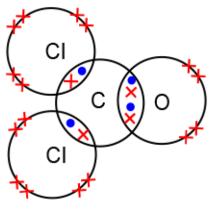
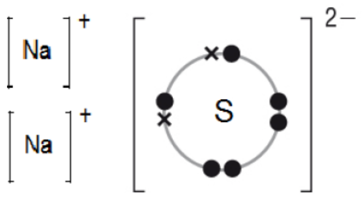
Mark scheme – Bonding and Structure

Question			Answer/Indicative content	Marks	Guidance
1		i	 ✓ ***CARE:** Check that lone pairs on Cl and O are included* • Cl (×2) has 6 non-bonded electrons (3 LPs) • O has 4 non-bonded electrons (2 LPs)	**1**	**NOTE:** O and Cl electrons **MUST** be shown differently from C electrons *(e.g. expected answer)* **IGNORE** inner shells **ALLOW** diagram with missing C, O or Cl symbols. For C=O bond, **ALLOW** sequence **× × • •** **ALLOW** non-bonding electrons unpaired **<u>Examiner's Comments</u>** Most candidates attempted a dot-and-cross diagram of a $COCl_2$ molecule, with ionic representations being rare. Candidates should take care to include any lone pairs in their diagrams. Omission of the O and Cl lone pairs was the most common error.
		ii	**Shape** Trigonal planar ✓ **Number of bonded regions** (C has) 3 electron (dense) regions **OR** 3 bonding regions ✓ **Electron pair repulsion** *(Seen anywhere)* electron pairs/bonded pairs/bonded regions repel **OR** electron pairs move as far apart as possible **OR** bonds repel ✓	**3**	**ALLOW** bp for bonded pair **ALLOW** 3 bonded pairs (**BOD**) **OR** 3 sigma bonds **OR** 2 bonded pairs and 1 double bond **OR** 4 bonded pairs **including** a double bond **IGNORE** bonded atoms **IGNORE** just 3 bonds **ALLOW** alternative phrases/words for repel e.g. 'push apart' **IGNORE** electrons repel *(pairs needed)* **DO NOT ALLOW** atoms repel **<u>Examiner's Comments</u>** This question discriminated well. Most candidates recognised that a $COCl_2$ molecule has a trigonal planar shape. The best answers explained this shape in terms of the three electron regions around the central C atom and their repulsion.

2.2.2 Bonding and Structure

<table>
<tr><td></td><td></td><td></td><td>Total</td><td>4</td><td></td></tr>
<tr><td>2</td><td>a</td><td></td><td>

Na shown with either 0 or 8 electrons
AND
S shown with 8 electrons with 6 dots and 2 crosses (or vice versa)
✓

Correct charges ✓</td><td>2</td><td>ALLOW $2[Na]^+$
ALLOW $[Na]^+_2$
Brackets not required

For first mark,
if eight electrons are shown around Na, the ‘extra’ electrons around S must match the symbol chosen for the electrons for Na.

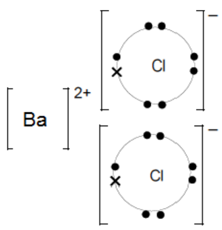
IGNORE inner shells

Circles not required

<u>Examiner’s Comments</u>

The majority of candidates obtained full marks on this question. The most common errors were incorrect charges or covalent structures.</td></tr>
<tr><td></td><td>b</td><td></td><td><table>
<tr><td></td><td>Na_2S</td><td>Na</td><td>S</td></tr>
<tr><td>Melting point / °C</td><td>1180</td><td>98</td><td>113</td></tr>
<tr><td>Type of structure</td><td>giant</td><td>giant</td><td>simple</td></tr>
<tr><td>Conductivity of solid</td><td>poor</td><td>good</td><td>poor</td></tr>
<tr><td>Conductivity of liquid</td><td>good</td><td>good</td><td>poor</td></tr>
<tr><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>
One mark for each correct column</td><td>3</td><td>Mark by COLUMN

