the dotted attraction 'another covalent bond'. Explain why this is incorrect. [2 marks]

Hydrogen bonding & properties

Question 40 | OCR A | 7 marks

(a) Draw two water molecules and show one hydrogen bond. Include δ+ and δ-, a lone pair, solid covalent bonds and a dotted intermolecular attraction. [5 marks]

(b) Identify the two atoms linked by the hydrogen bond in your diagram, and explain why the dotted line is not an O-H covalent bond. [2 marks]

Question 41 | OCR A | 8 marks

The boiling points of four hydrogen halides are shown.

Substance	Boiling point / °C
HF	19.5
HCl	−85
HBr	−67
HI	−35

(a) Explain why HF has a much higher boiling point than HCl. [4]

(b) Explain the increase in boiling point from HCl to HI. [4]

Question 42 | OCR A | 8 marks

Ethanol, CH_3CH_2OH, and methoxymethane, CH_3OCH_3, have the same molecular formula and relative molecular mass. Their boiling points are 78.4 °C and -24.8 °C respectively.

(a) State the strongest intermolecular force in each pure liquid. [2 marks]

(b) Explain the large difference in boiling point. [4 marks]

(c) Draw one hydrogen bond between ethanol and water. Show a lone pair and correct partial charges. [2 marks]

Question 43 | OCR A | 7 marks

Hydrazine has the structural formula $H_2N\text{-}NH_2$. Each nitrogen atom has three bonded pairs and one lone pair. Hydrazine boils at 114 °C; ethane, C_2H_6, boils at -89 °C. Their relative molecular masses are similar.

(a) State the shape name around each nitrogen atom and state how its bond angle compares with 109.5°. A drawing is not required in part (a). [3 marks]

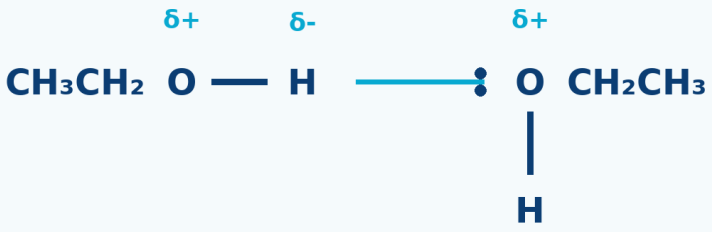
(b) Draw one hydrogen bond between two hydrazine molecules. Show the N-H bond, the neighbouring nitrogen lone pair and partial charges. [2 marks]

(c) Explain the large difference between the boiling points of hydrazine and ethane. [2 marks]

Question 44 | OCR A | 6 marks

A student’s proposed hydrogen-bond diagram for two ethanol molecules is shown.

Student diagram: proposed hydrogen bond between ethanol molecules



student has drawn the attraction as a solid line

(a) Identify three errors in the diagram. [3]

(b) Redraw the interaction correctly. [3]

Question 45 | OCR A | 8 marks

(a) Draw part of the open hydrogen-bonded lattice in ice. Distinguish O-H covalent bonds from hydrogen bonds. [3 marks]

(b) Explain why ice is less dense than liquid water. [3 marks]

(c) Explain why water has relatively high melting and boiling points. [2 marks]

Question 46 | OCR A | 7 marks

Consider iodine, I_2, methanol, CH_3OH, and hexane, C_6H_{14}.

(a) Predict whether iodine is more soluble in water or in hexane. Explain your answer using intermolecular forces. [3 marks]

(b) Predict whether methanol is more soluble in water or in hexane. Explain your answer. [3 marks]

(c) Explain why pure liquid methanol does not conduct electricity. [1 mark]

Question 47 | OCR A | 8 marks

Each carbon atom in the following chloromethanes is approximately tetrahedral.

Molecule	Boiling point / °C
CH_3Cl	−24
CH_2Cl_2	40
$CHCl_3$	61
CCl_4	77

(a) Explain why every C–Cl bond is polar. [2]

(b) Determine which molecules are polar. For the non-polar molecule, name its shape and explain dipole cancellation. A drawing is not required. [4]

(c) Explain why CCl_4 can have the highest boiling point despite being non-polar. [2]

Question 48 | OCR A | 7 marks

Three substances have similar relative molecular masses but very different boiling points.

Substance	Formula	M_r	Boiling point / °C
Ethane	C_2H_6	30	−89
Methanal	CH_2O	30	−19
Methanol	CH_3OH	32	65

(a) State the strongest intermolecular force in each substance. [3]

(b) Explain the boiling-point order, distinguishing all three types of intermolecular force. [4]

Question 49 | OCR A | 10 marks

Molecules X, Y and Z are CH_3F, CF_4 and CH_3OH respectively. Their boiling points are -78 °C, -128 °C and 65 °C. All three have four electron regions around carbon.

(a) For both CH_3F and CF_4, state the shape name and bond angle around carbon, then draw a clear 3-D diagram. [3 marks]

(b) Explain why CH_3F is polar but CF_4 is non-polar. [3 marks]

(c) State the strongest intermolecular force in each of X, Y and Z. [2 marks]

(d) Explain the boiling-point order Y < X < Z. [2 marks]

Answers & marking points

Equivalent correct chemistry and working are acceptable. Use the question number to find the matching answer.

Ionic bonding & formulae

Question 1 | OCR A | 7 marks

NO_3^- nitrate [1]; CO_3^{2-} carbonate [1]; SO_4^{2-} sulfate [1]; OH^- hydroxide [1]; NH_4^+ ammonium [1]; Zn^{2+} zinc [1]; Ag^+ silver [1]

Question 2 | OCR A | 7 marks

Aluminium oxide Al_2O_3 [1]; calcium nitrate $Ca(NO_3)_2$ [1]; ammonium sulfate $(NH_4)_2SO_4$ [1].

Magnesium hydroxide $Mg(OH)_2$ [1]; zinc carbonate $ZnCO_3$ [1]; silver nitrate $AgNO_3$ [1].

