



AQA 7405

Bonding 2

Original exam questions | TEST IT → EXAM STYLE → HARDER MIXED

SPECIFICATION-LED. PROGRESSIVE. EXAM-FOCUSED.

AQA SPECIFICATION

3.1.3.5 | 3.1.3.6 | 3.1.3.7

TEST IT

EXAM STYLE

HARDER MIXED

STRETCH

8

8

4

2

22 ORIGINAL QUESTIONS

196 TOTAL MARKS

Independent practice material. Every question is original and designed from recurring AQA assessment patterns.

Mapped to AQA Chemistry 7405 | specification checked September 2026

How to use this pack [START HERE](#)

1

Use the fixed VSEPR route

Count bonding pairs and lone pairs, identify the parent electron-pair geometry, then remove lone-pair positions and adjust the angle.

2

Separate bond polarity from molecular polarity

Assign partial charges from electronegativity, then use the three-dimensional shape to decide whether the bond dipoles cancel.

3

Build every property explanation as a chain

Name the intermolecular force, compare its strength, state the energy needed to overcome it, then link to boiling point or volatility.

4

Audit every diagram

Check similar bond lengths, wedge-and-dash geometry, lone pairs, partial charges and dotted intermolecular attractions before moving on.

ANGLE CONTROL Lone pair-lone pair repulsion > lone pair-bond pair repulsion > bond pair-bond pair repulsion.

FORCE CONTROL London (van der Waals) forces act between all particles. Permanent dipole-dipole forces require polar molecules. Hydrogen bonding needs H bonded to N, O or F and a lone pair on N, O or F in a neighbouring molecule.

AQA BOUNDARY This pack tests AQA 3.1.3.5-3.1.3.7 only. It does not reopen ionic, metallic or giant-structure content except for the specified ice link.

SECTION A TEST IT

Secure the language, shapes, angles, polarity and force identification

QUESTION 1 | TEST IT

(a) Define electronegativity. (2 marks)

.....

(b) Define a polar covalent bond. (2 marks)

.....

(c) State the three types of intermolecular force named in the AQA specification. (3 marks)

.....

(d) State which type of intermolecular force acts between all atoms and molecules. (1 mark)

.....

QUESTION 2 | TEST IT

(a) Explain why electron pairs around a central atom adopt particular positions in space. (2 marks)

.....

(b) Place these repulsions in decreasing order of strength: bond pair-bond pair, lone pair-bond pair, lone pair-lone pair. (2 marks)

.....

(c) Explain why a lone pair repels other electron pairs more strongly than a bonding pair. (2 marks)

.....

QUESTION 3 | TEST IT

Complete the table by writing the name of each molecular shape and its characteristic bond angle or angles. For shape prediction, treat each multiple bond as one bonding region.

(a) Complete all seven rows. (14 marks)

Species	Bonding regions	Lone pairs	Name of molecular shape	Characteristic angle(s)
CO ₂	2	0		
BF ₃	3	0		
CH ₄	4	0		
NH ₃	3	1		
H ₂ O	2	2		
PCl ₅	5	0		
SF ₆	6	0		

QUESTION 4 | TEST IT

Use solid wedges and dashed wedges where they are needed to show three-dimensional arrangement.

- (a)** Draw the shape of CH_4 . (2 marks)

Structure / working space

- (b)** Draw NH_3 , including the lone pair on nitrogen. (3 marks)

Structure / working space

- (c)** Draw H_2O , including both lone pairs, and label the H-O-H bond angle. (3 marks)

Structure / working space

QUESTION 5 | TEST IT

Use these Pauling electronegativity values: H 2.1, C 2.5, Br 2.8, Cl 3.0, O 3.5, F 4.0.

- (a)** Add δ^+ and δ^- to the H-Cl bond. (1 mark)

- (b)** Add δ^+ and δ^- to the C=O bond. (1 mark)

- (c)** Add δ^+ and δ^- to the O-H bond. (1 mark)

- (d)** Explain how the partial charges arise in a polar covalent bond. (2 marks)

- (e)** Place H-F, H-Cl and H-Br in decreasing order of bond polarity. Justify the first position. (2 marks)

QUESTION 6 | TEST IT

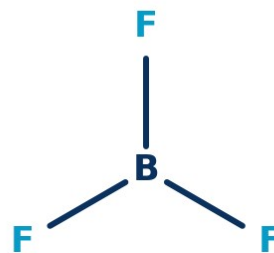
Figure 1 shows four molecules. Every bond to O, F or Cl shown is polar.

Figure 1

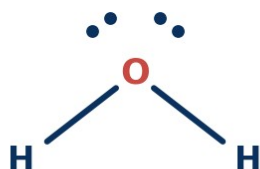
A

 CO_2

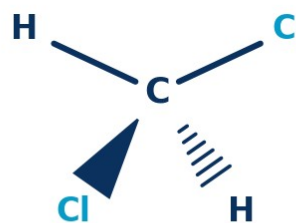
B

 BF_3

C

 H_2O

D

 CH_2Cl_2

(a) State whether each molecule A-D has a permanent dipole. (4 marks)

.....

.....

.....

(b) Explain why A and B do not have permanent dipoles. (2 marks)

.....

.....

.....

(c) Explain why C and D do have permanent dipoles. (2 marks)

.....

.....

QUESTION 7 | TEST IT

State the strongest type of intermolecular force present between molecules of each substance.

(a) HCl (1 mark)

.....

.....

(b) CH_4 (1 mark)

.....

.....

(c) NH_3 (1 mark)

.....