<u>Examiner’s Comments</u>

The majority of candidates obtained 2 or 3 marks on this question. Many candidates seemed unaware that sodium was a metal.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>5</td><td></td></tr>
<tr><td>3</td><td></td><td>i</td><td>

Barium ion with no (or eight) electrons
AND
two chloride ions with correct dot-and-cross octet (1)

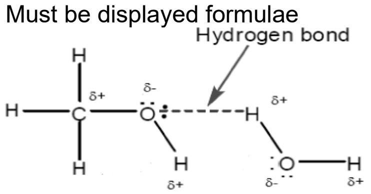
Correct charges (1)</td><td>2</td><td>For the first mark, if eight electrons are shown in the cation then the ‘extra’ electron in the anion must match the symbol chosen for electrons in the cation

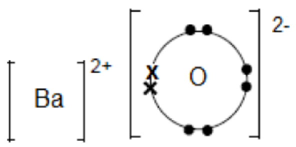
ignore inner shell electrons

Circles not essential

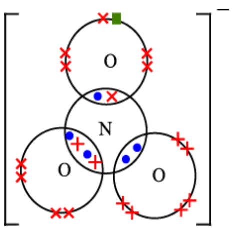
allow One mark if both electron arrangement and charges are correct but only one Cl is drawn

allow $2[Cl]^-$ (Bracket not required)</td></tr>
</table>

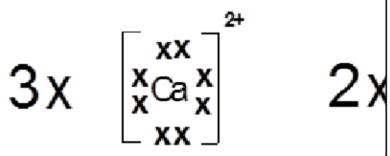
		ii	Barium hydroxide **OR** barium oxide **OR** barium carbonate	1	**allow** $Ba(OH)_2$ **OR** BaO **OR** $BaCO_3$
			Total	**3**	
4		i	$P_4 + 6Br_2 \rightarrow 4PBr_3$	1	**ignore** state symbols
		ii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **If answer = 3.01×10^{21} award 3 marks** $M_r(PBr_3) = 270.7$ (g mol^{-1}) (1) $n(PBr_3) = 1.3535 / 270.7 = 5.000 \times 10^{-3}$ mol (1) number of molecules = $5.000 \times 10^{-3} \times 6.02 \times 10^{23} = 3.01 \times 10^{21}$ molecules (1)	3	If there is an alternative answer, check to see if there is any **ecf** credit possible using working below. **allow** in working shown as 28.1 + 35.5 × 4 **allow ecf** from incorrect molar mass of PBr_3 **allow** 0.005(00) (mol) for two marks **allow ecf** for incorrect amount of PBr_3 **allow** calculator value or rounding to 3 significant figures or more **but ignore** 'trailing' zeroes, e.g. 0.200 allowed as 0.2 **do not allow** any marks for: $1.3535 \times 6.02 \times 10^{23} = 8.15 \times 10^{23}$
		iii	Pyramidal (1) (because there are) 3 bonded pairs and 1 lone pair (around the central phosphorus atom) (1) and electron pairs repel each other as far apart as possible so will take on a tetrahedral arrangement (giving a pyramidal shape overall) (1)	3	
			Total	**7**	
5			Displayed formulae of CH_3OH and H_2O **AND** C–O **AND** O–H polar bonds shown on CH_3OH molecule with δ+ and δ- **AND** Both O–H polar bonds shown on H_2O molecule with δ+ and δ- ✓ **Two** lone pairs shown on both oxygen atoms **AND** Hydrogen bond / H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol ✓	**2**	Must be displayed formulae  **IGNORE** δ+ shown on other H atoms **ALLOW** hydrogen bond between the H on methanol (OH) and the oxygen lone pair on water **Examiner's Comment:** Candidates did not cope well with the requirement to produce a hydrogen bonding diagram that was expected to match the content of all four of the bullet points listed in the question. Perhaps candidates did not read the question carefully enough but some diagrams did not include displayed

