



CrackingCHEM

GCSE | A-LEVEL

UNDERSTAND • APPLY • SUCCEED

OCR A H432

Bonding II

Original exam questions | TEST IT → EXAM STYLE → HARDER MIXED → STRETCH
SPECIFICATION-LED. PROGRESSIVE. EXAM-FOCUSED.

OCR A SPECIFICATION

2.2.2(g-m) | Shapes, polarity and intermolecular forces

TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	10	4	1

23 ORIGINAL QUESTIONS

174 TOTAL MARKS

FINAL SPECIFICATION-ALIGNED EDITION | SHAPES • POLARITY • INTERMOLECULAR FORCES

Independent practice material. Every question is original and stays within OCR A 2.2.2(g-m).



START HERE

How to use this pack

Read the central atom first, then prove the shape, polarity and property

- 1 Complete TEST IT without notes. Repair any imprecise definition before moving on.
- 2 For every shape: count bonding pairs and lone pairs, maximise separation, then give the shape and angle.
- 3 For polarity: mark each bond dipole, use the 3-D shape, then decide whether the dipoles cancel.
- 4 For every property: name the particles and intermolecular force, then link strength to energy or mobility.

✓ **OCR A boundary:** This pack covers 2.2.2(g-m): shapes and bond angles, electronegativity, bond and molecular polarity, induced and permanent dipoles, hydrogen bonding and water anomalies.

Held back: Bonding I definitions and giant structures are only used as brief prior-knowledge links. Later Periodicity trends and organic reactions are not assessed.

Shape routine: Count – arrange – name – angle – draw in 3-D. Lone pair-lone pair repulsion is strongest; bond pair-bond pair is weakest.

Polarity routine: Different electronegativities create bond dipoles. A molecule is polar only when the directed dipoles do not cancel.

OCR terminology: Use the most specific term. Induced dipole-dipole interactions may be called London dispersion forces; OCR also permits van der Waals forces for induced or permanent dipole interactions.



SECTION A

TEST IT

Eight direct checks of the OCR A Bonding II foundations

QUESTION 1 | TEST IT

- (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 2 | TEST IT

- (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.

DIPOLE DIAGRAM

[2 marks]

- (c) Distinguish bond polarity from the polarity of a whole molecule.

[2 marks]

**QUESTION 3 | TEST IT**

(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 4 | TEST IT

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

Substance	Ne	HCl	NH ₃	CH ₃ OH	CO ₂
Strongest force					

[5 marks]

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

[2 marks]

**QUESTION 5 | TEST IT**

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

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[2 marks]

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

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[3 marks]

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

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[1 mark]

QUESTION 6 | TEST IT

Complete the table by stating the name of the molecular shape and its bond angle(s) for each species. Names and angles only; diagrams are not required in this question.

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 ₂ O	2	2		
SF ₆	6	0		

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[12 marks]

**QUESTION 7 | TEST IT**

(a) For each molecule, state whether it is polar or non-polar: CO_2 , BF_3 , H_2O , NH_3 and CCl_4 .

Molecule	CO_2	BF_3	H_2O	NH_3	CCl_4
Polar / non-polar					

[5 marks]

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

[3 marks]

QUESTION 8 | TEST IT

(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.

HYDROGEN-BOND DIAGRAM

[5 marks]

(b) Identify the hydrogen-bond donor and acceptor in your diagram, and explain why the dotted line is not an O-H covalent bond.

[2 marks]



EXAM STYLE

Ten original structured questions using OCR A command words and marking logic

(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]



(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 in the box. Also state its bond angle.

NH₃ AND H₂O SHAPES

[4 marks]

- (c) Explain why the H-O-H angle is smaller than the H-N-H angle.

[2 marks]



Carbon dioxide, $\text{O}=\text{C}=\text{O}$, and hydrogen cyanide, $\text{H}-\text{C}\equiv\text{N}$, are both linear. Pauling electronegativities are H 2.1, C 2.5, N 3.0 and O 3.5.

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

(c) Explain why CO_2 is non-polar but HCN is polar.

Bonding II | OCR A | 9

**QUESTION 12 | EXAM STYLE**

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.

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[3 marks]

(b) Rank these three bonds from least polar to most polar.

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[2 marks]

(c) Use the values to suggest why MgCl_2 has mainly ionic bonding whereas CCl_4 has covalent bonding.

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[2 marks]

(d) State which atom is δ^- in a C=O bond.

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[1 mark]

**QUESTION 13 | EXAM STYLE**

- (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.

