AQA | Year 12 chemistry

Bonding

Questions & answers

49 original questions | 401 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-Q7

Covalent & dative bonds Q8-Q12

Metallic bonding Q13-Q14

Structures & properties Q15-Q26

Shapes & bond angles Q27-Q34

Electronegativity & polarity Q35-Q38

Intermolecular forces Q39-Q43

Hydrogen bonding & properties Q44-Q49

Ionic bonding & formulae

Question 1 | AQA | 7 marks

(a) Predict the ions formed by potassium, magnesium, nitrogen and sulfur atoms. [4]

(b) Explain why “ionic bonding is the transfer of electrons” is not a correct definition. Give the correct bonding description. [3]

Question 2 | AQA | 10 marks

(a) State the formula and charge of sulfate, hydroxide, nitrate, carbonate and ammonium ions. [5]

(b) Write the formulae of barium nitrate, aluminium sulfate, ammonium carbonate, magnesium hydroxide and aluminium oxide. [5]

Question 3 | AQA | 7 marks

The ionic compounds $X_2(SO_4)_3$ and $Y(OH)_2$ contain simple ions X and Y.

(a) Deduce the charges on X and Y. [2]

(b) Write the formula of X nitrate. [1]

(c) Write the formula of Y carbonate. [1]

(d) Write the formula of ammonium sulfate. [1]

(e) A student writes X_3SO_4. Explain why this is incorrect and give the correct sulfate formula. [2]

Question 4 | AQA | 8 marks

(a) Describe what is meant by a giant ionic lattice. [2]

(b) Explain why magnesium oxide has a high melting point. [3]

(c) Explain why solid magnesium oxide does not conduct electricity but molten magnesium oxide does. [3]

Question 5 | AQA | 3 marks

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

Question 6 | AQA | 3 marks

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

Question 7 | AQA | 9 marks

A solid oxide M_2O_3 melts at 2050 °C, does not conduct as a solid and conducts when molten.

(a) Deduce the charge on M ions. [1]

(b) Deduce the structure type. [1]

(c) Explain all three physical-property observations. [5]

(d) Write the formulae of M nitrate and M hydroxide. [2]

Covalent & dative bonds

Question 8 | AQA | 7 marks

(a) Define a single covalent bond. [2]

(b) State the number of shared pairs in Cl_2, O_2 and N_2 and give the line representation of each molecule. [3]

(c) State two pieces of information shown by a dot-and-cross diagram. [2]

Question 9 | AQA | 6 marks

(a) Draw a dot-and-cross diagram for Cl_2, showing outer-shell electrons only. [3]

(b) Draw a dot-and-cross diagram for O_2, showing outer-shell electrons only. [3]

Question 10 | AQA | 8 marks

(a) Define a dative covalent bond. [2]

(b) For $NH_3 + H^+ \rightarrow NH_4^+$, identify the donor and acceptor, state the arrow direction and state how the four N–H bonds compare after formation. [4]

(c) In $F^- + BF_3 \rightarrow BF_4^-$, identify the electron-pair donor and state the dative-arrow direction. [2]

Question 11 | AQA | 7 marks

Ammonia forms a dative covalent bond with $AlCl_3$. The electron-deficient aluminium atom accepts a lone pair.

(a) Identify the electron-pair donor and acceptor. [2]

(b) Draw the dative arrow on H_3N and $AlCl_3$. [2]

(c) Explain why ammonia can act as the donor. [1]

(d) Explain why an arrow from aluminium towards nitrogen would be incorrect. [2]

Question 12 | AQA | 13 marks

Fluoride ions form BF_4^- by donating a lone pair to BF_3. A salt contains Mg^{2+} and BF_4^- ions.

(a) Identify the dative donor and acceptor and describe the arrow fully. [4]

(b) Write the salt's formula. [1]

(c) State the bonding within BF_4^- and between Mg^{2+} and BF_4^- ions in the solid. [2]

(d) Explain why the solid does not conduct but the molten salt does. [3]

(e) Explain why a high melting point is expected. [3]

Metallic bonding

Question 13 | AQA | 7 marks

(a) Define metallic bonding. [3]

(b) Explain why solid magnesium conducts electricity. [2]

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

Question 14 | AQA | 8 marks

(a) State the particles present in barium fluoride, BaF_2, and in potassium metal. [2]

(b) Explain why solid potassium conducts electricity but solid barium fluoride does not. [4]

(c) Both substances conduct when molten. State the mobile charge carrier in each liquid. [2]

Structures & properties

Question 15 | AQA | 8 marks

For each structure below, state the particles present and the bond or attraction that holds the structure together. Give one correct entry in each empty cell. [8]

Structure	Particles present	Bond or attraction
Giant ionic	...	...
Metallic	...	...
Giant covalent	...	...
Simple molecular	...	...

Question 16 | AQA | 8 marks

Repair each statement using precise particle language.

(a) “Electron transfer is the ionic bond.” [3]

(b) “Molten iodine contains iodine atoms because its covalent bonds have broken.” [2]

(c) “Solid magnesium conducts because Mg^{2+} ions move through the lattice.” [3]

Question 17 | AQA | 8 marks

Four solids give the following data.

Solid	Melting point / °C	Conducts as solid?	Conducts when molten?
W	801	No	Yes
X	650	Yes	Yes
Y	3550	No	No
Z	114	No	No

(a) Identify the most likely structure type of W, X, Y and Z. [4]

(b) For each solid, quote the decisive evidence supporting your choice. [4]

Question 18 | AQA | 9 marks

Three samples are sodium chloride, graphite and iodine in an unknown order.

Sample	Thermal observation	Conducts as solid?	Conducts when molten?
P	Melts at 114 °C	No	No
Q	Melts at 801 °C	No	Yes
R	Remains solid above 3000 °C	Yes	Not tested

(a) Identify P, Q and R. [3]

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

(c) For each, explain one decisive observation using particles, attractions or mobile charge carriers. [3]

Question 19 | AQA | 9 marks

A contains atoms joined in a continuous three-dimensional covalent network. B contains discrete X_8 molecules. Neither conducts electricity.

(a) Classify their structures. [2]

(b) Explain why A has a much higher melting point than B. [5]

(c) Explain why neither conducts. [2]

Question 20 | AQA | 12 marks

Samples A–D are diamond, graphite, magnesium and iodine in an unknown order.

Sample	Physical evidence
A	Conducts as solid and liquid; melts at 650 °C
B	Conducts as solid; very high melting point; soft, layered
C	Does not conduct; very high melting point; extremely hard
D	Does not conduct; melts at 114 °C

(a) Identify A–D. [4]

(b) Compare B and C: explain their high melting points and why only B conducts. [5]

(c) Explain why D melts far below C, without referring to weak covalent bonds. [3]

Question 21 | AQA | 5 marks

(a) State the number of covalent bonds formed by each carbon in diamond. [1]

(b) Explain diamond's high melting point and lack of electrical conductivity. [4]

Question 22 | AQA | 10 marks

(a) State the structure type shared by diamond and graphite. [1]

(b) State how many covalent bonds each carbon atom forms in diamond and graphite. [2]

(c) Explain why both have very high melting points. [3]

(d) Explain why graphite conducts electricity but diamond does not. [3]

(e) Explain why graphite's layers can slide over one another. [1]

Question 23 | AQA | 10 marks

C consists of flat covalent layers. Each atom forms three covalent bonds and contributes one delocalised electron. Weak forces act between the layers.