					formulae, dipoles were often missing from the methanol molecule, lone pairs were absent from oxygen atoms and the hydrogen bond was marked in an incorrect position. This resulted in a low scoring question for a diagram that had produced much higher scores when asked on papers from the legacy specification.
			Total	**2**	
6		i	Tetrahedral **AND** 109.5(°) ✓ four **bonded** pairs repel **OR** four **bonds** repel ✓	**2**	**Mark each point independently** **ALLOW** range 109 – 110º **IGNORE** surrounded by four atoms **IGNORE** four areas of electron charge repel **IGNORE** four electron pairs repel (*one could be lp*) **DO NOT ALLOW** atoms repel **Examiner's Comments** This question was poorly answered. Many candidates ignored the instruction to give the shape around the carbon atom in the alkyl group and instead focussed on the bond angle and shape around the carbonyl carbon. Even candidates who could identify the correct shape and bond angle did not explain that it is due to the repulsion between four bonding pairs.
		ii	104.5(°) ✓	**1**	**ALLOW** range 104 – 105° **Examiner's Comments** Generally well answered but many examples of incorrect bond angles including 107, 120 and 180 were seen here.
			Total	**3**	
7		i	<u>Electrostatic</u> <u>attraction</u> between positive and negative ions ✓	**1**	**ALLOW** oppositely charged ions **ALLOW** cations and anions **ALLOW** '+' for positive and '−' for negative **IGNORE** references to metal and non-metal **IGNORE** references to transfer of electrons **Examiner's Comments** The specification describes ionic bonding as an electrostatic attraction and a small proportion of answers were missing this key phrase.
		ii	 Ba shown with either 0 or 8 electrons **AND** O shown with 8 electrons with 6	**2**	**For first mark,** if eight electrons are shown around Ba, the 'extra' electrons around O must match the symbol chosen for the electrons for Ba. **IGNORE** inner shells Circles **not** required Brackets **not** required

			dots and 2 crosses (or vice versa) ✓ Correct charges on both ions ✓		**Examiner's Comments** Covalent bonding diagrams were not common and this question was well answered by the vast majority of candidates.
		iii	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 5.89×10^{21} award 2 marks for calculation *Moles of barium oxide* n(BaO) =1.50/153.3 **OR** 9.78×10^{-3} ✓ *Number of barium ions* ($9.78 \times 10^{-3} \times 6.02 \times 10^{23}$) = 5.89×10^{21} ✓ 3 **SF AND** standard form required	**2**	**ALLOW** 0.00978 up to calculator value 0.009784735 **ALLOW ECF** from incorrect moles of BaO **Common incorrect answers are shown below** **IF** 137.3 is used for the molar mass **ALLOW 1 mark** total for 6.58×10^{21} (0.010924981 mol) **OR** 6.56×10^{21} (0.0109 mol) **IF** 153 is used for the molar mass **ALLOW 1 mark** total for 5.90×10^{21} **Examiner's Comments** Use of the relative mass of barium to calculate moles of barium oxide was a common error but these candidates were usually able to pick up one mark for correctly multiplying their moles by the Avogadro constant. Some candidates correctly calculated moles but then divided by two thus losing the final mark.
			Total	**5**	
8	a		Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** reference to specific compounds e.g. comparing methane and methanol Second marking point requires **BOTH** types of intermolecular forces in response i.e comparison of hydrogen bonds **AND** van der Waals is **essential** **DO NOT ALLOW** the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water **ALLOW** more energy required to break hydrogen bonds than van der Waals' forces **ALLOW** it is harder to overcome the hydrogen bonds than van der Waals' forces **IGNORE** more energy is needed to break bonds **Examiner's Comments**