(d) CH_3OCH_3 (1 mark)

(e) Explain why all four have London (van der Waals) forces. (2 marks)

QUESTION 8 | TEST IT

(a) Draw a hydrogen bond between two water molecules. Show the relevant partial charges and a lone pair on the acceptor molecule. (4 marks)

Structure / working space

(b) Explain why HCl molecules do not form hydrogen bonds with one another. (2 marks)

(c) State why a hydrogen bond must not be drawn as a solid covalent bond. (1 mark)

SECTION B EXAM STYLE

Apply shape, polarity and intermolecular-force ideas in linked AQA-style questions

QUESTION 9 | EXAM STYLE

The table gives the numbers of bonding regions and lone pairs around the central atom. For shape prediction, treat each multiple bond as one bonding region.

Species	Bonding regions	Lone pairs
NH_4^+	4	0
SO_2	2	1
I_3^-	2	3
XeF_4	4	2

(a) Determine and state the name of the molecular shape of each species. (4 marks)

(b) State one characteristic bond angle for each species. (4 marks)

- (c) Draw XeF_4 . Show the two lone pairs on Xe and their positions relative to the square plane of F atoms. (2 marks)

Structure / working space

QUESTION 10 | EXAM STYLE

CH_4 , NH_3 and H_2O each have four electron pairs around the central atom.

- (a) State the name of the molecular shape and the bond angle of each molecule. (6 marks)

.....

.....

.....

.....

- (b) Explain why the bond angle decreases from CH_4 to NH_3 to H_2O . (2 marks)

.....

.....

.....

QUESTION 11 | EXAM STYLE

The table gives boiling points for Group 18 elements.

Element	Number of electrons	Boiling point / °C
Ne	10	-246
Ar	18	-186
Kr	36	-153
Xe	54	-108

- (a) Name the force that acts between the atoms. (1 mark)

.....

- (b) Explain the boiling-point trend from Ne to Xe. (4 marks)

.....

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.....

- (c) Predict how the boiling point of Rn compares with that of Xe. Justify your prediction. (3 marks)

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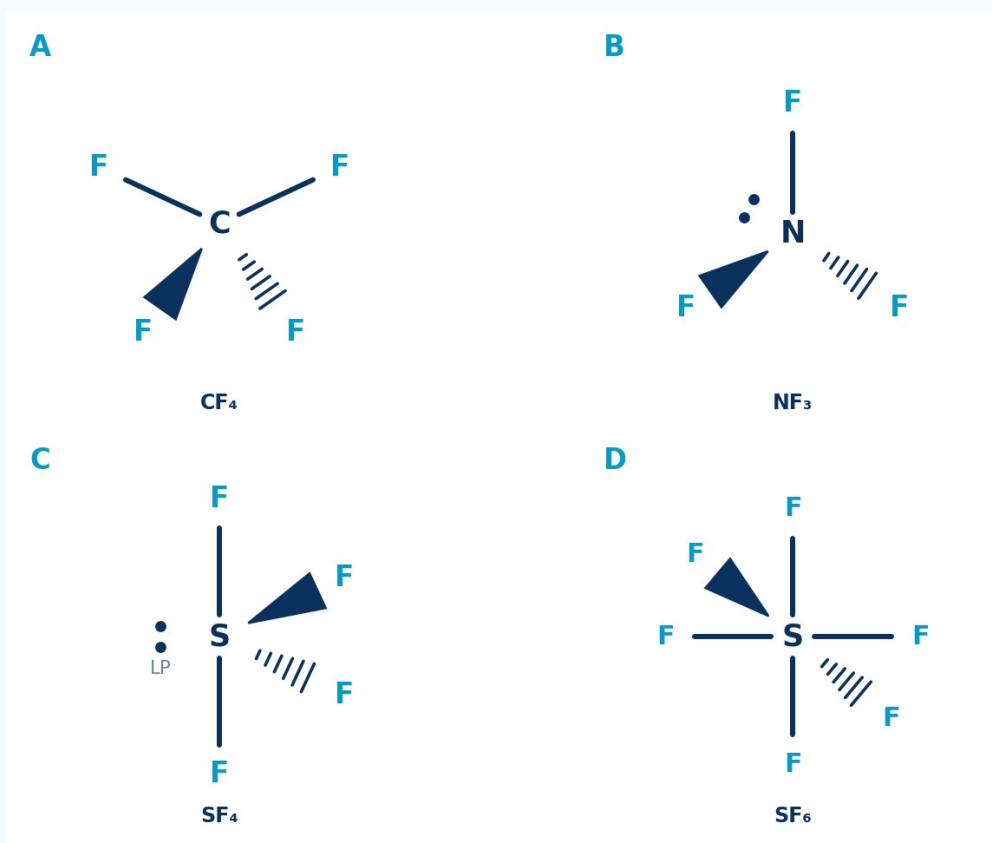
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QUESTION 12 | EXAM STYLE

Figure 2 shows the three-dimensional shapes of four molecules. Each bond to F is polar.

Figure 2



(a) Identify the two molecules that do not have a permanent dipole. (2 marks)

.....

(b) Identify the two molecules that do have a permanent dipole. (2 marks)

.....

(c) Explain why the bond dipoles cancel in the two non-polar molecules. (2 marks)

.....

(d) Explain why the bond dipoles do not cancel in NF_3 and SF_4 . (2 marks)

.....

(e) State why the presence of polar bonds alone cannot establish that a molecule is polar. (1 mark)

.....

QUESTION 13 | EXAM STYLE

Three C_5H_{12} isomers have the same number of electrons but different shapes.

Compound	Boiling point / $^{\circ}\text{C}$
pentane	36.1
2-methylbutane	27.8
2,2-dimethylpropane	9.5

(a) Place the compounds in order of increasing volatility. (1 mark)

(b) Explain why their boiling points differ even though their molecular formulae are identical. (4 marks)

QUESTION 14 | EXAM STYLE

The table shows boiling points of Group 16 hydrides.