(a) Classify C’s structure. [1]

(b) Predict and explain its melting point. [3]

(c) Predict and explain its electrical conductivity. [2]

(d) Predict and explain whether its layers can slide. [2]

(e) Explain why C should not be described as simple molecular. [2]

Question 24 | AQA | 7 marks

A student writes: “Iodine melts at a low temperature because the weak covalent bonds in I_2 molecules break.”

(a) Identify two errors. [2]

(b) Explain correctly what happens when solid iodine melts. [3]

(c) Explain why diamond melts at a much higher temperature than iodine. [2]

Question 25 | AQA | 7 marks

(a) State the particles present in ice. [1]

(b) State which attractions are overcome when ice melts and which bonds are not broken. [2]

(c) State whether melting absorbs or releases energy. [1]

(d) Describe the attraction and energy changes when water freezes. [2]

(e) Explain why each water molecule's chemical identity is unchanged during melting. [1]

Question 26 | AQA | 6 marks

(a) Draw exactly five I_2 molecules. [2]

(b) Draw a touching, alternating lattice containing exactly four Na^+ ions and four Cl^- ions. Show every charge. [3]

(c) State the particle represented in each diagram. [1]

Shapes & bond angles

Question 27 | AQA | 6 marks

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

(b) Place bond pair–bond pair, lone pair–bond pair and lone pair–lone pair repulsions in decreasing strength. [2]

(c) Explain why a lone pair repels more strongly than a bonding pair. [2]

Question 28 | AQA | 4 marks

(a) Deduce CS_2's shape and bond angle around carbon. [2]

(b) Deduce BCl_3's shape and angle around boron. [2]

Question 29 | AQA | 8 marks

Use solid and hashed wedges where needed to show three-dimensional arrangement.

(a) Draw CH_4. [2]

(b) Draw NH_3, including its lone pair. [3]

(c) Draw H_2O, including both lone pairs, and label the H–O–H angle. [3]

Question 30 | AQA | 8 marks

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

(a) State the shape and bond angle of each molecule. [6]

(b) Explain the angle decrease from CH_4 to NH_3 to H_2O. [2]

Question 31 | AQA | 14 marks

Complete all seven rows with the molecular shape and characteristic angle(s). Treat each multiple bond as one bonding region. [14]

Species	Bonding regions	Lone pairs	Shape	Angle(s)
CO_2	2	0	…	…
BF_3	3	0	…	…
CH_4	4	0	…	…
NH_3	3	1	…	…
H_2O	2	2	…	…
PCl_5	5	0	…	…
SF_6	6	0	…	…

Question 32 | AQA | 13 marks

In AX_mE_n, A is the central atom, X a bonded atom and E a lone pair on A.

Species	AX_mE_n
A SF_4	AX_4E
B ClF_3	AX_3E_2
C XeF_2	AX_2E_3
D BrF_5	AX_5E

(a) Determine the molecular shape of A–D. [4]

(b) Explain why the lone pairs in A–C occupy equatorial positions. [2]

(c) Give characteristic angles, using “less than” where lone-pair repulsion compresses ideal angles. [4]

(d) Predict whether C and D have permanent dipoles and explain. [3]

Question 33 | AQA | 10 marks

Use the supplied counts; each multiple bond counts 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 each molecular shape. [4]

(b) State one characteristic angle for each. [4]

(c) Draw XeF_4, showing the two Xe lone pairs relative to the square plane. [2]

Question 34 | AQA | 13 marks

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

(a) Determine U's shape and the positions of its two lone pairs. [2]

(b) Determine V's shape and the relative positions of its lone pairs. [2]

(c) Predict each molecule's polarity and explain. [2]

(d) Suggest why V can have the higher melting point despite being non-polar. [4]

(e) Draw both molecules with all central lone pairs and appropriate 3D conventions. [3]

Electronegativity & polarity

Question 35 | AQA | 8 marks

(a) Define electronegativity. [2]

(b) Define a polar covalent bond. [2]

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

(d) State which type acts between all atoms and molecules. [1]

Question 36 | AQA | 7 marks

Use 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 H–Cl. [1]

(b) Add δ+ and δ− to C=O. [1]

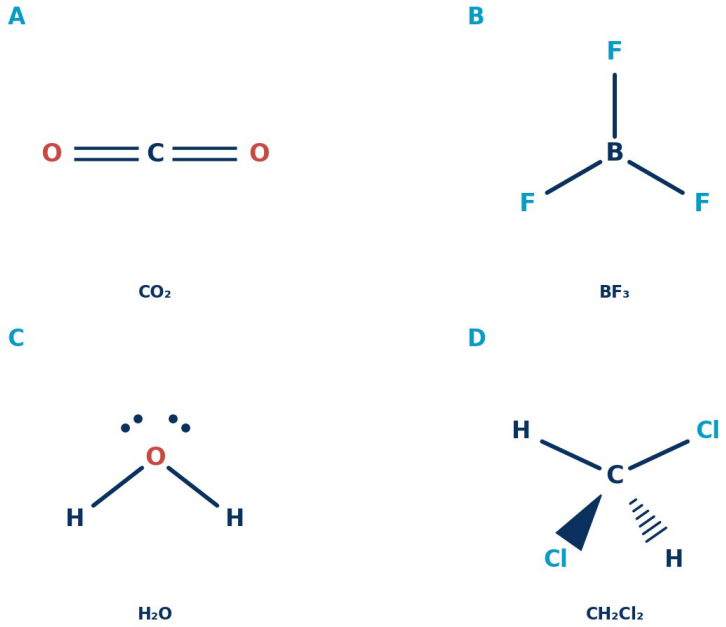
(c) Add δ+ and δ− to O–H. [1]

(d) Explain how partial charges arise in a polar covalent bond. [2]

(e) Place H–F, H–Cl and H–Br in decreasing bond polarity. Justify the first position. [2]

Question 37 | AQA | 8 marks

The figure shows A: CO_2, B: BF_3, C: H_2O and D: CH_2Cl_2. Every bond to O, F or Cl shown is polar.