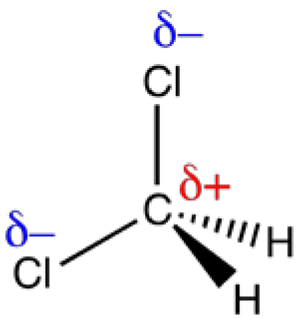
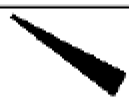
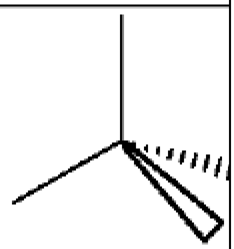
					Many candidates attributed the difference in boiling point between alkanes and alcohols to the relative strength of hydrogen bonds compared with van der Waals' forces. Weaker responses simply identified alcohols as being able to form hydrogen bonds, but failed to compare these with van der Waals' forces.
	b		2-methylpropan-1-ol has less surface (area of) contact **OR** fewer points of contact ✓ 2-methylpropan-1-ol has fewer / weaker van der Waals' forces **OR** less energy required to break van der Waals' forces in 2-methylpropan-1-ol ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Both answers need to be comparisons** **ALLOW ORA** throughout Reference to just surface area / closeness of molecules is **not** sufficient **IGNORE** reference to H bonds **IGNORE** less energy is needed to break bonds **Examiner's Comments** Most candidates recognised that 2-methylpropan-1-ol is branched and communicated both marking points succinctly. Weaker responses identified that 2-methypropan-1-ol would have weaker intermolecular forces, but failed to specify these as van der Waals' forces.
			Total	**4**	
9		i	$NiO + 2HNO_3 \rightarrow Ni(NO_3)_2 + H_2O$ ✓	1	**ALLOW** multiples **IGNORE** state symbols (even if wrong) **<u>Examiner's Comments</u>** This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide and HNO_3, and H_2 shown as a product instead of H_2O.
		ii	 **Global rules** • N and O electrons must be shown differently, e.g. • for N and × for O • 'Extra' electron shown with different symbol **MARKING** ***Bonding around central N atom*** ✓	2	**NOT REQUIRED** • Charge ('−') • Brackets • Circles **IGNORE** inner shells **ALLOW** rotated diagram **ALLOW** diagram with missing N or O symbols. *Shown as diagram on anyway* In **N=O bond**, **ALLOW** sequence **× × • •**

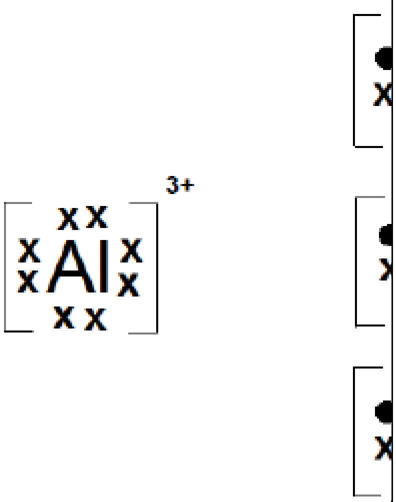
			○ 5 electrons for N shown as • **OR** × ○ 3 electrons for O, different from N as • **OR** × • N=O bond with 2 N electrons **AND** 2 O electrons • N→O bond with 2 N electrons • N–O bond with 1 N electron **AND** 1 O electron ***Non-bonded (nb) electrons around 3 O atoms*** ✓ • N=O oxygen has 4 nb 'O' electrons • N→O oxygen has 6 nb 'O' electrons • N–O⁻ oxygen has 5 nb 'O' electrons **AND** 1 'extra' electron with different symbol		In **N−O bond**, **ALLOW** 'extra' electron with different symbol for O electron **ALLOW** non-bonding electrons unpaired If 'extra' electron has been used **in N−O⁻ bond**, N−O⁻ oxygen **MUST** have 6 nb 'O' electrons **ALLOW** 'extra' electron as • **OR** × if it has been **labelled** 'extra electron' or similar **<u>Examiner's Comments</u>** Most candidates attempted this novel *'dot-and-cross'* diagram. Many candidates correctly showed the bonding electrons around the central nitrogen atom. The remaining electrons around the oxygen atoms proved to be more difficult, with many omitting to show the 'extra electron'.
			Total	**3**	
10		i	$Ca(OH)_2$ **OR** Calcium hydroxide **OR** CaO **OR** Calcium oxide ✓ 1	1	**ALLOW** Calcium carbonate **OR** $CaCO_3$ **Examiner's Comments** The unusual equation involving P4 molecules was answered well. Weaker candidates assumed that phosphorus was monatomic and consequentially lost credit.
		ii	$6Ca + P_4$ ◊ $2Ca_3P_2$ ✓	1	**ALLOW** multiples **IGNORE** state symbols **Examiner's Comments** This potentially difficult dot-and-cross diagram of the ions present was done well by candidates.