Use brackets only when more than one of a compound ion is needed, so the subscript applies to the whole ion [1]

Question 3 | OCR A | 4 marks

(a) Ionic bonding is the electrostatic attraction [1] between positive and negative ions [1]. [2]

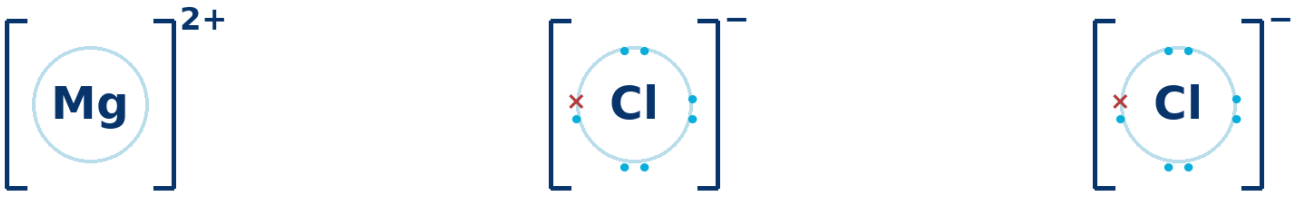
(b) Electron transfer is the process that forms the ions [1]; the bond is the attraction between the ions after transfer [1]. [2]

Question 4 | OCR A | 5 marks

One Mg^{2+} ion and two Cl^- ions, all bracketed and correctly charged [2].

Each chloride ion has eight outer-shell electrons [1], with one electron on each chloride shown as transferred from Mg [1]. Magnesium has lost two electrons in total [1]. [5]

$MgCl_2$: electron-origin ionic diagram



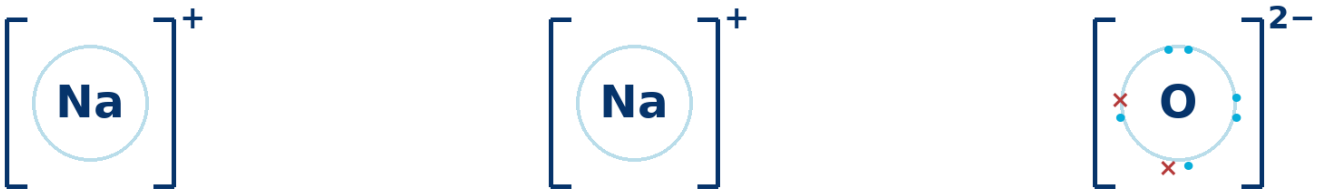
• = anion's original electron × = transferred electron from the metal

Question 5 | OCR A | 7 marks

(a) Two Na^+ ions are needed for one O^{2-} ion, so the formula is Na_2O [1]. [1]

(b) Two bracketed Na^+ ions and one bracketed O^{2-} ion [2]; oxide has eight outer-shell electrons [1], including two electrons shown as transferred from sodium [2]; electron totals and charges are consistent with Na_2O [1]. [6]

Na_2O: electron-origin ionic diagram



• = anion's original electron × = transferred electron from the metal

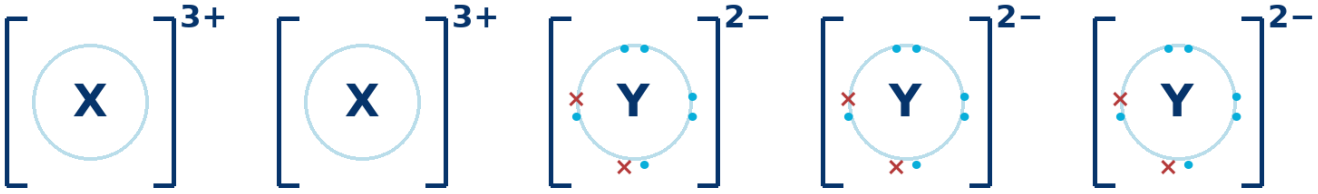
Question 6 | OCR A | 10 marks

(a) Charge balance requires 2 × (+3) and 3 × (−2), so the formula is X_2Y_3 [2]. [2]

(b) Two X atoms each lose three electrons, so six electrons are transferred in total [2]. [2]

(c) Two bracketed X^{3+} ions and three bracketed Y^{2-} ions [2]; each Y^{2-} has eight outer-shell electrons [1], with two transferred electrons shown on each [2]; all charges and the 2:3 ratio are correct [1]. [6]

X_2Y_3: electron-origin ionic diagram



• = anion's original electron × = transferred electron from the metal

Question 7 | OCR A | 12 marks

(a) X has 12 electrons, so X is magnesium, Mg [1]. Y has 9 electrons, so Y is fluorine, F [1]. [2]

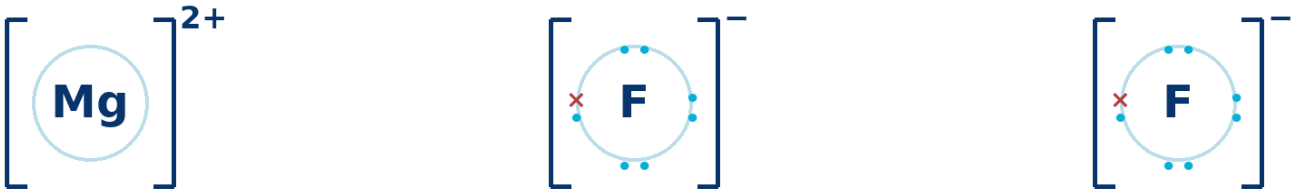
(b) Mg loses two electrons to form Mg^{2+} [1]; F gains one electron to form F^- [1]. [2]

(c) One Mg^{2+} requires two F^- ions, so the formula is MgF_2 [1]. [1]

(d) One bracketed Mg^{2+} and two bracketed F^- ions [2]; each fluoride has eight outer-shell electrons [1], including one electron shown as transferred from Mg [1]; final electron totals and charges are correct [1]. [5]

(e) In solid MgF_2, ions are fixed and cannot carry charge [1]. When molten, the ions are mobile and carry charge [1]. [2]

MgF_2: electron-origin ionic diagram



• = anion's original electron × = transferred electron from the metal

Question 8 | OCR A | 3 marks

CaO has the higher melting point. Ca^{2+} and O^{2-} have larger charges than K^+ and Cl^- [1], giving stronger electrostatic attractions between oppositely charged ions [1]. More energy is required to overcome these attractions when CaO melts [1].