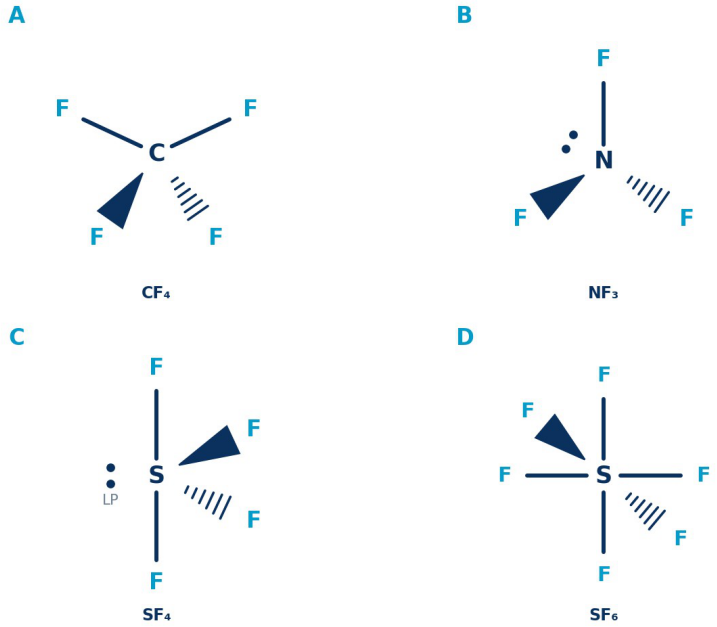
(a) State whether each molecule A–D has a permanent dipole. [4]

(b) Explain why A and B do not. [2]

(c) Explain why C and D do. [2]

Question 38 | AQA | 9 marks

The figure shows A: CF_4, B: NF_3, C: SF_4 and D: SF_6. Each bond to F is polar.



(a) Identify the two molecules without permanent dipoles. [2]

(b) Identify the two with permanent dipoles. [2]

(c) Explain cancellation in the non-polar molecules. [2]

(d) Explain why dipoles do not cancel in NF_3 and SF_4. [2]

(e) Explain why polar bonds alone cannot establish molecular polarity. [1]

Intermolecular forces

Question 39 | AQA | 6 marks

(a) State the strongest intermolecular force in HCl. [1]

(b) State the strongest intermolecular force in CH_4. [1]

(c) State the strongest intermolecular force in NH_3. [1]

(d) State the strongest intermolecular force in CH_3OCH_3. [1]

(e) Explain why all four have van der Waals forces. [2]

Question 40 | AQA | 8 marks

The table gives Group 0 data.

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

(a) Name the force between the atoms. [1]

(b) Explain the trend from Ne to Xe. [4]

(c) Predict how Rn’s boiling point compares with Xe’s and justify your answer. [3]

Question 41 | AQA | 5 marks

The three C_5H_{12} isomers have the same electron count but different shapes.

Compound	Boiling point / °C
Pentane	36.1
2-Methylbutane	27.8
2,2-Dimethylpropane	9.5

(a) Place them in increasing volatility. [1]

(b) Explain why boiling points differ despite identical molecular formulae. [4]

Question 42 | AQA | 8 marks

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_3F	1.85	−78
CH_3Cl	1.87	−24
CH_3Br	1.82	4
CH_3I	1.62	42

(a) Explain why all four have permanent dipoles. [2]

(b) Explain the boiling-point trend from CH_3F to CH_3I. [4]

(c) Evaluate the claim using the data. [2]

Question 43 | AQA | 10 marks

All C–Cl bonds are polar.

Molecule	Permanent dipole / D	Boiling point / °C
CH_4	0	−162
CH_3Cl	1.87	−24
CH_2Cl_2	1.60	40
$CHCl_3$	1.04	61
CCl_4	0	77

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

(b) Explain why CCl_4 has no permanent dipole despite polar C–Cl bonds. [2]

(c) Explain why boiling point rises from CH_3Cl to CCl_4 as permanent dipole decreases. [4]

(d) Evaluate "CCl_4 has weaker intermolecular forces than CH_3Cl because CCl_4 has no permanent dipole." [2]

Hydrogen bonding & properties

Question 44 | AQA | 6 marks

(a) Draw a hydrogen bond between two water molecules, showing relevant partial charges and a lone pair on oxygen. [4]

(b) Explain why HCl molecules do not hydrogen-bond to one another. [1]

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

Question 45 | AQA | 10 marks

Hydride	H_2O	H_2S	H_2Se	H_2Te
Boiling point / °C	100	−60	−41	−2

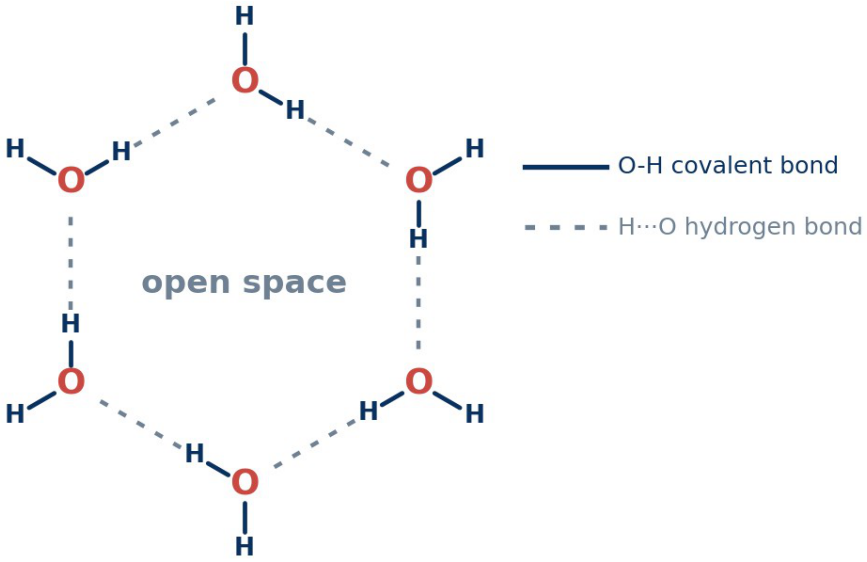
(a) Explain the trend from H_2S to H_2Te. [3]

(b) Explain water's anomalously high boiling point. [3]

(c) Draw one hydrogen bond between water molecules, with partial charges and an oxygen lone pair. [4]

Question 46 | AQA | 7 marks

The figure shows a simplified open structure of ice.