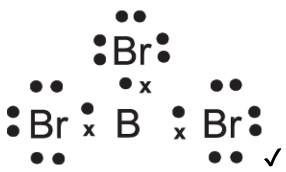
		iii	Ca with 8 (or no) electrons AND phosphide ion with dot-and-cross outermost octet ✓ Three Ca ions **AND** two phosphide ions with correct charges ✓	2	For first mark: If 8 electrons are shown on the cation then the extra electron in the anion must match the symbol chosen for the electrons in the cation. **IGNORE** inner shells **IGNORE** circles **ALLOW** one mark if both electron arrangements and charges are correct but only one of each ion is drawn. **ALLOW** (brackets not required) $3[Ca^{2+}]$ $3[Ca]^{2+}$ $[Ca^{2+}]_3$ $2[P^{3-}]$ $2[P]^{3-}$ $[P^{3-}]_2$ **DO NOT ALLOW** $[Ca_3]^{2+}$ $[3Ca]^{2+}$ $[Ca]^{32+}$ $[P_2]^{3-}$ $[2P]^{3-}$ $[P]_2$
			Total	**4**	
11		i	δ− on each F **AND** δ+ on O ✓	1	**ALLOW** δ2+ **OR** δ+ δ+ on O **Examiner's Comments** The application of dipoles to the molecule was done well.
		ii	Shape: non-linear **AND** Bond angle: 104.5° ✓	1	For shape **ALLOW** alternative words eg 'V-shaped' 'bent' 'angular'. In the absence of words allow a diagram with a non-linear shape F – O – F bond angle > 90°. For bond angle **ALLOW** 106> bond angle ≥102 (Actual = 102°) **Examiner's Comments** Only a few candidates failed to realise that two bonding pairs and two non-bonding pairs would lead to the molecule being bent-shaped with an expected bond angle of 104.5°.
		iii	+2 ✓	1	**ALLOW 2+** **Examiner's Comments** The question told candidates that fluorine was the most electronegative element which should have led them to realising that oxygen's oxidation state had to be a positive number. Many chose to ignore this despite allocating the oxygen atom a partial positive charge in part (i).
			Total	**3**	
12			Simple molecular lattice ✓	1	**ALLOW** 'simple covalent' **OR** 'simple molecular' ie 'simple' must be seen. **DO NOT ALLOW** 'simple covalent *bonds*'