Question 9 | OCR A | 3 marks

The smaller F^- ion allows the centres of opposite ions to be closer together [1]. With the same ion charges, electrostatic attractions are stronger in NaF [1], so more energy is needed to overcome them on melting [1].

Question 10 | OCR A | 7 marks

(a) NaCl has many strong electrostatic attractions between oppositely charged ions throughout a giant lattice [1]; much energy is required to overcome them [1]. [2]

(b) In solid NaCl, ions are fixed in position, so there are no mobile charge carriers [1]. When molten, the ions are mobile [1] and carry charge through the liquid [1]. [3]

(c) In aqueous NaCl, dissolved Na^+ and Cl^- ions are mobile and carry charge [1]. [1]

(d) Ionic compounds are often, but not always, soluble in water; solubility depends on whether new water-ion attractions compensate for separating the ions in the lattice [1]. [1]

Question 11 | OCR A | 8 marks

(a) Transfer forms the ions [1]; ionic bonding is the electrostatic attraction between oppositely charged ions [1]. [2]

(b) The charge carriers are mobile Na^+ and Cl^- ions [1], not free electrons [1]. [2]

(c) Melting iodine overcomes intermolecular forces between I_2 molecules [1]; the I-I covalent bonds remain intact [1]. [2]

(d) Ionic compounds are often but not always water-soluble [1]; solubility depends on the balance between attractions broken and new solvent-ion attractions formed [1]. [2]

Covalent, dative & bond strength

Question 12 | OCR A | 5 marks

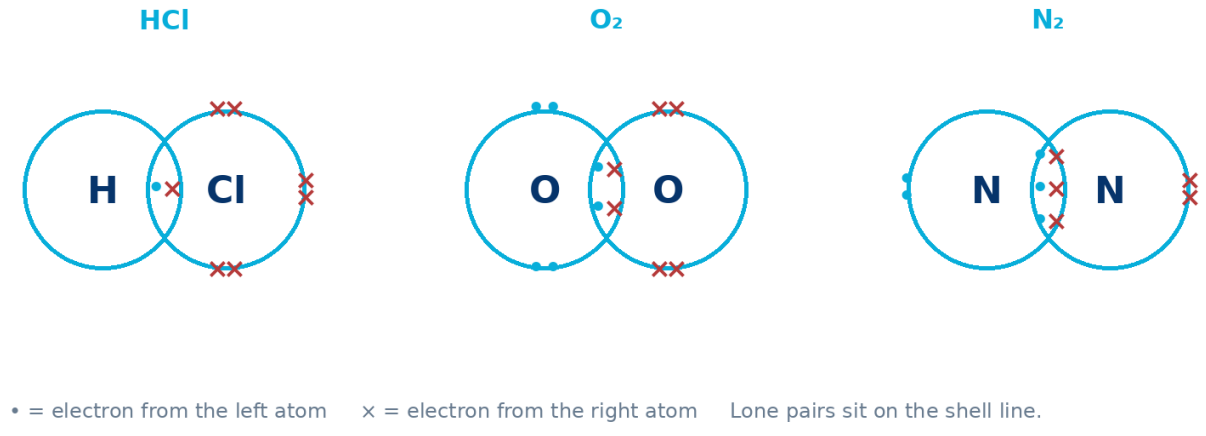
(a) A covalent bond is the strong electrostatic attraction [1] between a shared pair of electrons [1] and the nuclei of the bonded atoms [1]. [3]

(b) H_2 has one shared pair; O_2 has two; N_2 has three [2]. [2]

Question 13 | OCR A | 7 marks

HCl: one shared dot-and-cross pair and three lone pairs on Cl [2]. O_2: two shared pairs and two lone pairs on each O [2]. N_2: three shared pairs and one lone pair on each N [3]. [7]

Model electron-origin diagrams



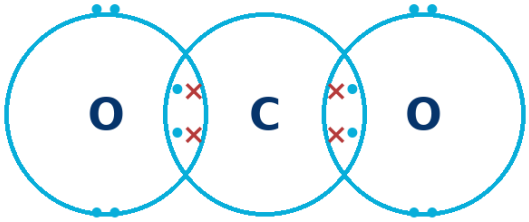
• = electron from the left atom × = electron from the right atom Lone pairs sit on the shell line.

Question 14 | OCR A | 7 marks

(a) Two C=O double bonds contain four shared electron pairs in total [1]. [1]

(b) Carbon is central with two shared pairs to each oxygen [2]; electron origin is shown consistently in all four shared pairs [2]; each oxygen has two lone pairs and carbon has no lone pairs [2]. [6]

Carbon dioxide: two C=O double bonds



• = oxygen electron × = carbon electron Shared pairs are in the overlaps; lone pairs sit on the shell line.

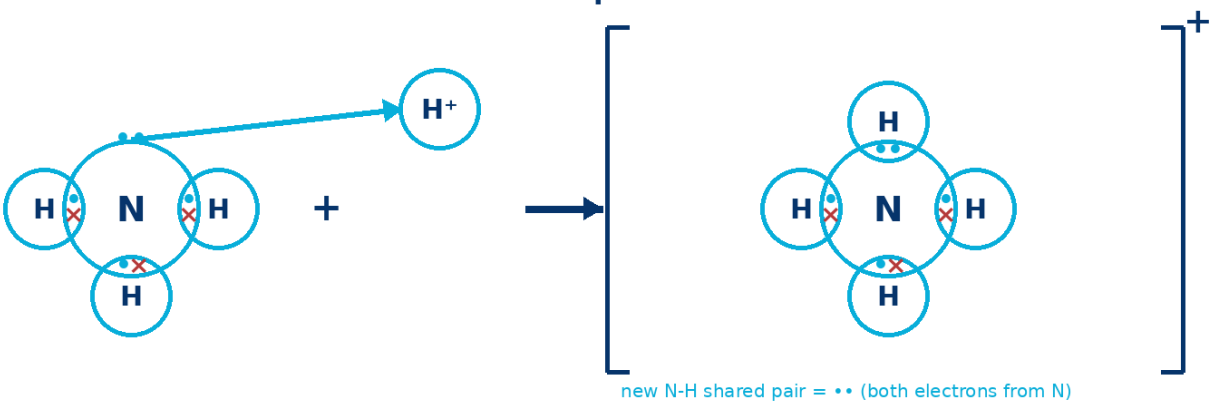
Question 15 | OCR A | 6 marks

(a) A dative covalent bond is a shared pair of electrons [1] in which both electrons were supplied by the same atom [1]. [2]