HCl INTERMOLECULAR-FORCE DIAGRAM

[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]

**QUESTION 14 | EXAM STYLE**

The boiling points of three halogens are shown.

Substance	Cl ₂	Br ₂	I ₂
Boiling point / °C	-34.0	58.8	184.3

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

[1 mark]

(b) Explain the boiling-point trend from Cl₂ to I₂.

[4 marks]

(c) Predict whether F₂ has a boiling point above or below -34.0 °C. Justify your answer.

[2 marks]

**QUESTION 15 | EXAM STYLE**

The boiling points of four hydrogen halides are shown.

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

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

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[4 marks]

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

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[4 marks]

**QUESTION 16 | EXAM STYLE**

Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, 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.

ETHANOL-WATER HYDROGEN BOND

[2 marks]

**QUESTION 17 | EXAM STYLE**

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

PART OF AN ICE LATTICE

[3 marks]

- (b) Explain why ice is less dense than liquid water.

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[3 marks]

- (c) Explain why water has relatively high melting and boiling points.

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[2 marks]

**QUESTION 18 | EXAM STYLE**

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]



SECTION C

HARDER MIXED

Four less-scaffolded applications combining shape, dipoles and physical properties

QUESTION 19 | HARDER MIXED

The boiling points of four chloromethanes are shown. Each carbon atom is approximately tetrahedral.

Molecule	CH_3Cl	CH_2Cl_2	CHCl_3	CCl_4
Boiling point / $^{\circ}\text{C}$	-24	40	61	77

(a) Explain why every C-Cl bond is polar.

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[2 marks]

(b) Determine which of the four molecules are polar. For the non-polar molecule, state its shape name and explain why its bond dipoles cancel. A drawing is not required.

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[4 marks]

(c) Explain why CCl_4 can have the highest boiling point even though it is non-polar.

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[2 marks]



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

Substance	Formula	Mr	Boiling point / °C
ethane	C ₂ H ₆	30	-89
methanal	CH ₂ O	30	-19
methanol	CH ₃ OH	32	65

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

[3 marks]

(b) Explain the order of boiling points. Your answer must distinguish all three types of intermolecular force.

[4 marks]

**QUESTION 21 | HARDER MIXED**

Hydrazine has the structural formula $\text{H}_2\text{N}-\text{NH}_2$. 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 donor, acceptor lone pair and partial charges.

HYDRAZINE HYDROGEN BOND**[2 marks]**

(c) Explain the large difference between the boiling points of hydrazine and ethane.

[2 marks]

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

CCOC(=O)OCC

student has drawn the attraction as a solid line

- (a) Identify three errors in the diagram.

[3 marks]

- (b)** Redraw the interaction correctly.

CORRECTED HYDROGEN-BOND DIAGRAM

CORRECTED HYDROGEN-BOND DIAGRAM

[3 marks]



SECTION D

STRETCH / SYNOPTIC

One final problem connecting 3-D shape, dipole cancellation and boiling point

QUESTION 23 | STRETCH / SYNOPTIC

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 in the box.

TWO TETRAHEDRAL MOLECULES

[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 $\text{Y} < \text{X} < \text{Z}$.

[2 marks]



CrackingCHEM

GCSE | A-LEVEL

UNDERSTAND • APPLY • SUCCEED

OCR A H432

Bonding II

Fully worked answers | OCR A-style marking guidance

FULLY WORKED. PRECISELY MARKED. BUILT FOR IMPROVEMENT.

OCR A SPECIFICATION

2.2.2(g-m) | Shapes, polarity and intermolecular forces

TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	10	4	1

23 QUESTIONS MARKED

174 MARKS EXPLAINED

FINAL SPECIFICATION-ALIGNED EDITION | SHAPES • POLARITY • INTERMOLECULAR FORCES

Independent practice material. Every question is original and stays within OCR A 2.2.2(g-m).