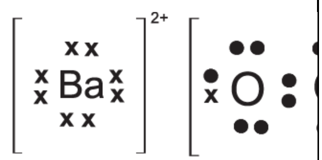
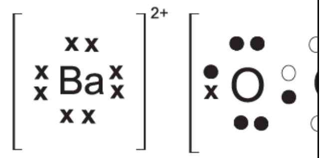
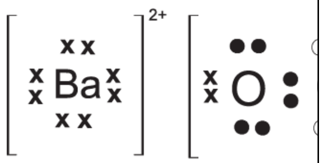
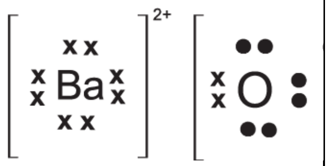
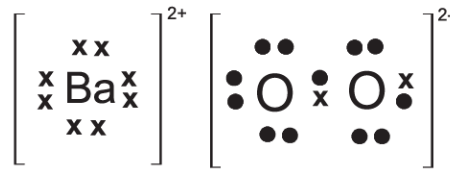
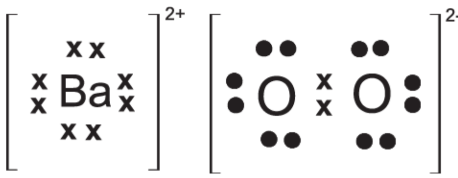
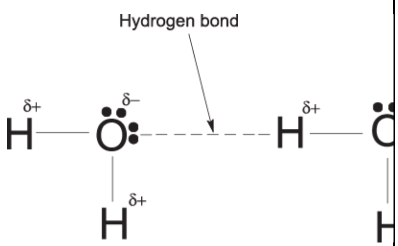
					Examiner's Comments Nearly all candidates understood that halogens consisted of simple molecular lattices.
			Total	**1**	
13				1	**ALLOW** *all* dots or *all* crosses. **Examiner's Comments** Nearly all were able to draw an accurate 'dot-and-cross' diagram of a nitrogen molecule.
			Total	**1**	
14			104.5° ✓	1	**ALLOW** 104–105
			(oxygen atom) has two bond pairs and two lone pairs ✓	1	**ALLOW** lp and bp **ALLOW** bonding regions for bond pairs
			Bonded pairs / lone pairs / electron pairs repel ✓	1	**IGNORE** bonds repel / electrons repel **DO NOT ALLOW** atoms repel
			Lone pairs repel **more than bonding pairs** ✓ **NOTE**: 'Lone pairs repel more than bonding pairs' would gain the last two marking points	1	**ALLOW** alternative phrases / words to repel e.g. 'push apart' **Examiner's Comments** Although the weaker candidates appear to have little idea of the bond angles found in simple molecules many were able to pick up one or two marks for communicating that lone pairs repel more than bonding pairs. The more able candidates also described the number of lone pairs and bonding pairs and obtained the correct bond angle.
			Total	**4**	
15			Phosphorus has more electrons ✓	1	**ALLOW ORA** but comparison should be used for the all marks **DO NOT ALLOW** Phosphorus has more electrons in the outer shell or larger electron cloud. **IGNORE** Phosphorus molecules are bigger or have greater M_r. **Examiner's Comments** It as pleasing to see that the vast majority of candidates were able to use the terms London forces or induced dipole–dipole interactions rather than van der Waals as used in the legacy specification. Unfortunately, many candidates also chose to discuss how the strength of the covalent bonds increased melting points rather than just considering the intermolecular forces. Answers were either very good or very poor. Where a candidate only scored two marks it was mainly due to not discussing the influence the number of electrons has on the strength of the force.
			Stronger London forces **OR**	1	**ALLOW** 'more' for 'stronger' **ALLOW** stronger van der Waals' / vdW forces