Hydride	H ₂ O	H ₂ S	H ₂ Se	H ₂ Te
Boiling point / °C	100	-60	-41	-2

(a) Explain the trend in boiling point from H₂S to H₂Te. (3 marks)

(b) Explain why the boiling point of H₂O is anomalously high. (3 marks)

(c) Draw one hydrogen bond between two water molecules. Include partial charges and the acceptor lone pair. (4 marks)

Structure / working space

QUESTION 15 | EXAM STYLE

Ethanol, CH₃CH₂OH, boils at 78 °C. Methoxymethane, CH₃OCH₃, boils at -25 °C. Both have molecular formula C₂H₆O.

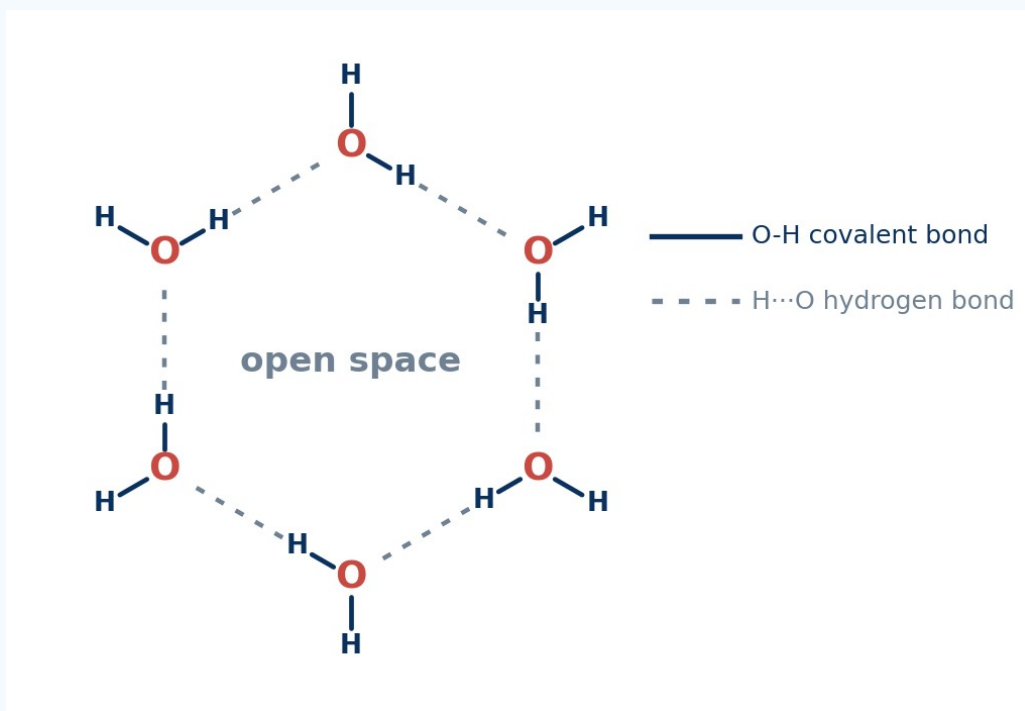
(a) State the strongest intermolecular force between molecules of each substance. (2 marks)

(b) Explain the difference in boiling point. (3 marks)

(c) Both substances can form hydrogen bonds with water. Explain this statement and identify one difference in their hydrogen-bonding behaviour. (2 marks)

QUESTION 16 | EXAM STYLE

Figure 3 is a simplified section of the open structure of ice.

Figure 3

(a) Identify the attraction shown by the dotted lines and the bond shown by the solid lines. (2 marks)

.....

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

.....

(c) State what is overcome when ice melts and what remains unbroken within each water molecule. (2 marks)

.....

SECTION C HARDER MIXED

Select the route across unfamiliar shapes, force competition and imperfect claims

QUESTION 17 | HARDER MIXED

AX_mE_n notation is used below: A is the central atom, X is a bonded atom and E is a lone pair on A.

Species	AX_mE_n description	Electron-pair geometry
A SF_4	AX_4E	trigonal bipyramidal
B ClF_3	AX_3E_2	trigonal bipyramidal
C XeF_2	AX_2E_3	trigonal bipyramidal
D BrF_5	AX_5E	octahedral

(a) Determine and state the name of the molecular shape of each species A-D. (4 marks)

(b) Explain why the lone pairs in A-C occupy equatorial positions in the parent geometry. (2 marks)

(c) State the characteristic bond angle or angles expected for each molecular shape. Use 'less than' where lone-pair repulsion compresses an ideal angle. (4 marks)

(d) Predict whether C and D have permanent dipoles. Explain both predictions. (3 marks)

QUESTION 18 | HARDER MIXED

Four molecular substances are compared.

Substance	Formula	M_r	Boiling point / °C
A	$\text{CH}_3\text{CH}_2\text{CH}_3$	44	-42
B	CH_3CHO	44	21
C	$\text{CH}_3\text{CH}_2\text{OH}$	46	78
D	$\text{HOCH}_2\text{CH}_2\text{OH}$	62	197

(a) State the strongest intermolecular force between molecules of A-D. (4 marks)

(b) Explain why B has a higher boiling point than A even though their relative molecular masses are equal. (2 marks)

(c) Explain why C has a higher boiling point than B. (2 marks)

(d) Explain why D has a higher boiling point than C. (3 marks)

(e) Place A-D in order of increasing volatility. (1 mark)

QUESTION 19 | HARDER MIXED

A student claims that the molecule with the largest permanent dipole must have the highest boiling point.

Molecule	Dipole moment / D	Boiling point / °C
CH ₃ F	1.85	-78
CH ₃ Cl	1.87	-24
CH ₃ Br	1.82	4
CH ₃ I	1.62	42

(a) Explain why all four molecules have permanent dipoles. (2 marks)

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(b) Explain the boiling-point trend from CH₃F to CH₃I. (4 marks)

.....

.....