OCR A MAP

How this pack matches OCR A 2.2.2(g-m)

Full coverage of shapes, polarity and intermolecular forces with later content held back

Specification area	Recurring OCR demand	Frequent trap	Questions
Shapes 2.2.2(g-h)	Count bonded and lone pairs; predict and draw 3-D shape and angle.	Naming the electron-pair arrangement instead of the molecular shape.	5-11, 21, 23
Electronegativity 2.2.2(i)	Define electronegativity and interpret Pauling values.	Treating bond type as a sharp numerical cut-off.	1-2, 12, 19, 23
Polarity 2.2.2(j)	Combine bond dipoles with molecular shape and cancellation.	Assuming any molecule with polar bonds must be polar.	2, 7, 11-13, 19-20, 23
Intermolecular forces 2.2.2(k-l)	Use induced, permanent and hydrogen-bonding models precisely.	Drawing an intermolecular attraction as a solid covalent bond.	3-4, 8, 13-16, 18, 20-23
Water anomalies 2.2.2(m)	Relate hydrogen bonding to ice density and melting/boiling points.	Saying hydrogen bonds are stronger in liquid water than in ice.	17

Research basis: Checked against OCR A Chemistry H432 specification Version 3.1 and the CrackingChem Year 12 master specification map. Every question is original.

Assessment boundary: No later Periodicity trend explanations, organic reactions or energetics calculations are assessed. Bonding I appears only as prerequisite language.

Step	Self-marking action
1 Count	Recount bonding pairs and lone pairs around the central atom.
2 Draw	Check equal bond lengths, wedge/dash direction, labels and lone pairs.
3 Decide	Mark bond dipoles, then use geometry to test cancellation.
4 Explain	Name the force before linking strength to energy, boiling point or solubility.



SECTION A

TEST IT answers

Exact OCR A terminology, completed tables and model diagrams

TEST IT 1

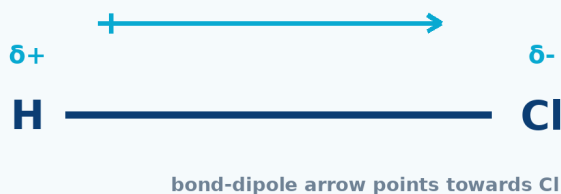
- (a) Electronegativity is the ability of an atom to attract the bonding electrons [1] in a covalent bond [1]. [2]
- (b) Fluorine is the most electronegative element [1]; electronegativity generally increases towards fluorine, across a period and up a group [1]. [2]
- (c) C-H: $|2.5 - 2.1| = 0.4$ [1]. O-H: $|3.5 - 2.1| = 1.4$ [1]. O-H is more polar because it has the larger electronegativity difference [1]. [3]

Examiner guidance: Do not award a definition that says only 'how much an atom wants electrons'. It must refer to bonding electrons in a covalent bond.

TEST IT 2

- (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 $\delta+$ and Cl is $\delta-$ [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



TEST IT 3

- (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]

Examiner guidance: OCR accepts induced dipole-dipole as London (dispersion) force. Both induced and permanent dipole interactions may also be described as van der Waals forces, but the more specific term is better here.

TEST IT 4

- (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]

**TEST IT 5**

- (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]

TEST IT 6

- 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]

Examiner guidance: For SF_6 , 180° also occurs between opposite bonds, but the characteristic octahedral angle required is 90° .

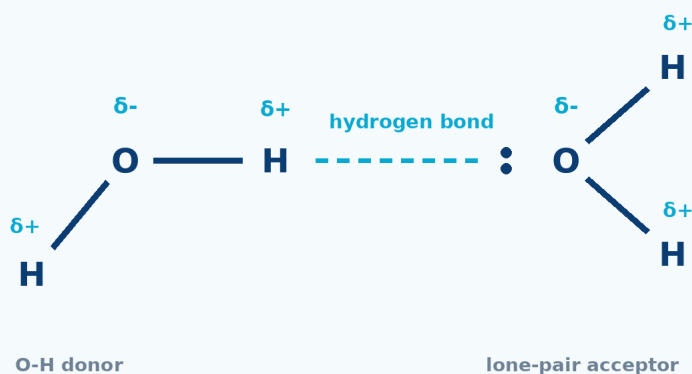
TEST IT 7

- (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 $\text{C}=\text{O}$ bond is polar [1], but the molecule is linear and symmetrical [1], so equal dipoles act in opposite directions and cancel [1]. [3]

Examiner guidance: BF_3 or CCl_4 earns the same three-mark chain when symmetry and dipole cancellation are explained correctly.