(a) Identify the dotted attraction and the solid bond. [2]

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

(c) State what is overcome on melting and what remains unbroken within each molecule. [2]

Question 47 | AQA | 12 marks

Substance	Formula	M_r	Boiling point / °C
A	$CH_3CH_2CH_3$	44	−42
B	CH_3CHO	44	21
C	CH_3CH_2OH	46	78
D	$HOCH_2CH_2OH$	62	197

(a) State the strongest intermolecular force in each. [4]

(b) Explain why B boils above A despite equal M_r. [2]

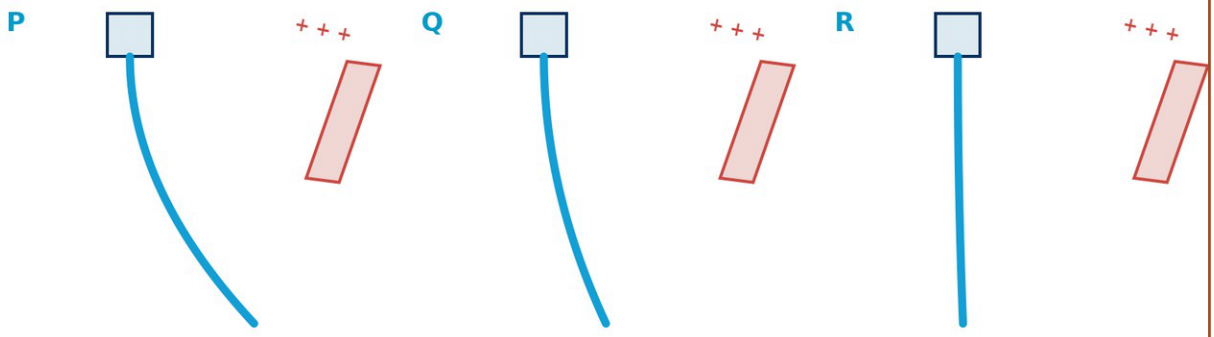
(c) Explain why C boils above B. [2]

(d) Explain why D boils above C. [3]

(e) Place A–D in increasing volatility. [1]

Question 48 | AQA | 12 marks

Three liquid jets are tested with the same charged rod.



Charged rod held at the same distance from each liquid jet

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]

(b) Explain why a charged rod deflects a polar liquid jet. [2]

(c) Explain why deflection alone does not prove self hydrogen bonding. [2]

(d) Explain why P boils highest despite having the lowest M_r. [2]

(e) Explain why non-polar R boils above Q. [3]

Question 49 | AQA | 7 marks

Ethanol, CH_3CH_2OH, boils at 78 °C. Methoxymethane, CH_3OCH_3, boils at −25 °C. Both have formula C_2H_6O.

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

(b) Explain the boiling-point difference. [3]

(c) Both hydrogen-bond with water. Explain and identify one difference in their hydrogen-bonding behaviour. [2]

Answers & marking points

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

Ionic bonding & formulae

Question 1 | AQA | 7 marks

(a) K^+ [1]; Mg^{2+} [1]; N^{3-} [1]; S^{2-} [1].

(b) Electron transfer forms the ions [1]. Ionic bonding is electrostatic attraction [1] between oppositely charged ions in a lattice [1].

Question 2 | AQA | 10 marks

(a) SO_4^{2-}; OH^-; NO_3^-; CO_3^{2-}; NH_4^+. One mark each.

(b) $Ba(NO_3)_2$; $Al_2(SO_4)_3$; $(NH_4)_2CO_3$; $Mg(OH)_2$; Al_2O_3. One mark each.

Question 3 | AQA | 7 marks

(a) X^{3+} [1]; Y^{2+} [1].

(b) $X(NO_3)_3$ [1].

(c) YCO_3 [1].

(d) $(NH_4)_2SO_4$ [1].

(e) X_3SO_4 is not electrically neutral [1]. $X_2(SO_4)_3$ is correct [1].

Question 4 | AQA | 8 marks

(a) A regular, repeating three-dimensional arrangement [1] of oppositely charged ions [1].

(b) A giant ionic lattice [1] with strong electrostatic attractions between Mg^{2+} and O^{2-} ions throughout [1]; much energy is needed to overcome these attractions [1].

(c) Solid ions are fixed in lattice positions [1]. Molten ions are mobile [1] and carry charge [1].

Question 5 | AQA | 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 6 | AQA | 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 7 | AQA | 9 marks

(a) M^{3+} [1].

(b) Giant ionic [1].

(c) A giant lattice of M^{3+} and O^{2-} ions [1]; strong electrostatic attractions [1] require much energy to overcome [1]. Solid ions are fixed, so no conduction [1]; molten ions are mobile and carry charge [1].

(d) $M(NO_3)_3$ [1]; $M(OH)_3$ [1].

Covalent & dative bonds

Question 8 | AQA | 7 marks

(a) A shared pair of electrons [1], attracted to both positive nuclei [1].

(b) Cl_2: one shared pair, Cl–Cl [1]; O_2: two shared pairs, O=O [1]; N_2: three shared pairs, N≡N [1].

(c) The outer-shell electrons [1] and the atom from which each electron originated [1].

Question 9 | AQA | 6 marks

(a) One shared pair containing one dot and one cross [1]; three lone pairs on each chlorine [1]; consistent electron-origin symbols [1].

(b) Two shared pairs, each containing one dot and one cross [1]; two lone pairs on each oxygen [1]; consistent electron-origin symbols [1].

Model dot-and-cross diagrams (outer-shell electrons only)

Cl_2: one shared pair



O_2: two shared pairs



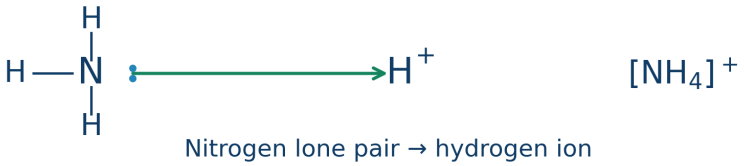
Question 10 | AQA | 8 marks

(a) A shared pair of electrons [1] with both electrons supplied by one atom [1].

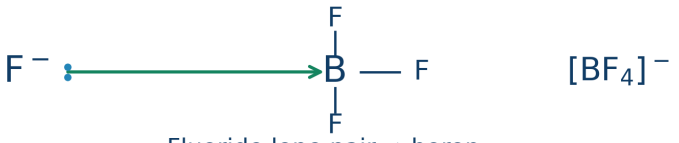
(b) NH_3, through nitrogen, is the donor [1]; H^+ is the acceptor [1]; the arrow starts at the nitrogen lone pair and points to H^+ [1]; all four N–H bonds become equivalent [1].

(c) F^- is the donor [1]; the arrow points from a fluoride lone pair towards boron [1].

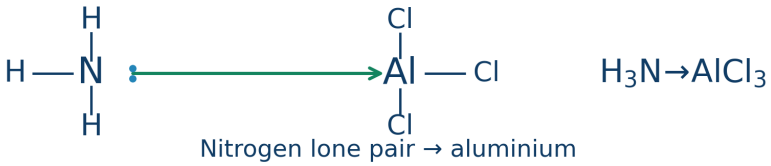
Dative arrows start at the lone pair



Nitrogen lone pair → hydrogen ion



Fluoride lone pair → boron



Nitrogen lone pair → aluminium

Question 11 | AQA | 7 marks

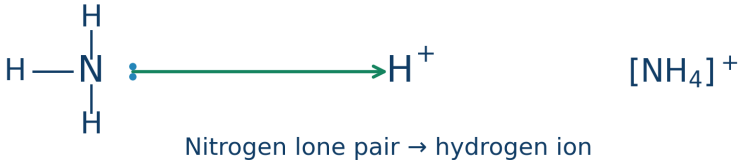
(a) NH_3 through N is the donor [1]; $AlCl_3$ through Al is the acceptor [1].