(b) NH_3 is the electron-pair donor and H^+ is the acceptor [1]; the arrow begins at the N lone pair and points towards H^+ [1]. [2]

(c) NH_4^+ is enclosed in square brackets with an overall + charge [1]; the new N-H shared pair contains two electrons originating from N [1]. [2]

Dative-bond formation: NH_3 donates a lone pair to H^+



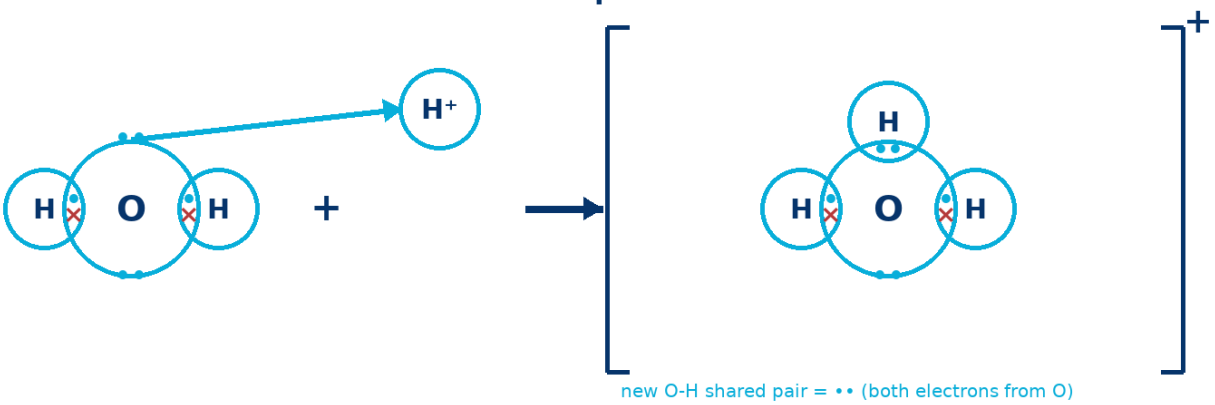
• = electron from N × = electron from H Arrow starts at the donated pair and points to H^+.

Question 16 | OCR A | 6 marks

(a) H_2O is the donor [1]; H^+ is the acceptor [1]; the arrow starts at an oxygen lone pair and points to H^+ [1]. [3]

(b) H_3O^+ is bracketed and has an overall + charge [1]; the newly formed O-H shared pair contains two electrons from O [1]; the remaining outer electrons are complete and consistently shown [1]. [3]

Dative-bond formation: H_2O donates a lone pair to H^+



new O-H shared pair = •• (both electrons from O)

• = electron from O × = electron from H Arrow starts at the donated pair and points to H^+.

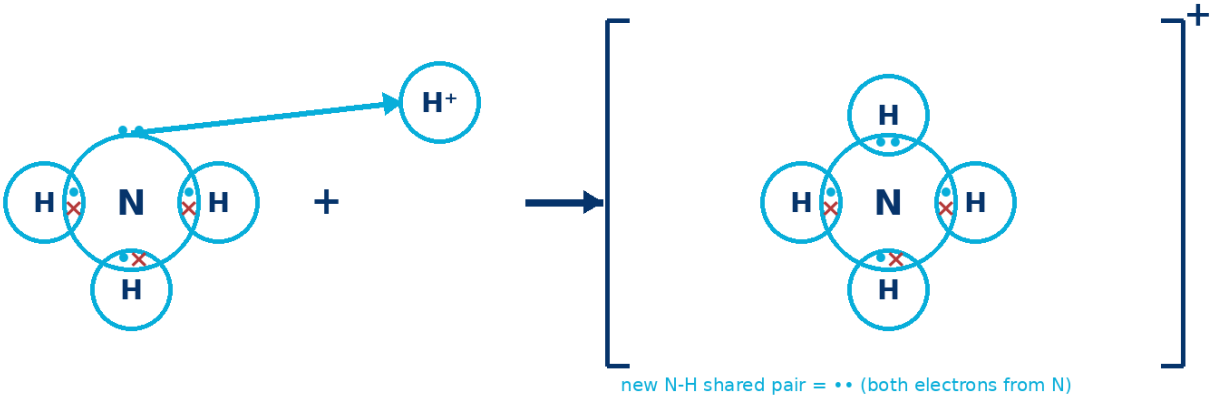
Question 17 | OCR A | 8 marks

(a) Calcium nitrate is $Ca(NO_3)_2$: one Ca^{2+} requires two NO_3^- ions [2]. Ammonium sulfate is $(NH_4)_2SO_4$: two NH_4^+ ions balance one SO_4^{2-} ion [2]. [4]

(b) The arrow is reversed; it must begin at the nitrogen lone pair and point to H^+ [1]. The product must be enclosed in square brackets with an overall + charge [1]. [2]

(c) Correct model: NH_3 donates its lone pair to H^+ and forms bracketed NH_4^+ [2]. [2]

Dative-bond formation: NH_3 donates a lone pair to H^+



new N-H shared pair = •• (both electrons from N)

• = electron from N × = electron from H Arrow starts at the donated pair and points to H^+.