TEST IT 8

- (a) Two correct bent H_2O molecules with solid O-H bonds [1]; O δ^- and H δ^+ [1]; a lone pair on the acceptor O [1]; dotted $\text{H}\cdots\text{O}$ attraction [1]; line joins δ^+ H to a lone pair / δ^- O of the other molecule [1]. [5]
- (b) The molecule supplying O-H is the donor and the lone-pair oxygen is the acceptor [1]. The dotted line is an intermolecular electrostatic attraction, not a shared electron pair / covalent bond [1]. [2]

Model hydrogen bond between two water molecules



SECTION B

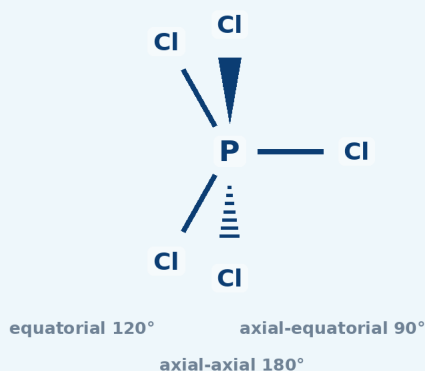
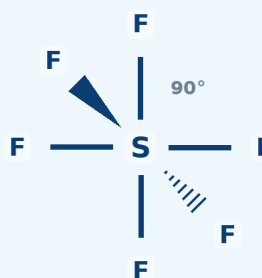
EXAM STYLE answers

Complete reasoning routes, accurate 3-D models and OCR A marking guidance

EXAM STYLE 9

- (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

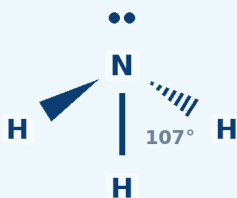
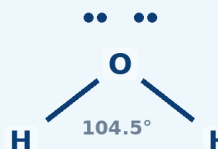
 PCl_5 | trigonal bipyramidal SF_6 | octahedral

Examiner guidance: Equivalent bonds should be drawn to a consistent length. Wedges and hashed wedges show bonds out of and behind the page; they do not indicate different bond types.

EXAM STYLE 10

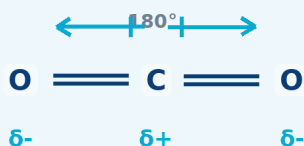
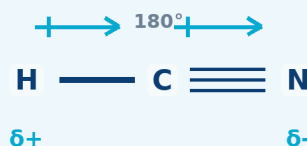
- (a) NH_3 : three bonding pairs and one lone pair [1]. H_2O : two bonding pairs and two lone pairs [1]. [2]
- (b) NH_3 : correctly named and drawn pyramidal shape [1], 107° [1]. H_2O : correctly named and drawn non-linear shape [1], 104.5° [1]. [4]
- (c) H_2O has two lone pairs rather than one [1]; 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° 

**EXAM STYLE 11**

- (a) CO₂ is linear, 180° [2]. HCN is linear around carbon, 180° [2]. [4]
- (b) Correct terminal partial charges and dipole directions towards O in CO₂ and towards C then N across H-C≡N [1 each molecule]. [2]
- (c) CO₂ 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]

Same linear shape, different molecular polarity**CO₂ | dipoles cancel****HCN | dipoles do not cancel****EXAM STYLE 12**

- (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]

Examiner guidance: Electronegativity difference is evidence for a continuum of bond character. Do not treat one numerical threshold as an absolute law.

**EXAM STYLE 13**

- (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**EXAM STYLE 14**

- (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]

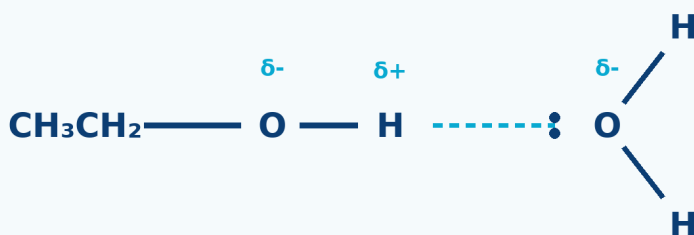
**EXAM STYLE 15**

- (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]

Examiner guidance: Do not explain the trend using the strength of the H-X covalent bond. Boiling separates molecules; it does not break the covalent bond inside each molecule.