(c) Evaluate the student's claim using the data. (2 marks)

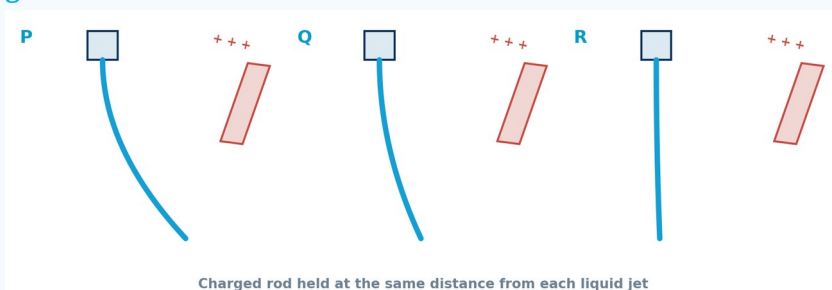
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QUESTION 20 | HARDER MIXED

Figure 4 shows the deflection of three liquid jets by the same charged rod. The table gives additional data.

Figure 4



Jet	Deflection	M _r	Boiling point / °C
P	strong	18	100
Q	moderate	58	56
R	negligible	86	69

(a) Identify P, Q and R from water, propanone and hexane. (3 marks)

.....

.....

(b) Explain why a charged rod deflects a jet of a polar liquid. (2 marks)

.....

.....

(c) Explain why jet deflection alone does not prove that molecules hydrogen-bond to one another. (2 marks)

(d) Explain why P has the highest boiling point despite having the lowest M_r . (2 marks)

(e) Explain why R boils at a higher temperature than Q even though R is non-polar. (3 marks)

SECTION D STRETCH / SYNOPTIC

Resolve competing effects and deduce unfamiliar molecular behaviour

QUESTION 21 | STRETCH / SYNOPTIC

The table shows data for methane and the chloromethanes. All C-Cl bonds are polar.

Molecule	Permanent dipole / D	Boiling point / °C
CH ₄	0	-162
CH ₃ Cl	1.87	-24
CH ₂ Cl ₂	1.60	40
CHCl ₃	1.04	61
CCl ₄	0	77

(a) Identify the two non-polar molecules. (2 marks)

(b) Explain why CCl₄ has no permanent dipole although each C-Cl bond is polar. (2 marks)

(c) Explain why boiling point rises from CH₃Cl to CCl₄ even though the permanent dipole decreases. (4 marks)

(d) A student says that CCl₄ has weaker intermolecular forces than CH₃Cl because CCl₄ has no permanent dipole. Evaluate this statement. (2 marks)

QUESTION 22 | STRETCH / SYNOPTIC

U is ClF_3 and V is XeF_4 . In AX_mE_n notation, A is the central atom, X is a bonded atom and E is a lone pair on A. U is AX_3E_2 and contains 44 electrons per molecule. V is AX_4E_2 and contains 90 electrons per molecule. V has the higher melting point.

(a) Determine and state the name of the molecular shape of U, and state where its two lone pairs are positioned. (2 marks)

(b) Determine and state the name of the molecular shape of V, and state the relative positions of its two lone pairs. (2 marks)

(c) Predict whether U and V have permanent dipoles. Explain each prediction. (2 marks)

(d) Suggest why V can have the higher melting point even though it is non-polar. (4 marks)

(e) Draw ClF_3 and XeF_4 , including all lone pairs on the central atom and suitable three-dimensional conventions. (3 marks)

Structure / working space



CrackingCHEM

GCSE | A-LEVEL

UNDERSTAND • APPLY • SUCCEED

AQA 7405

Bonding 2

Fully worked answers | AQA-style marking guidance

FULLY WORKED. PRECISELY MARKED. BUILT FOR IMPROVEMENT.

AQA SPECIFICATION

3.1.3.5 | 3.1.3.6 | 3.1.3.7

TEST IT

EXAM STYLE

HARDER MIXED

STRETCH

8

8

4

2

22 QUESTIONS MARKED

196 TOTAL MARKS

Use the marking points to diagnose exactly which reasoning step needs repair.

Mapped to AQA Chemistry 7405 | specification checked September 2026

Specification coverage audit

AQA area	Deliberate practice	Questions
3.1.3.5 Shapes	Electron-pair repulsion; 2-6 domains; lone-pair positions; common and unfamiliar molecular shapes; bond angles; 3D drawings	2-4, 6, 9-10, 12, 17, 22
3.1.3.6 Polarity	Electronegativity; partial charges; polar bonds; whole-molecule dipoles; shape and cancellation	1, 5-6, 12, 19, 21-22
3.1.3.7 Forces	London (van der Waals), permanent dipole-dipole and hydrogen bonding; existence, strength and physical-property consequences	1, 7-8, 11, 13-16, 18-22
Ice and anomalies	Hydrogen bonding, open ice lattice, anomalous boiling points and energy needed to overcome attractions	14, 16, 20
Boundary protected	No substantial Bonding I, energetics, kinetics or later organic chemistry is required	All questions

ORIGINALITY Every question is newly written from recurring AQA assessment patterns. No past-paper question has been reproduced.

SECTION A TEST IT

Core language, shapes, angles, polarity and force identification

TEST IT 1

- (a) The power / ability of an atom to attract the bonding pair of electrons [1] in a covalent bond [1].
- (b) A covalent bond with an unequal distribution of bonding electrons [1], producing δ^+ and δ^- ends [1].
- (c) Induced dipole-dipole forces, also called London (van der Waals) forces [1]; permanent dipole-dipole forces [1]; hydrogen bonding [1].
- (d) London (van der Waals) / induced dipole-dipole forces. [1]

Common trap London (van der Waals) forces act in polar molecules as well as non-polar molecules.