Question 18 | OCR A | 3 marks

(a) Metallic bonding is the strong electrostatic attraction [1] between positive metal ions and delocalised electrons [1]. [2]

(b) Bond Y is stronger because it has the larger average bond enthalpy, so more energy is needed to break it [1]. [1]

Question 19 | OCR A | 4 marks

(a) N≡N is strongest because 945 kJ mol^{-1} is the largest average bond enthalpy [1], so it requires the most energy to break [1]. [2]

(b) C=C is stronger than C-C [1] because 612 kJ mol^{-1} is greater than 347 kJ mol^{-1} [1]. [2]

Metallic bonding

Question 20 | OCR A | 6 marks

(a) Magnesium contains positive metal ions and delocalised electrons [1] with strong electrostatic attraction between them [1]. [2]

(b) Delocalised electrons are mobile in both solid and liquid magnesium [1] and carry electrical charge [1]. [2]

(c) Strong electrostatic attractions act throughout the giant lattice [1], so much energy is needed to overcome them [1]. [2]

Structures & properties

Question 21 | OCR A | 8 marks

(a) Diamond is a giant three-dimensional covalent network [1]; many strong covalent bonds must be broken, requiring much energy [1]. [2]

(b) All four outer electrons of each carbon are localised in covalent bonds [1], so there are no mobile charged particles [1]. [2]

(c) Each carbon in graphite forms three covalent bonds, leaving delocalised electrons [1] that move along the layers and carry charge [1]. [2]

(d) Only weak attractions act between graphite layers [1], so little energy is needed for layers to slide [1]. [2]

Question 22 | OCR A | 8 marks

(a) Graphite contains delocalised electrons [1] that are mobile along the layers [1] and carry electrical charge through the electrode [1]. [3]

(b) Diamond is a rigid three-dimensional network [1] in which each carbon forms four strong covalent bonds [1], making it very hard and resistant to deformation [1]. [3]

(c) Graphite layers are held together by weak attractions [1], allowing the layers to slide over one another [1]. [2]

Question 23 | OCR A | 6 marks

(a) Solid iodine contains neutral I_2 molecules [1] attracted to one another by intermolecular forces [1]. [2]

(b) Melting iodine overcomes only weak intermolecular (van der Waals) forces between I_2 molecules [1]. Much more energy is required to break the strong C–C covalent bonds in diamond [1]. [2]

(c) Intermolecular forces are overcome; the I-I covalent bonds remain intact [1]. [1]

(d) Neutral molecules provide no mobile ions or delocalised electrons [1]. [1]

Question 24 | OCR A | 8 marks

(a) A ionic [1]; B metallic [1]; C giant covalent [1]; D simple molecular [1]. [4]

(b) A conducts only when its ions become mobile in the liquid [1]. B conducts in both states because delocalised electrons remain mobile [1]. C has no mobile charged particles [1]. D contains neutral molecules and no mobile charge carriers [1]. [4]

Conductivity alone cannot distinguish C from D: neither conducts. Their very different melting points provide the additional evidence.

Question 25 | OCR A | 9 marks

(a) P simple molecular [1]; Q giant covalent [1]; R ionic [1]; S metallic [1]. [4]

(b) In solid R, ions are fixed and cannot carry charge [1]. On melting, ions become mobile [1] and carry charge through the liquid [1]. [3]

(c) Q requires many strong covalent bonds in a giant network to be broken [1], whereas P requires only intermolecular forces between molecules to be overcome [1]. [2]

Question 26 | OCR A | 8 marks

(a) Barium fluoride: giant ionic [1]; potassium: giant metallic [1]; iodine: simple molecular [1].

(b) Solid BaF_2 has fixed ions and no mobile charge carriers [1]. Potassium has mobile delocalised electrons that carry charge [1]. Neutral I_2 molecules provide no mobile ions or delocalised electrons [1].

(c) BaF_2 has strong electrostatic attractions between Ba^{2+} and F^- ions throughout its lattice [1]. These require much more energy to overcome than the weak intermolecular forces between I_2 molecules [1].

Shapes & bond angles

Question 27 | OCR A | 6 marks

(a) Electron pairs around a central atom repel [1] and adopt positions of maximum separation / minimum repulsion [1]. [2]

(b) lone pair-lone pair [1] > lone pair-bond pair [1] > bond pair-bond pair [1]. [3]

(c) A lone pair occupies more space and repels bonding pairs more strongly, pushing bonds closer together [1]. [1]

Question 28 | OCR A | 12 marks

$BeCl_2$: linear [1], 180° [1]. BF_3: trigonal planar [1], 120° [1].

CH_4: tetrahedral [1], 109.5° [1]. NH_3: pyramidal [1], 107° [1].

H_2O: non-linear [1], 104.5° [1]. SF_6: octahedral [1], 90° between adjacent bonds [1]. [12]

Question 29 | OCR A | 8 marks

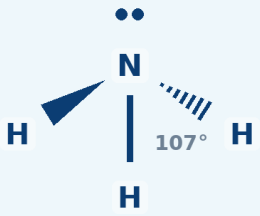
(a) NH_3: three bonding pairs and one lone pair [1]. H_2O: two bonding pairs and two lone pairs [1]. [2]

(b) NH_3: correctly named and drawn pyramidal shape [1], 107° [1]. H_2O: correctly named and drawn non-linear shape [1], 104.5° [1]. [4]

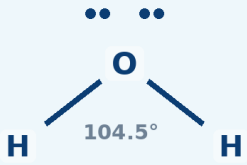
(c) H_2O has two lone pairs rather than one [1]; stronger lone-pair repulsions compress H-O-H more than H-N-H [1]. [2]

Lone pairs change shape and compress bond angles

NH_3 | pyramidal | 107°



H_2O | non-linear | 104.5°



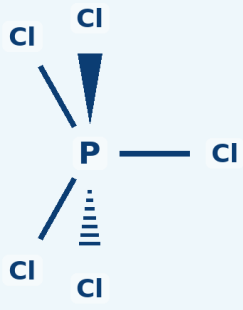
Question 30 | OCR A | 8 marks

(a) PCl_5: trigonal bipyramidal [1], with 120° between equatorial bonds [1], and 90° between axial and equatorial bonds plus 180° between the two axial bonds [1]. SF_6: octahedral [1], with 90° between adjacent bonds [1] and 180° between opposite bonds [1]. [6]

(b) One chemically correct 3-D drawing for each molecule, with the five or six bonds arranged correctly [1 each]. [2]