(b) The arrow starts at the N lone pair [1] and points towards Al: $H_3N \rightarrow AlCl_3$ [1].

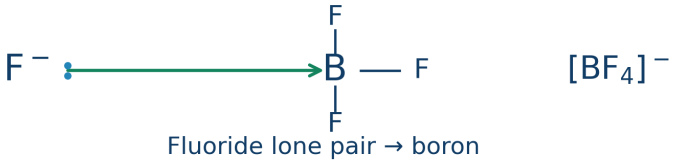
(c) N has an available lone pair [1].

(d) N supplies both electrons, not Al [1]; an Al → N arrow reverses donor-to-acceptor direction [1].

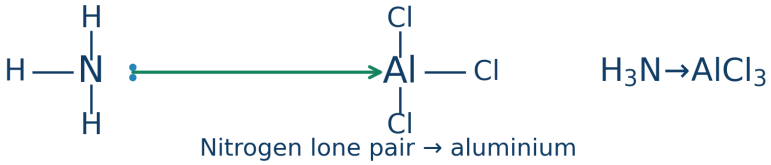
Dative arrows start at the lone pair



Nitrogen lone pair → hydrogen ion



Fluoride lone pair → boron



Nitrogen lone pair → aluminium

Question 12 | AQA | 13 marks

(a) F^- donor [1]; B in BF_3 acceptor [1]; arrow starts at fluoride lone pair [1] and points to B [1].

(b) $Mg(BF_4)_2$ [1].

(c) Covalent within BF_4^- [1]; ionic between Mg^{2+} and BF_4^- [1].

(d) Solid ions are fixed [1]; molten ions are mobile [1] and carry charge [1].

(e) Giant ionic lattice [1]; strong electrostatic attractions between opposite ions [1] require much energy to overcome [1].

Metallic bonding

Question 13 | AQA | 7 marks

(a) Strong electrostatic attraction [1] between positive metal ions [1] and delocalised electrons [1].

(b) Delocalised electrons are mobile [1] and carry charge through the solid lattice [1].

(c) Strong attractions between positive ions and delocalised electrons [1] require substantial energy to overcome [1].

Question 14 | AQA | 8 marks

(a) BaF_2: Ba^{2+} and F^- ions [1]. Potassium: K^+ ions and delocalised electrons [1].

(b) In solid BaF_2 the ions are fixed [1], so there are no mobile charge carriers [1]. Potassium has mobile delocalised electrons [1] that carry charge [1].

(c) Ba^{2+} and F^- ions in molten BaF_2 [1]; delocalised electrons in molten potassium [1].

Structures & properties

Question 15 | AQA | 8 marks

Structure	Particles present	Bond or attraction
Giant ionic	Positive and negative ions	Electrostatic attractions between oppositely charged ions
Metallic	Positive metal ions and delocalised electrons	Electrostatic attraction between positive ions and delocalised electrons
Giant covalent	Atoms	Many strong covalent bonds throughout a network
Simple molecular	Molecules	Forces between molecules

Award one mark for each completed cell: 8 marks.

Question 16 | AQA | 8 marks

(a) Transfer forms positive and negative ions [1]. Ionic bonding is electrostatic attraction [1] between oppositely charged ions in a lattice [1].

(b) Molten iodine still contains I_2 molecules [1]; only forces between molecules are overcome, not I–I bonds [1].

(c) Mg^{2+} ions are fixed in the solid [1]; delocalised electrons are mobile [1] and carry charge [1].

Question 17 | AQA | 8 marks

(a) W: giant ionic; X: metallic; Y: giant covalent; Z: simple molecular. One mark each.

(b) W conducts only when molten, consistent with mobile ions [1]. X conducts in both states, consistent with mobile delocalised electrons [1]. Y has a very high melting point and no mobile charge carriers [1]. Z has a low melting point and does not conduct [1].

Question 18 | AQA | 9 marks

(a) P: iodine; Q: sodium chloride; R: graphite. One mark each.

(b) P: simple molecular; Q: giant ionic; R: giant covalent. One mark each.

(c) P melts at relatively low temperature because forces between I_2 molecules are overcome [1]. Q's molten ions carry charge [1]. R has mobile delocalised electrons [1].

Question 19 | AQA | 9 marks

(a) A: giant covalent [1]; B: simple molecular [1].

(b) A has many strong covalent bonds throughout a network [1]; many must be broken [1], requiring much energy [1]. B has discrete X_8 molecules [1]; melting overcomes forces between them, not X–X bonds [1].

(c) A has no mobile charged particles [1]; neither does B [1].

Question 20 | AQA | 12 marks

(a) A: magnesium; B: graphite; C: diamond; D: iodine. One mark each.

(b) Both giant covalent with many strong bonds [1], requiring much energy to break [1]. Graphite has delocalised electrons [1] that are mobile and carry charge [1]. Diamond's outer electrons are used in bonds, so it has no mobile charge carriers [1].

(c) D has discrete I_2 molecules [1]. Melting overcomes forces between molecules [1], requiring much less energy than breaking diamond's covalent bonds [1].

Question 21 | AQA | 5 marks

(a) Four [1].

(b) A giant covalent network [1] has many strong covalent bonds requiring much energy to break [1]. All four outer electrons are used in bonds [1], leaving no mobile charge carriers [1].

Question 22 | AQA | 10 marks

(a) Giant covalent [1].

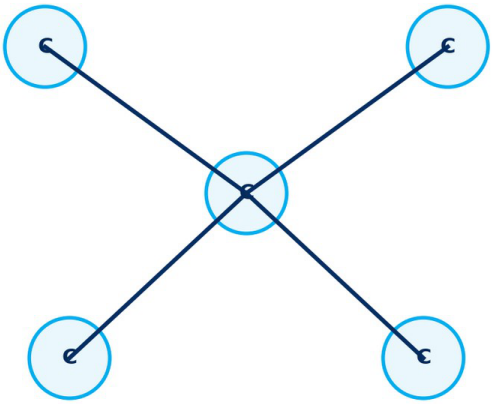
(b) Diamond: four [1]; graphite: three [1].

(c) Many strong covalent bonds [1] extend throughout giant structures [1], so much energy is required to break them [1].

(d) Graphite has one mobile delocalised electron per carbon [1] that carries charge [1]. Diamond's four outer electrons are used in bonds, so it has no mobile charge carriers [1].

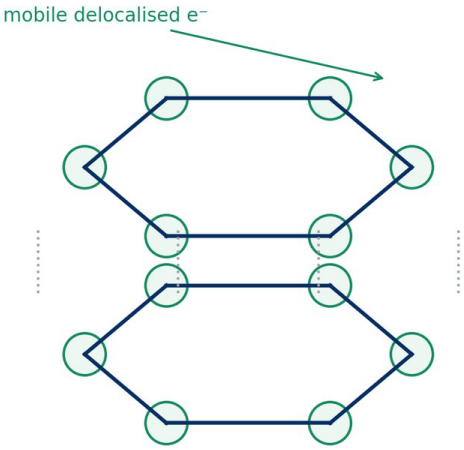
(e) Weak forces between the layers allow them to slide [1].