TEST IT 2

- (a) Electron pairs / charge clouds repel one another [1] and arrange as far apart as possible to minimise repulsion [1].
- (b) Lone pair-lone pair > lone pair-bond pair [1] > bond pair-bond pair [1].
- (c) A lone pair is attracted to only one nucleus [1], so its electron density occupies more space near the central atom and repels more strongly [1].

TEST IT 3

- (a) CO₂ linear [1], 180° [1]; BF₃ trigonal planar [1], 120° [1]; CH₄ tetrahedral [1], 109.5° [1]; NH₃ trigonal pyramidal [1], 107° [1]; H₂O bent / non-linear [1], 104.5° [1]; PCl₅ trigonal bipyramidal [1], 90° and 120° [1]; SF₆ octahedral [1], 90° [1].

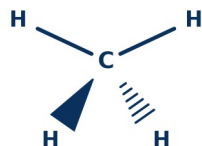
Examiner insight A double bond counts as one bonding region when predicting shape.

TEST IT 4

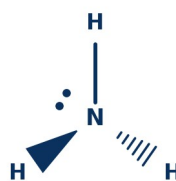
- (a) Four C-H bonds in a tetrahedral arrangement [1], shown with a valid three-dimensional wedge-and-dash representation [1].
- (b) Three N-H bonds in a trigonal-pyramidal arrangement [1], one lone pair on N [1], and a valid 3D representation [1].
- (c) Bent H-O-H arrangement [1], two lone pairs on O [1], and 104.5° labelled [1].

Model diagrams; equivalent orientations are accepted

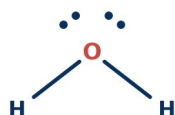
A

CH₄ tetrahedral 109.5°

B

NH₃ trigonal pyramidal 107°

C

H₂O bent 104.5°

TEST IT 5

- (a) H δ^+ - Cl δ^- . [1]
 (b) C δ^+ = O δ^- . [1]
 (c) O δ^- - H δ^+ . [1]
 (d) The more electronegative atom attracts the bonding pair more strongly [1], causing an unsymmetrical electron distribution and partial charges [1].
 (e) H-F > H-Cl > H-Br [1]. H-F has the largest electronegativity difference [1].

TEST IT 6

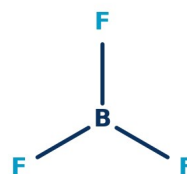
- (a) A CO₂: no [1]; B BF₃: no [1]; C H₂O: yes [1]; D CH₂Cl₂: yes [1].
 (b) CO₂ is linear, so its equal bond dipoles act in opposite directions and cancel [1]. BF₃ is trigonal planar and symmetrical, so its three bond dipoles cancel [1].
 (c) H₂O is bent, so its O-H bond dipoles do not cancel [1]. CH₂Cl₂ is tetrahedral but not symmetrical because the outer atoms are not all identical, so its bond dipoles do not cancel [1].

A and B cancel; C and D have a resultant molecular dipole

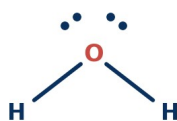
A

CO₂

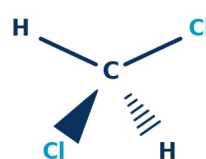
B

BF₃

C

H₂O

D

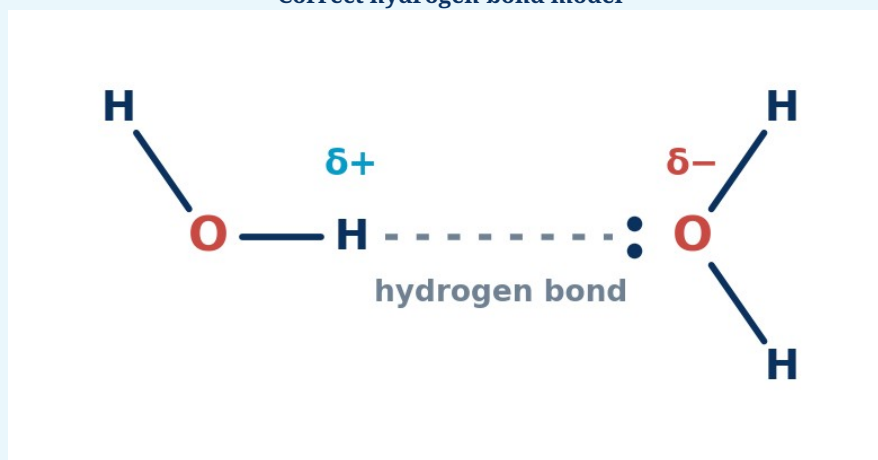
CH₂Cl₂

TEST IT 7

- (a) Permanent dipole-dipole forces. [1]
- (b) London (van der Waals) / induced dipole-dipole forces. [1]
- (c) Hydrogen bonding. [1]
- (d) Permanent dipole-dipole forces. [1]
- (e) Electrons move continuously, producing an instantaneous / temporary dipole [1] that induces a dipole in a neighbouring particle and creates an attraction [1].

TEST IT 8

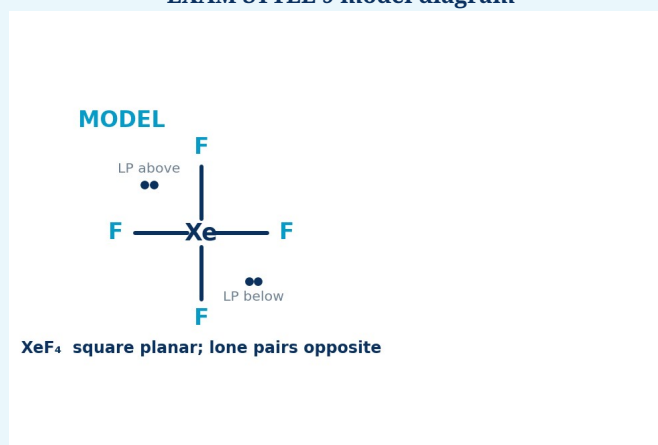
- (a) Show an O-H covalent bond within the donor molecule [1]; $H\delta^+$ and an acceptor $O\delta^-$ [1]; a lone pair on the acceptor O [1]; and a dotted attraction from $H\delta^+$ to that lone pair / O [1].
- (b) Hydrogen in HCl is not covalently bonded to N, O or F [1], so HCl does not meet the AQA hydrogen-bond donor condition [1].
- (c) A hydrogen bond is an intermolecular electrostatic attraction, not a shared pair of electrons. [1]