Five and six electron-pair shapes

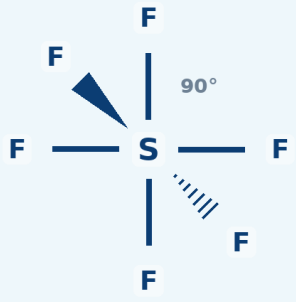
PCl_5 | trigonal bipyramidal



equatorial 120° axial-equatorial 90°

axial-axial 180°

SF_6 | octahedral



Electronegativity & polarity

Question 31 | OCR A | 7 marks

(a) Electronegativity is the ability of an atom to attract the bonding electrons [1] in a covalent bond [1]. [2]

(b) Fluorine is the most electronegative element [1]; electronegativity generally increases towards fluorine, across a period and up a group [1]. [2]

(c) C-H: |2.5 - 2.1| = 0.4 [1]. O-H: |3.5 - 2.1| = 1.4 [1]. O-H is more polar because it has the larger electronegativity difference [1]. [3]

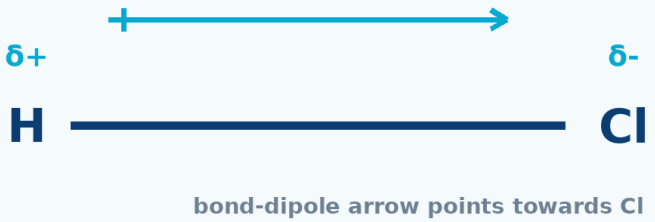
Question 32 | OCR A | 6 marks

(a) A polar covalent bond has an unequal distribution of bonding electron density caused by different electronegativities [1], producing permanent partial charges / a permanent dipole [1]. [2]

(b) H is δ+ and Cl is δ- [1]; the dipole arrow points from H towards Cl, with the crossed tail at the H end [1]. [2]

(c) Bond polarity concerns one bond [1]. Molecular polarity is the vector result of all bond dipoles in the 3-D shape; they may reinforce or cancel [1]. [2]

Bond dipole in HCl



Question 33 | OCR A | 8 marks

(a) Mg-Cl: 3.0 - 1.2 = 1.8 [1]; C-Cl: 3.0 - 2.5 = 0.5 [1]; O-H: 3.5 - 2.1 = 1.4 [1]. [3]

(b) C-Cl < O-H < Mg-Cl [2]. [2]

(c) Mg-Cl has a much larger electronegativity difference, indicating much greater ionic character [1]; C-Cl has a smaller difference and the electrons are shared covalently [1]. [2]

(d) O is δ- because it is more electronegative than C [1]. [1]

Question 34 | OCR A | 8 marks

(a) CO_2 non-polar [1]; BF_3 non-polar [1]; H_2O polar [1]; NH_3 polar [1]; CCl_4 non-polar [1]. [5]

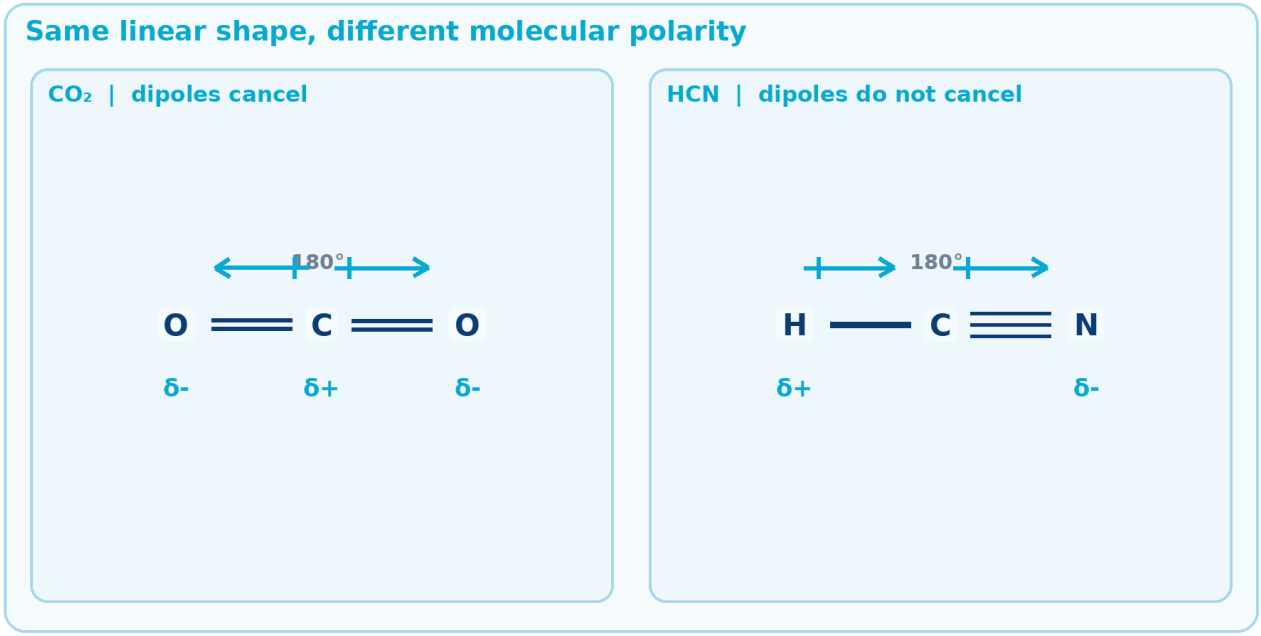
(b) Example CO_2: each C=O bond is polar [1], but the molecule is linear and symmetrical [1], so equal dipoles act in opposite directions and cancel [1]. [3]

Question 35 | OCR A | 8 marks

(a) CO_2 is linear, 180° [2]. HCN is linear around carbon, 180° [2]. [4]

(b) Correct terminal partial charges and dipole directions towards O in CO_2 and towards C then N across H-C≡N [1 each molecule]. [2]

(c) CO_2 has equal opposite C=O dipoles that cancel [1]. HCN is unsymmetrical, so its directed bond dipoles do not cancel and it has an overall dipole [1]. [2]



Intermolecular forces

Question 36 | OCR A | 6 marks

(a) A fluctuation in electron density creates an instantaneous dipole [1], which induces an opposite dipole in a neighbouring particle and causes attraction [1]. [2]

(b) Opposite partial charges on neighbouring polar molecules attract [2]. [2]