EXAM STYLE 16

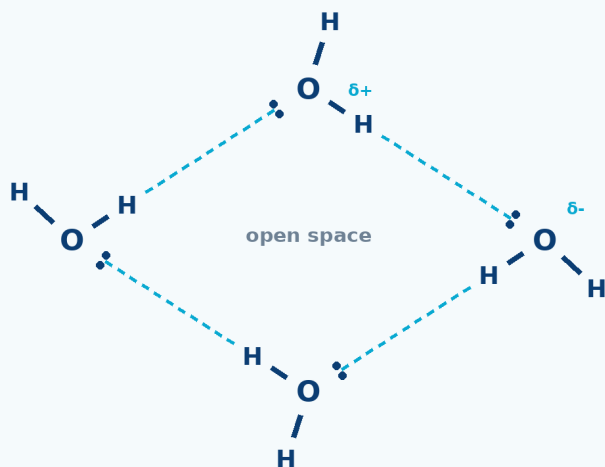
- (a) Ethanol: hydrogen bonding [1]. Methoxymethane: permanent dipole-dipole attraction [1]. [2]
- (b) Ethanol contains an O-H bond and can form hydrogen bonds between its molecules [1]. Methoxymethane has no H directly bonded to O, N or F and cannot hydrogen-bond with itself [1]. Hydrogen bonds are stronger than its permanent dipole-dipole attractions [1], so more energy is required to separate ethanol molecules [1]. [4]
- (c) Correct O-H donor, lone-pair O acceptor, δ signs and dotted H $\cdots$ O attraction [2]. [2]

Hydrogen bonding between ethanol and water

H $\cdots$ O hydrogen bond

**EXAM STYLE 17**

- (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

Examiner guidance: Do not say the O-H covalent bonds break when ice melts or water boils.

EXAM STYLE 18

- (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]



SECTION C

HARDER MIXED answers

Less-scaffolded diagrams, data comparisons and complete explanation chains

HARDER MIXED 19

- (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]

Examiner guidance: The trend is a useful warning: molecular polarity is not the only factor controlling boiling point. London forces can dominate as electron-cloud size increases.

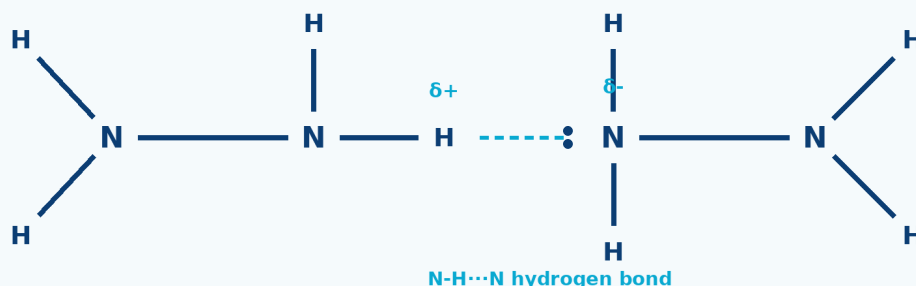
HARDER MIXED 20

- (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]

HARDER MIXED 21

- (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 with N-H donor [1] and lone-pair N acceptor / correct partial charges [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]

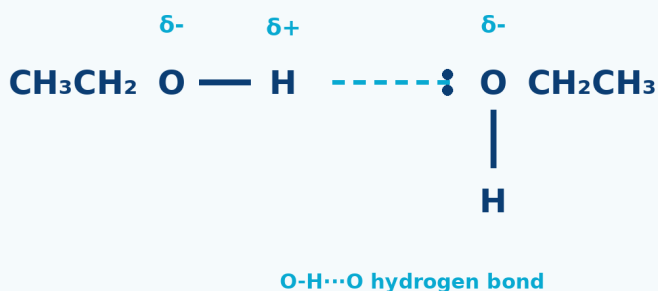
Hydrogen bond between two hydrazine molecules



HARDER MIXED 22

- (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 the acceptor oxygen [1]. [3]

Correct hydrogen bond between ethanol molecules





SECTION D

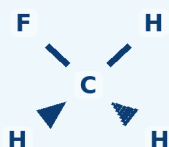
STRETCH / SYNOPTIC answers

One final explanation joining shape, dipole cancellation and intermolecular force

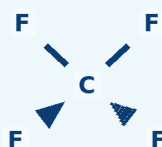
STRETCH / SYNOPTIC 23

- (a) Both molecules are tetrahedral around carbon with a bond angle of approximately 109.5° [1]. Award one further mark for 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]

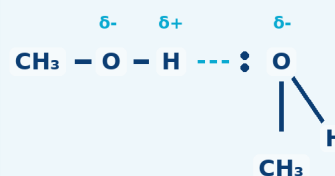
Shape, polarity and strongest intermolecular force

X CH_3F 109.5° 

polar molecule
permanent dipole-dipole

Y CF_4 109.5° 

non-polar molecule
induced dipole-dipole

Z CH_3OH 

hydrogen bonding
also permanent + induced

Examiner guidance: A complete answer separates bond polarity from molecular polarity, then names the intermolecular force before discussing boiling point.