Diamond: part of a 3D network



each carbon forms four covalent bonds

Graphite: covalent layers



weak forces act between layers

Question 23 | AQA | 10 marks

(a) Giant covalent [1].

(b) Very high [1]; many strong covalent bonds within continuous layers [1] require much energy to break [1].

(c) Conducts [1] because mobile delocalised electrons carry charge [1].

(d) Layers can slide [1] because forces between them are weak [1].

(e) Atoms form continuous covalent layers [1], not separate molecules [1].

Question 24 | AQA | 7 marks

(a) The I–I covalent bonds are not broken on melting [1]; iodine's melting point is not low because those bonds are weak [1].

(b) Iodine is a molecular crystal of I_2 molecules [1]. Melting overcomes forces between molecules [1]; the molecules remain intact [1].

(c) Diamond is a giant covalent network. Melting iodine overcomes only weak intermolecular (van der Waals) forces between I_2 molecules [1]; breaking the strong C–C covalent bonds in diamond requires much more energy [1].

Question 25 | AQA | 7 marks

(a) H_2O molecules [1].

(b) Forces between water molecules are partly overcome [1]; O–H covalent bonds remain intact [1].

(c) Energy is absorbed [1].

(d) An ordered network of attractions forms between water molecules [1]; energy is released [1].

(e) The O–H bonds remain intact, so the molecules remain H_2O [1].

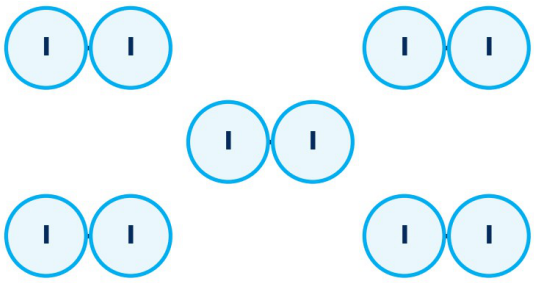
Question 26 | AQA | 6 marks

(a) Five distinct I–I pairs [1], with ten atoms arranged as five molecules [1].

(b) Exactly four Na^+ and four Cl^- ions [1]; opposite charges alternate in a touching lattice [1]; all charges correct [1].

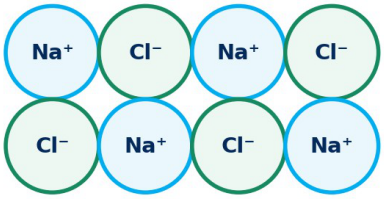
(c) Molecules for iodine; ions for sodium chloride [1].

Exactly five I_2 molecules



5 molecules = 10 iodine atoms

Exactly four Na^+ and four Cl^- ions



touching, alternating, every charge shown

Shapes & bond angles

Question 27 | AQA | 6 marks

(a) Charge clouds repel [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].

Question 28 | AQA | 4 marks

(a) Carbon forms two C=S double bonds. Each double bond is one bonding region; carbon has no lone pairs. The two regions repel as far apart as possible, giving a linear shape [1] and 180° bond angle [1].

(b) Three bonding regions and no lone pairs: trigonal planar [1], 120° [1].

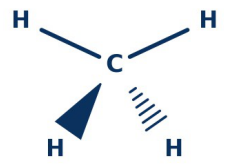
Question 29 | AQA | 8 marks

(a) Four bonds in a tetrahedral arrangement [1], using valid wedge-and-dash representation [1].

(b) Three bonds in a trigonal-pyramidal arrangement [1], one N lone pair [1], valid 3D representation [1].

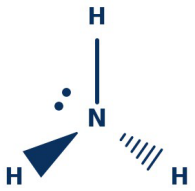
(c) Bent arrangement [1], two O lone pairs [1], 104.5° [1].

A



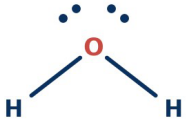
CH_4 tetrahedral 109.5°

B



NH_3 trigonal pyramidal 107°

C



H_2O bent 104.5°

Question 30 | AQA | 8 marks

(a) CH_4: tetrahedral, 109.5° [2]; NH_3: trigonal pyramidal, 107° [2]; H_2O: bent, 104.5° [2].

(b) Lone pair–bond pair repulsion is stronger than bond pair–bond pair repulsion [1]. Water has two lone pairs, compared with ammonia's one, compressing the bonding pairs further [1].

Question 31 | AQA | 14 marks

Species	Bonding regions	Lone pairs	Shape	Angle(s)
CO_2	2	0	Linear	180°
BF_3	3	0	Trigonal planar	120°
CH_4	4	0	Tetrahedral	109.5°
NH_3	3	1	Trigonal pyramidal	107°
H_2O	2	2	Bent / non-linear	104.5°
PCl_5	5	0	Trigonal bipyramidal	90°, 120° (also 180° between axial bonds)
SF_6	6	0	Octahedral	90° (also 180° between opposite bonds)

One mark per correct shape and one per correct angle entry: 14 marks.

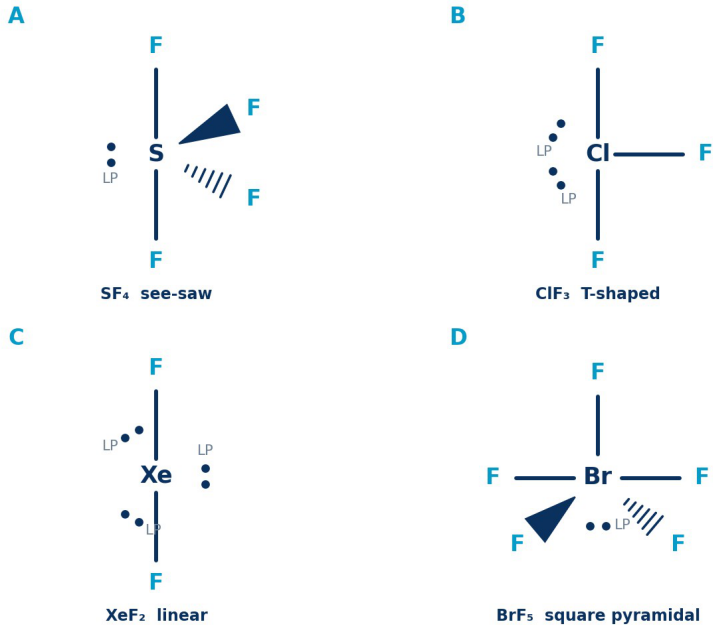
Question 32 | AQA | 13 marks

(a) A seesaw; B T-shaped; C linear; D square pyramidal. One mark each.

(b) Equatorial positions [1] have fewer 90° interactions and minimise strong lone-pair repulsion [1].

(c) SF_4: <90°, <120° and <180° [1]; ClF_3: <90° and <180° [1]; XeF_2: 180° [1]; BrF_5: approximately 90° and 180°, with distortions from lone-pair repulsion [1].