			Stronger induced dipole(-dipole) interactions ✓		
			More energy required to break the intermolecular forces / bonds **OR** London forces ✓	1	**DO NOT ALLOW** attraction between atoms-or that covalent bonds are broken
			Total	**3**	
16			*M1 NH_3 forces mark* NH_3 has hydrogen bonding ✓ *M2 F_2 **AND** Br_2 forces mark* F_2 **AND** Br_2 have van der Waals' (forces) ✓ *M3 Type of particle mark* Forces **OR** attractions are between molecules **OR** are intermolecular for ammonia **AND** Forces **OR** attractions are between molecules **OR** are intermolecular for fluorine **OR** for bromine ✓ *M4 Br_2 / F_2 comparison mark* The van der Waals' forces in Br_2 are greater than in F_2 **AND** Because bromine has more electrons than fluorine ✓ *M5 Br_2 / NH_3 / F_2 comparison mark* The van der Waals' forces in Br_2 are greater than hydrogen bonding in NH_3 **AND** hydrogen bonding in NH_3 is	5	*Quality of written communication:* 'molecule(s)' or 'intermolecular' spelled correctly once and used in context for the third marking point. **ALLOW** H-bonding for hydrogen bonding **IGNORE** van der Waals' forces **AND** permanent dipoles in M1 **IGNORE** covalent bonds for M1 **AND** M2 **ALLOW**, for van der Waal's: vdWs **OR** induced dipole temporary **OR** instantaneous dipole (-dipole) forces **ALLOW** for forces: attractions **OR** interactions; **DO NOT ALLOW** M3, M4 or M5 if covalent **OR** ionic bonds are the forces between the particles in that mark M3 can be seen anywhere eg in M1 NH_3 has hydrogen bonding between molecules **AND** the intermolecular force in Br_2 is stronger than that of F_2 eg a generic statement such as 'boiling point of these substances is determined by strength of *intermolecular bonding'* eg 'All these *molecules* are *held* together by weak forces' If correct force is given in M2 **ALLOW**, for M4, 'intermolecular force in Br_2 is stronger than that in F_2' **ALLOW** more van der Waals' for greater van der Waals' **ALLOW** more shells of electrons **IGNORE** 'permanent dipoles' in NH_3 for M5 if quoted in addition to hydrogen bonding If correct force is given in M1 **AND** M2 **ALLOW**, for M5, 'intermolecular force in Br_2 is stronger than that in NH_3' **AND** 'intermolecular force in NH_3 is stronger than that in F_2' If incorrect intermolecular force is given in M1 **OR** M2 **ALLOW** this as ECF for M5 but **DO NOT ALLOW** if the comparison is based only on van der Waals' forces Eg **DO NOT ALLOW** the van der Waals' forces in bromine are stronger than those in ammonia which in turn are stronger than those in fluorine **Examiner's Comments** This was a challenging question. Most candidates knew that ammonia has hydrogen bonding and many also knew that the intermolecular forces in F_2 and Br_2 were van der Waals. Hereafter, the marks proved more difficult to award. The next most common mark was for linking the strength of van der Waals' forces between F_2 and Br_2 to the number of electrons. The mark for

			stronger than van der Waals' forces in F_2 ✓		establishing that the forces acted between molecules was often missed as the candidates simply did not really address this part of the question despite being told to include the particles involved in their answers. The final mark for comparing the strength of intermolecular forces between all three molecules was very rarely awarded. Weaker candidates relied upon the false mantra of 'van der Waals' forces are weaker than hydrogen bonding' which the data clearly disproved. Other candidates attempted to explain the relative strength of the intermolecular forces solely in terms of the strength of van der Waals' forces between all three types of molecule. Only the most able students were able to secure full marks on this question.
			Total	**5**	
17		i	The ability of an atom to attract electrons ✓ (Electron pair) in a (covalent) bond ✓	2	**ALLOW** 'Measure' for ability **ALLOW** 'attraction' for 'ability to attract' **ALLOW** 'The ability of an atom to attract a shared pair of electrons' for two marks **Examiner's Comments** This definition enabled many candidates to pick up both marks. Where errors did arise they tended to be from not making clear that the attraction has to be for the electrons in the covalent bond or for there to be confusion between electronegativity and electron affinity.
		ii	 Correct orientation of 3-D tetrahedral arrangement of bonds around C atom ✓ δ + on C atom **AND** δ– on both Cl atoms ✓	2	For a 3D structure, For bond in the plane of paper, a solid line is expected:  For bond out of plane of paper, a solid wedge is expected:  For bond into plane of paper, **ALLOW**:  **ALLOW** a hollow wedge for 'in bond' **OR** an 'out bond', provided it is different from the other in or out wedge e.g.:  **ALLOW** any 3D representation with a minimum of one bond into the plane of paper **AND** minimum of one out of plane of paper **ALLOW** 2 lines in the plane + 2 different bonds for M1