(c) Hydrogen bonding is an intermolecular attraction involving H bonded to N, O or F [1] and a lone pair on N, O or F in another molecule [1]. [2]

Question 37 | OCR A | 7 marks

(a) Ne: induced dipole-dipole [1]; HCl: permanent dipole-dipole [1]; NH_3: hydrogen bonding [1]; CH_3OH: hydrogen bonding [1]; CO_2: induced dipole-dipole [1]. [5]

(b) Every electron cloud fluctuates [1], so HCl also forms instantaneous dipoles that induce dipoles in neighbouring molecules [1]. [2]

Question 38 | OCR A | 7 marks

(a) Induced dipole-dipole / London dispersion forces [1]. [1]

(b) From Cl_2 to I_2 the molecules contain more electrons and have larger, more polarisable electron clouds [1]; instantaneous dipoles are larger [1], so induced dipole-dipole attractions are stronger [1] and more energy is needed to separate the molecules [1]. [4]

(c) F_2 should boil below -34.0 °C [1] because it has fewer electrons / a less polarisable cloud and weaker induced dipole-dipole attractions than Cl_2 [1]. [2]

Question 39 | OCR A | 7 marks

(a) Two solid H-Cl covalent bonds [1]; H δ+ and Cl δ- on both molecules [1]; a dotted line between Cl δ- and H δ+ [1]; molecules aligned so opposite partial charges attract [1]. [4]

(b) Permanent dipole-dipole attraction [1]. [1]

(c) No electron pair is shared between the molecules [1]; the dotted line is an electrostatic intermolecular attraction and is much weaker than the intramolecular H-Cl covalent bond [1]. [2]

Permanent dipole-dipole attraction between HCl molecules



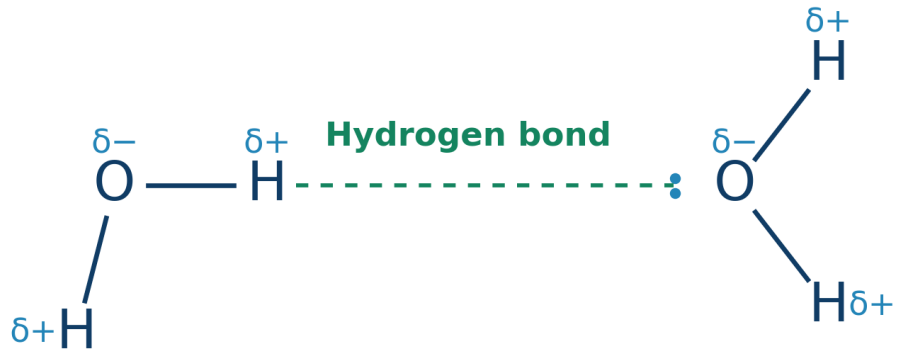
Hydrogen bonding & properties

Question 40 | OCR A | 7 marks

(a) Two correct bent H_2O molecules with solid O-H bonds [1]; O δ- and H δ+ [1]; a lone pair on O [1]; dotted H···O attraction [1]; line joins δ+ H to a lone pair / δ- O of the other molecule [1]. [5]

(b) The hydrogen bond joins the δ+ H of one water molecule to the lone pair on O of another [1]. The dotted line is an intermolecular electrostatic attraction, not a shared electron pair / covalent bond [1]. [2]

A hydrogen bond between two water molecules



Question 41 | OCR A | 8 marks

(a) F is highly electronegative, so HF has a strongly polar H-F bond [1]. The H δ+ of one molecule is attracted to a lone pair on F of another [1], forming hydrogen bonds [1]. More energy is required to overcome these stronger attractions [1]. [4]

(b) HCl to HI have progressively more electrons / larger electron clouds [1], which are more easily polarised [1]. Induced dipoles and London forces therefore become stronger [1], so more energy is needed and boiling point rises [1]. [4]

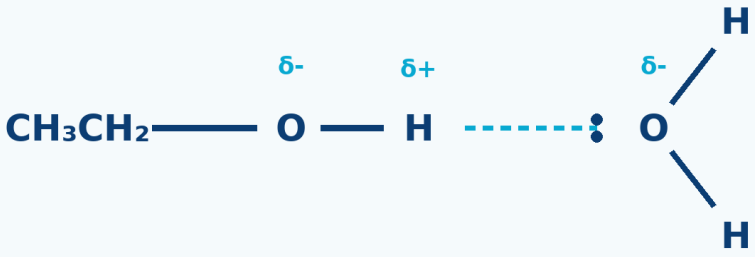
Question 42 | OCR A | 8 marks

(a) Ethanol: hydrogen bonding [1]. Methoxymethane: permanent dipole-dipole attraction [1]. [2]

(b) Ethanol contains an O-H bond and can form hydrogen bonds between its molecules [1]. Methoxymethane has no H directly bonded to O, N or F and cannot hydrogen-bond with itself [1]. Hydrogen bonds are stronger than its permanent dipole-dipole attractions [1], so more energy is required to separate ethanol molecules [1]. [4]

(c) Correct O-H bond, lone pair on the neighbouring O, δ signs and dotted H···O attraction [2]. [2]

Hydrogen bonding between ethanol and water



H···O hydrogen bond

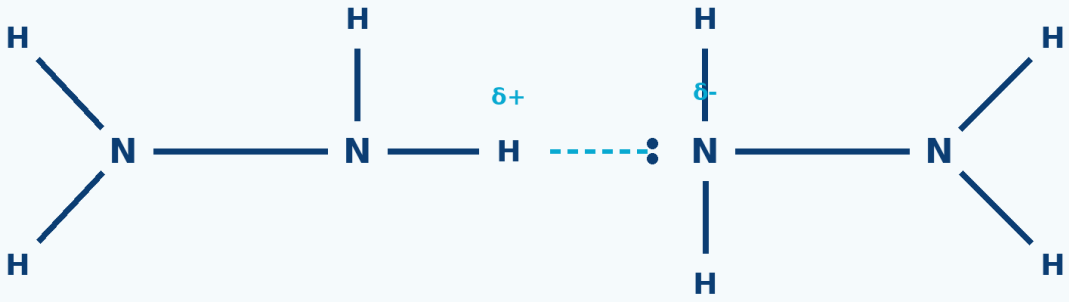
Question 43 | OCR A | 7 marks

(a) Each N has four electron pairs, one of which is lone, so the shape around each N is pyramidal [2]. Lone-pair repulsion compresses the angle below 109.5° [1]. [3]