Correct hydrogen-bond model**SECTION B****EXAM STYLE**

Linked applications of VSEPR, polarity and intermolecular forces

EXAM STYLE 9

- (a) NH_4^+ tetrahedral [1]; SO_2 bent / non-linear [1]; I_3^- linear [1]; XeF_4 square planar [1].
- (b) NH_4^+ 109.5° [1]; SO_2 slightly less than 120° [1]; I_3^- 180° [1]; XeF_4 90° [1].
- (c) Four F atoms in a square plane around Xe [1], with the two lone pairs opposite one another perpendicular to that plane [1].

EXAM STYLE 9 model diagram

EXAM STYLE 10

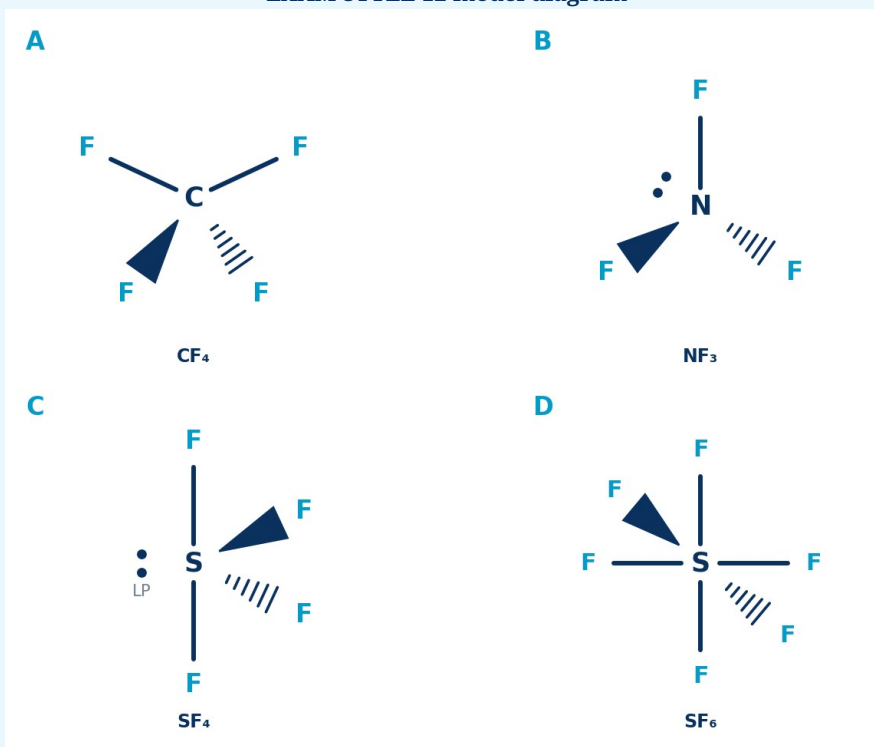
- (a) CH_4 tetrahedral [1], 109.5° [1]; NH_3 trigonal pyramidal [1], 107° [1]; H_2O bent / non-linear [1], 104.5° [1].
 (b) Lone pair-bond pair repulsion is stronger than bond pair-bond pair repulsion [1]; H_2O has two lone pairs, so the bonding pairs are compressed more than in NH_3 , which has one [1].

EXAM STYLE 11

- (a) London (van der Waals) / induced dipole-dipole forces. [1]
 (b) The number of electrons increases [1], making the electron cloud more polarisable [1]. Stronger instantaneous dipoles and London (van der Waals) attractions result [1], so more energy is needed to separate the atoms and boiling point rises [1].
 (c) Rn should have a boiling point above -108°C [1] because it has more electrons / a more polarisable cloud [1] and therefore stronger London (van der Waals) forces than Xe [1].

EXAM STYLE 12

- (a) A CF_4 [1] and D SF_6 [1].
 (b) B NF_3 [1] and C SF_4 [1].
 (c) CF_4 and SF_6 have symmetrical arrangements of identical polar bonds [1], so their bond dipoles cancel [1].
 (d) The lone pair makes each molecular shape asymmetrical [1], so the N-F or S-F bond dipoles do not cancel [1].
 (e) Molecular shape and the vector directions of all bond dipoles must also be considered. [1]

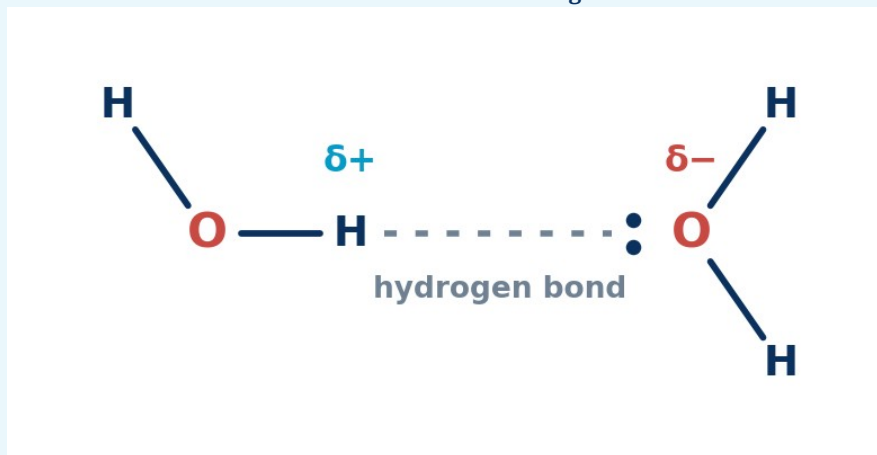
EXAM STYLE 12 model diagram**EXAM STYLE 13**

- (a) pentane < 2-methylbutane < 2,2-dimethylpropane in increasing volatility. [1]
 (b) They have the same number of electrons / similar potential for London (van der Waals) forces [1], but increased branching makes a molecule more compact and reduces surface contact [1]. London (van der Waals) attractions between neighbouring molecules are then weaker [1], so less energy is needed and boiling point falls [1].