(d) XeF_2 is linear [1], so its equal opposite dipoles cancel [1]. BrF_5 is asymmetric square pyramidal, so its dipoles do not cancel and it is polar [1].

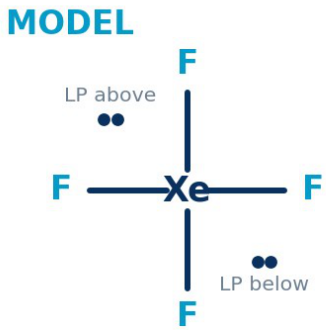


Question 33 | AQA | 10 marks

(a) NH_4^+: tetrahedral; SO_2: bent; I_3^-: linear; XeF_4: square planar. One mark each.

(b) 109.5°; slightly less than 120°; 180°; 90°, respectively. One mark each.

(c) Four F atoms in a square plane [1]; opposite lone pairs perpendicular to it [1].



Question 34 | AQA | 13 marks

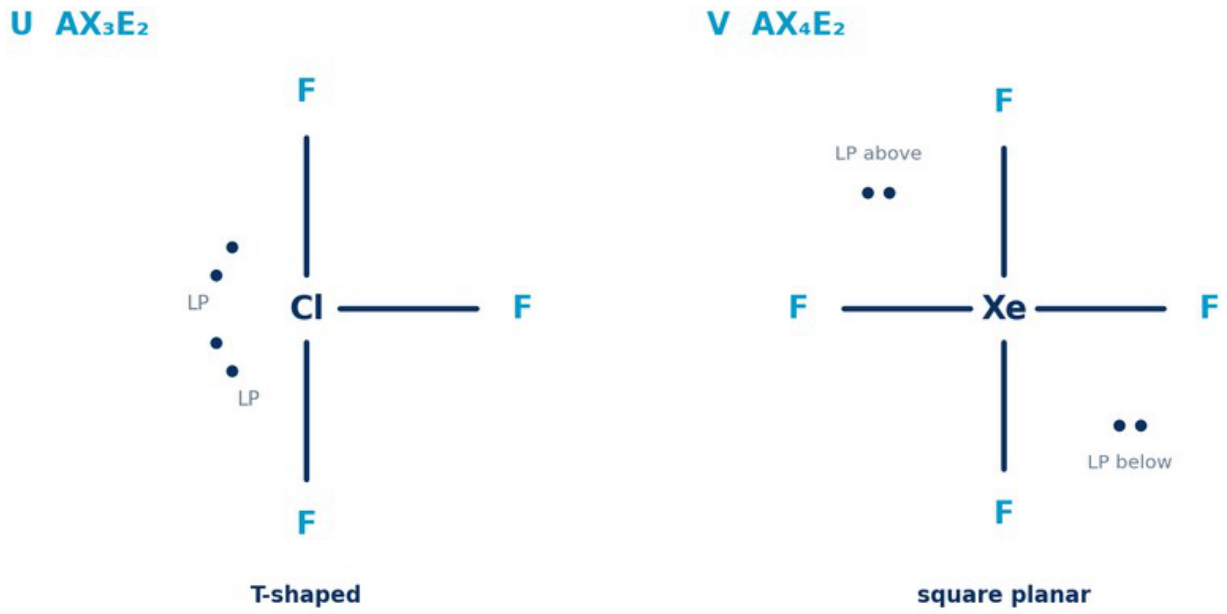
(a) U is T-shaped [1], with two equatorial lone pairs in a trigonal-bipyramidal arrangement [1].

(b) V is square planar [1], with two opposite lone pairs perpendicular to the plane [1].

(c) U is polar: its T-shaped dipoles do not cancel [1]. V is non-polar: its square-planar dipoles cancel [1].

(d) XeF_4 has more electrons [1], a more polarisable cloud [1] and stronger van der Waals forces [1], so more energy is needed [1]. This explains why a non-polar substance can melt higher; crystal packing can also affect melting points.

(e) ClF_3: AX_3E_2 with two equatorial lone pairs [1]. XeF_4: AX_4E_2 with opposite lone pairs [1]. Correct 3D conventions and atom labels [1].



Electronegativity & polarity

Question 35 | AQA | 8 marks

(a) The power of an atom to attract the bonding pair of electrons [1] in a covalent bond [1].

(b) A covalent bond with unequal distribution of bonding electrons [1], producing δ+ and δ− ends [1].

(c) Induced dipole–dipole (van der Waals) forces [1]; permanent dipole–dipole forces [1]; hydrogen bonding [1].

(d) Induced dipole–dipole (van der Waals) forces [1].

Question 36 | AQA | 7 marks

(a) $H^{\delta+}$–$Cl^{\delta-}$ [1].

(b) $C^{\delta+}$=$O^{\delta-}$ [1].

(c) $O^{\delta-}$–$H^{\delta+}$ [1].

(d) The more electronegative atom attracts the bonding pair more strongly [1], producing unsymmetrical electron distribution and partial charges [1].

(e) H–F > H–Cl > H–Br [1]; H–F has the largest electronegativity difference [1].

Question 37 | AQA | 8 marks

(a) A: no; B: no; C: yes; D: yes. One mark each.

(b) CO_2 is linear with equal opposite dipoles that cancel [1]. BF_3 is symmetrical trigonal planar, so its three dipoles cancel [1].

(c) H_2O is bent, so dipoles do not cancel [1]. CH_2Cl_2 has unlike outer atoms in a tetrahedral arrangement, so its dipoles do not cancel [1].

Question 38 | AQA | 9 marks

(a) A CF_4 [1] and D SF_6 [1].

(b) B NF_3 [1] and C SF_4 [1].

(c) Symmetrical arrangements of identical polar bonds [1] give cancellation [1].

(d) The lone pair produces an asymmetric molecular shape [1], so bond dipoles do not cancel [1].

(e) The shape and vector directions of all bond dipoles must also be considered [1].

Intermolecular forces

Question 39 | AQA | 6 marks

(a) Permanent dipole–dipole [1].

(b) Induced dipole–dipole (van der Waals) [1].

(c) Hydrogen bonding [1].

(d) Permanent dipole–dipole [1].

(e) Continuously moving electrons produce instantaneous dipoles [1], which induce dipoles in neighbouring molecules and cause attraction [1].

Question 40 | AQA | 8 marks

(a) Induced dipole–dipole (van der Waals) forces [1].

(b) More electrons [1] give a more polarisable cloud [1], stronger temporary dipoles and attractions [1], requiring more energy to separate atoms [1].

(c) Above −108 °C [1]; more electrons / greater polarisability [1] give stronger van der Waals forces [1].

Question 41 | AQA | 5 marks

(a) Pentane < 2-methylbutane < 2,2-dimethylpropane [1].

(b) Same electron count / similar potential for van der Waals forces [1]. More branching makes molecules compact and reduces surface contact [1]; attractions become weaker [1], so less energy is needed and boiling point falls [1].