(b) Dotted N-H···N attraction from δ+ H in an N-H bond [1] to a lone pair on the neighbouring δ− N [1]. [2]

(c) Hydrazine forms hydrogen bonds whereas ethane has only induced dipole-dipole attractions [1]; more energy is needed to separate hydrazine molecules [1]. [2]

Hydrogen bond between two hydrazine molecules



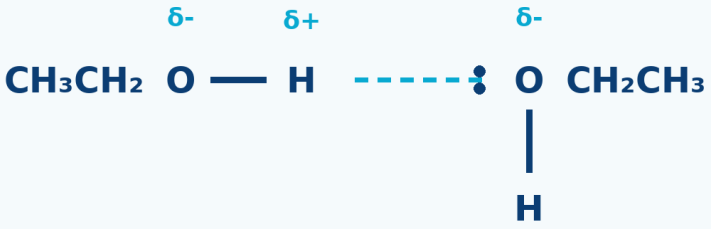
N-H···N hydrogen bond

Question 44 | OCR A | 6 marks

(a) O atoms should be δ-, not δ+ [1]; H in O-H should be δ+, not δ- [1]; the intermolecular attraction must be dotted / broken rather than drawn as a solid covalent-bond line [1]. [3]

(b) Correct solid covalent bonds [1], δ+ H···O δ- dotted attraction [1] and a lone pair on oxygen in the neighbouring molecule [1]. [3]

Correct hydrogen bond between ethanol molecules



O-H···O hydrogen bond

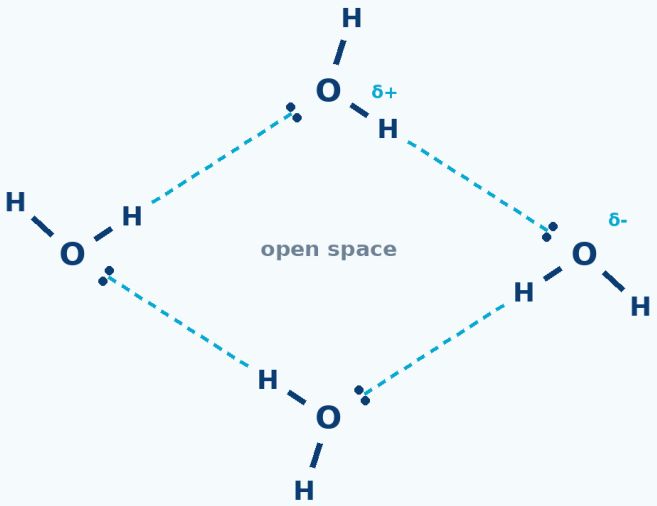
Question 45 | OCR A | 8 marks

(a) Water molecules are linked in an open arrangement by dotted hydrogen bonds [1], with solid O-H covalent bonds clearly distinguished [1] and the dotted attraction joining H δ+ to O δ- / a lone pair [1]. [3]

(b) In ice, hydrogen bonds hold water molecules in a fixed open lattice [1] with relatively large spaces [1]. The same mass therefore occupies a larger volume than in liquid water, so ice has lower density [1]. [3]

(c) Many hydrogen bonds between water molecules must be overcome [1], requiring relatively large energy input [1]. [2]

Part of the open hydrogen-bonded lattice in ice



Solid lines: O-H covalent bonds Dotted lines: hydrogen bonds

Question 46 | OCR A | 7 marks

(a) I_2 is more soluble in hexane [1]. Both are non-polar and interact mainly through induced dipole-dipole forces [1]; comparable new attractions can replace those broken on mixing [1]. [3]

(b) Methanol is more soluble in water [1]. Both are polar and methanol can form hydrogen bonds with water [1], giving favourable solute-solvent attractions [1]. [3]

(c) Pure methanol contains neutral molecules and has no mobile ions or delocalised electrons to carry charge [1]. [1]

Question 47 | OCR A | 8 marks

(a) Cl is more electronegative than C [1], so electron density is drawn towards Cl and each C-Cl bond has C δ+ and Cl δ- [1]. [2]

(b) CH_3Cl, CH_2Cl_2 and $CHCl_3$ are polar [3]. CCl_4 is tetrahedral and symmetrical, so its four equal C-Cl dipoles cancel and it is non-polar [1]. [4]

(c) CCl_4 has the largest electron cloud / most electrons [1], so it has the strongest induced dipole-dipole forces and needs the most energy to separate its molecules [1]. [2]

Question 48 | OCR A | 7 marks

(a) Ethane: induced dipole-dipole [1]. Methanal: permanent dipole-dipole [1]. Methanol: hydrogen bonding [1]. [3]

(b) Similar Mr values reduce the difference in London forces [1]. Methanal has a permanent C=O dipole, giving stronger attraction than in non-polar ethane [1]. Methanol molecules form hydrogen bonds [1], the strongest interaction in the set, so methanol requires the most energy to boil [1]. [4]

Question 49 | OCR A | 10 marks

(a) Both molecules are tetrahedral around carbon with a bond angle of approximately 109.5° [1]. Award one mark for each of two clear 3-D wedge-and-dash diagrams with four bonds and similar bond lengths [2]. [3]

(b) In CH_3F, the polar C-F bond produces a resultant dipole that is not cancelled by the three C-H bond dipoles [2]. In CF_4, four identical C-F dipoles are arranged symmetrically and cancel [1]. [3]

(c) X CH_3F: permanent dipole-dipole; Y CF_4: induced dipole-dipole; Z CH_3OH: hydrogen bonding. Award [2] for all three correct or [1] for any two. [2]

(d) CF_4 has only induced dipole forces; CH_3F also has permanent dipole attractions; CH_3OH forms hydrogen bonds, so progressively more energy is needed to separate the molecules [2]. [2]