Common trap The covalent bonds within the isomers are not broken during boiling.

EXAM STYLE 14

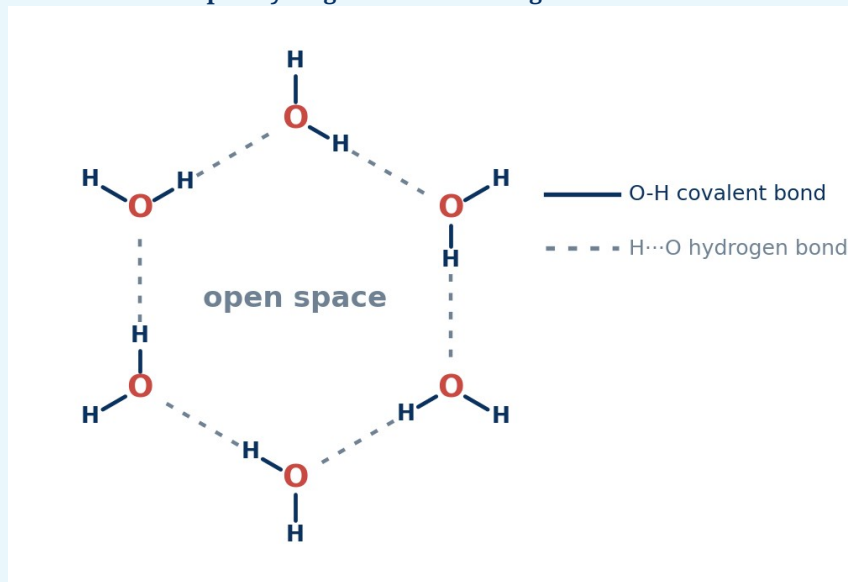
- (a) From H_2S to H_2Te , electron number and polarisability increase [1], London (van der Waals) forces become stronger [1], and more energy is required, so boiling point rises [1].
- (b) Water molecules form hydrogen bonds [1]. These are stronger than the intermolecular attractions in the other hydrides [1], so more energy is needed and water has an anomalously high boiling point [1].
- (c) Show $\text{H}\delta+$ on the donor hydrogen [1], $\text{O}\delta-$ on the acceptor oxygen [1], a lone pair on the acceptor oxygen [1], and a dotted attraction from $\text{H}\delta+$ to that lone pair / oxygen [1], as shown in the model.

EXAM STYLE 14 model diagram**EXAM STYLE 15**

- (a) Ethanol: hydrogen bonding [1]. Methoxymethane: permanent dipole-dipole forces [1].
- (b) Ethanol molecules hydrogen-bond to one another because ethanol contains O-H [1]. Methoxymethane has no H bonded to N, O or F, so it cannot hydrogen-bond to itself [1]. Hydrogen bonds are stronger, so more energy is needed to boil ethanol [1].
- (c) The O atom in each substance has a lone pair and can accept a hydrogen bond from water [1]. Ethanol can also donate a hydrogen bond through O-H; methoxymethane cannot [1].

EXAM STYLE 16

- (a) Dotted lines: hydrogen bonds [1]. Solid O-H lines: covalent bonds [1].
- (b) Hydrogen bonds hold water molecules in an open lattice [1], placing molecules further apart so the same mass occupies a larger volume [1]; density is therefore lower [1].
- (c) Some hydrogen bonds between molecules are overcome as the lattice collapses [1]; the O-H covalent bonds within water molecules remain unbroken [1].