Question 42 | AQA | 8 marks

(a) C–X is polar [1]; unlike outer atoms make the tetrahedral molecule asymmetric, so dipoles do not cancel [1].

(b) More electrons [1], greater polarisability [1], stronger van der Waals forces [1], greater energy needed to separate molecules [1].

(c) False: CH_3Cl has the largest dipole but CH_3I boils highest [1]. van der Waals forces can dominate the total attraction [1].

Question 43 | AQA | 10 marks

(a) CH_4 [1] and CCl_4 [1].

(b) Symmetrical tetrahedral arrangement [1] makes four equal C–Cl dipoles cancel [1].

(c) Replacing H by Cl increases electron number [1] and polarisability [1], strengthening van der Waals forces [1] and increasing the energy needed to boil [1].

(d) False: both have van der Waals forces [1]; CCl_4's more polarisable cloud gives stronger overall attractions and a higher boiling point [1].

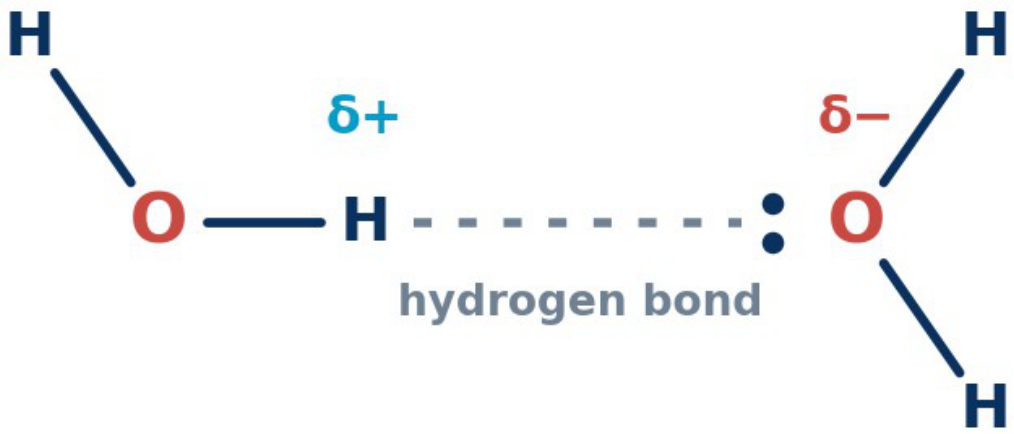
Hydrogen bonding & properties

Question 44 | AQA | 6 marks

(a) O–H covalent bond [1]; Hδ+ and Oδ− on the neighbouring molecule [1]; oxygen lone pair [1]; dotted attraction from Hδ+ to that lone pair [1].

(b) H is not directly bonded to N, O or F [1].

(c) It is an intermolecular electrostatic attraction, not a shared pair of electrons [1].

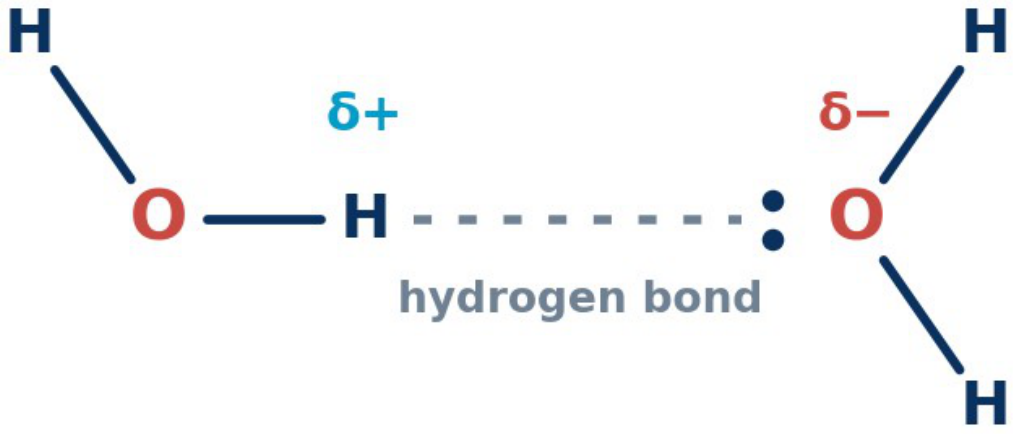


Question 45 | AQA | 10 marks

(a) Electron count and polarisability increase [1]; van der Waals forces strengthen [1], so more energy is required [1].

(b) Water forms hydrogen bonds [1]; its overall attractions are stronger than those in the other hydrides [1], so more energy is needed [1].

(c) Hδ+ in an O–H bond [1]; Oδ− on the neighbouring molecule [1]; O lone pair [1]; dotted attraction from H to the lone pair [1].



Question 46 | AQA | 7 marks

(a) Dotted: hydrogen bonds [1]; solid O–H: covalent bonds [1].

(b) Hydrogen bonds hold an open lattice [1]; molecules are further apart and the same mass occupies a larger volume [1], so density is lower [1].

(c) Some intermolecular hydrogen bonds are overcome as the lattice collapses [1]; O–H covalent bonds remain intact [1].

Question 47 | AQA | 12 marks

(a) A van der Waals; B permanent dipole–dipole; C hydrogen bonding; D hydrogen bonding. One mark each.

(b) B has permanent dipole–dipole attractions as well as van der Waals forces [1], giving stronger overall attractions and greater energy needed than A [1].

(c) C forms hydrogen bonds [1], so its overall attractions require more energy to overcome than B’s [1].

(d) D has two O–H groups and a more extensive hydrogen-bonded network [1], plus more electrons and stronger van der Waals forces [1], so greater energy is needed [1].

(e) D < C < B < A [1].

Question 48 | AQA | 12 marks

(a) P water [1]; Q propanone [1]; R hexane [1].

(b) The electric field aligns / attracts permanent molecular dipoles [1], giving a net sideways force [1].

(c) In this comparison, deflection indicates polarity rather than uniquely identifying hydrogen bonding [1]. Propanone deflects but has no H directly bonded to N, O or F, so it cannot hydrogen-bond with itself [1].

(d) Water forms hydrogen bonds [1], requiring more energy to overcome its overall attractions [1].

(e) Hexane has more electrons and greater polarisability [1]; its stronger van der Waals forces [1] outweigh propanone's permanent dipole contribution [1].

Question 49 | AQA | 7 marks

(a) Ethanol: hydrogen bonding [1]; methoxymethane: permanent dipole–dipole [1].

(b) Ethanol's O–H groups allow self hydrogen bonding [1]. Methoxymethane has no H bonded to N, O or F, so it cannot self hydrogen-bond [1]. Stronger overall attractions in ethanol require more energy to overcome [1].

(c) Both have O lone pairs that attract δ+ H atoms in water [1]. Ethanol also has a δ+ H in an O–H bond that can hydrogen-bond to a water oxygen lone pair; methoxymethane has no O–H bond [1].