Open hydrogen-bonded arrangement in ice

SECTION C

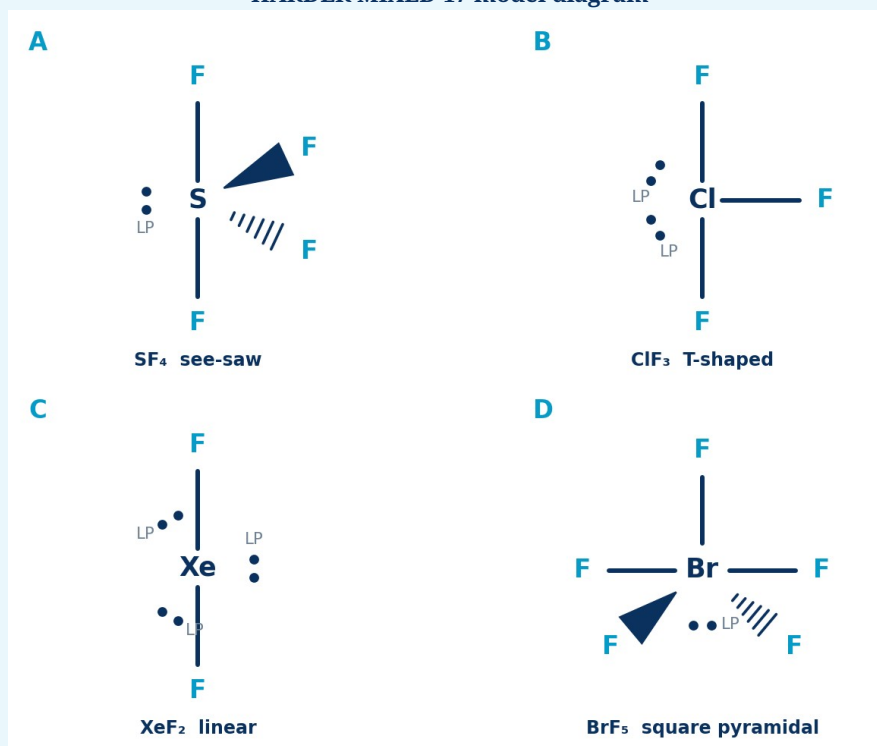
HARDER MIXED

Unfamiliar shapes, competing forces and evaluation of claims

HARDER MIXED 17

- (a) A SF_4 see-saw [1]; B ClF_3 T-shaped [1]; C XeF_2 linear [1]; D BrF_5 square pyramidal [1].
- (b) In a trigonal-bipyramidal arrangement, lone pairs occupy equatorial positions [1] because this gives fewer 90° interactions / minimises strong lone-pair repulsion [1].
- (c) SF_4 : less than 90° , less than 120° and less than 180° [1]; ClF_3 : less than 90° and less than 180° [1]; XeF_2 : 180° [1]; BrF_5 : approximately 90° and 180° , accepting slightly less than 90° where lone-pair repulsion compresses adjacent bonds [1].
- (d) XeF_2 is linear [1], so its two Xe-F dipoles cancel and it has no permanent dipole [1]. BrF_5 has a permanent dipole because square-pyramidal geometry is asymmetrical and its dipoles do not cancel [1].

HARDER MIXED 17 model diagram



Examiner insight The parent electron-pair geometry is not always the molecular shape.

HARDER MIXED 18

- (a) A: London (van der Waals) forces [1]; B: permanent dipole-dipole forces [1]; C: hydrogen bonding [1]; D: hydrogen bonding [1].
- (b) B is polar and has permanent dipole-dipole attractions in addition to London (van der Waals) forces [1]; these require more energy to overcome than the London (van der Waals) forces between A molecules of similar M_r [1].
- (c) C forms hydrogen bonds [1], which are stronger and require more energy to overcome than the permanent dipole-dipole forces in B [1].
- (d) D has two O-H groups and can form a more extensive hydrogen-bonded network [1]; it also has more electrons and stronger London (van der Waals) forces [1], so more energy is needed to separate its molecules [1].
- (e) $D < C < B < A$ in increasing volatility. [1]

HARDER MIXED 19

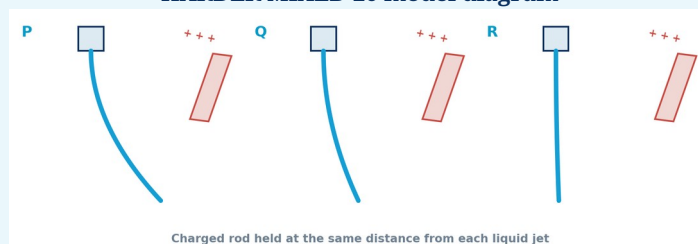
- (a) Each C-X bond is polar [1], and the tetrahedral molecule is asymmetrical because three H atoms and one halogen are present, so the dipoles do not cancel [1].

- (b) Electron number increases from F to I [1], electron clouds become more polarisable [1], London (van der Waals) forces strengthen [1], and more energy is needed to separate the molecules, so boiling point rises [1].
- (c) The claim is false: CH_3Cl has the largest dipole but CH_3I has the highest boiling point [1]; London (van der Waals) forces can dominate the total intermolecular attraction [1].

HARDER MIXED 20

- (a) P water [1]; Q propanone [1]; R hexane [1].
- (b) The electric field aligns / attracts permanent molecular dipoles [1], producing a net sideways force [1].
- (c) Deflection shows a permanent dipole, not hydrogen bonding [1]. Propanone deflects but cannot hydrogen-bond to itself because it has no H bonded to N, O or F [1].
- (d) Water forms strong hydrogen bonds [1], so more energy is needed to overcome its intermolecular attractions [1].
- (e) Hexane has more electrons and a more polarisable cloud [1], so its stronger London (van der Waals) forces [1] outweigh propanone's permanent dipole-dipole contribution [1].

HARDER MIXED 20 model diagram



SECTION D STRETCH / SYNOPTIC

Competing effects and unfamiliar molecular behaviour

STRETCH / SYNOPTIC 21

- (a) CH_4 [1] and CCl_4 [1].
- (b) CCl_4 is tetrahedral and symmetrical [1], so its four equal C-Cl bond dipoles cancel [1].
- (c) Electron number increases as H is replaced by Cl [1], so the electron cloud becomes more polarisable [1], London (van der Waals) forces strengthen [1] and more energy is needed to boil the liquid [1].
- (d) The statement is false because both substances have London (van der Waals) forces [1]; CCl_4 's more polarisable cloud gives stronger London (van der Waals) attractions and the higher boiling point [1].

STRETCH / SYNOPTIC 22

- (a) U is T-shaped [1]; both lone pairs are equatorial in the trigonal-bipyramidal parent arrangement [1].
- (b) V is square planar [1]; its lone pairs are opposite and perpendicular to the square plane [1].
- (c) U is polar because its T-shaped bond dipoles do not cancel [1]; V is non-polar because its four square-planar bond dipoles cancel [1].
- (d) XeF_4 has more electrons [1], a more polarisable cloud [1] and stronger London (van der Waals) forces [1], so more energy is needed to melt it [1].
- (e) ClF_3 drawn as AX_3E_2 with two equatorial lone pairs [1]; XeF_4 drawn as AX_4E_2 with opposite lone pairs [1]; valid 3D conventions and atom labels [1].

STRETCH / SYNOPTIC 22 model diagram