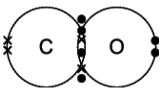
						IGNORE dipole charges on H **Examiner's Comments** It was surprising to see just how many different versions of 3-D shape were presented. The dipole mark was frequently lost usually due to omission of a partial charge on the central C atom.
		iii	The dipoles do not cancel out **OR** Because the molecule is non-symmetrical ✓	1		**ALLOW** partial charges do not cancel **IGNORE** charges do not cancel **ALLOW** (the more) electronegative atoms are on one side of the molecule **Examiner's Comments** Most candidates correctly focussed upon the fact that the molecule was not symmetrical.
			Total	**5**		
18	a	i	Repeating pattern ✓ of oppositely charged ions ✓	2		**ALLOW** 'regular' **OR** 'alternating' **OR** 'uniform (arrangement)' for 'repeating pattern' **ALLOW** positive and negative ions **OR** aluminium ions and fluoride ions **ALLOW** oppositely charged ions from a labelled diagram **Examiner's Comments** Most candidates were quick to describe ionic bonding by making reference to ions of opposite charge and so were awarded the first mark. Very few went on to describe the repeating or regular nature of the lattice.
		ii	 Al with 8 (or no) outermost electrons **AND** 3 × fluoride (ions) with '*dot-and-cross*' outermost octet ✓ Correct charges ✓	2		For first mark: If 8 electrons are shown in the cation then the 'extra' electron in the anion must match the symbol chosen for the electrons in the cation **IGNORE** inner shells **IGNORE** circles **ALLOW** one mark if both electron arrangements and charges are correct but only one F is drawn. **ALLOW** one mark if incorrect symbol is the only error, unless ECF from 2(a) in which both marks are available **DO NOT ALLOW** any marks for BF_3 **ALLOW** $3[F^-]$ $3[F]^-$ $[F^-]_3$ (brackets not required) **DO NOT ALLOW** $[F_3]^-$ $[F_3]^{3-}$ $[3F]^{3-}$ $[F]_3^-$ **Examiner's Comments** This question was answered by the majority of candidates. It is noteworthy, however, that some candidates gave unacceptable versions of the diagram when attempting to show the presence of three fluoride ions e.g.$[F]_3^-$ suggests one anion. with a single negative charge, consisting of three F species.
	b	i	A shared pair of electrons.	1		**Examiner's Comments**

					The quality of answers to this question were very high. Only the weakest of candidates failed to state that it is a pair (or two) of electrons which are shared.
		ii		1	**Examiner's Comments** As with the previous '*dot-and-cross*' diagram this was well answered. Only a very few attempted to show the molecule's bonding as ionic. Some candidates did lose the mark by adding a lone pair to the boron atom.
			Total	**6**	
19		i	**Reaction 1:** $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$ ✓ **Reaction 2:** $Ba_3N_2 + 6H_2O \rightarrow 3Ba(OH)_2 + 2NH_3$ Correct products ✓ Balancing ✓	3	Ignore state symbols **Examiner's Comments** Both equations were relatively challenging. Reaction 1 was a direct question about reactions of Group 2 elements. Reaction 2 demanded a higher level of application based upon information given. Many identified the alkaline gas as NH3, but then incorrectly assumed that the alkaline solution was BaO instead of $Ba(OH)_2$. Weaker candidates suggested equations with hypothetical species that could not have born any relation to formulae that they might have encountered before.
		ii	Giant ionic (lattice) ✓	1	**ALLOW** 'Giant lattice with ionic bonds' **ALLOW** 'Giant ionic bonds' **DO NOT ALLOW** 'atoms or molecules or dipoles' **Examiner's Comments** This question was relatively well answered, although some candidates did negate the mark by referring to molecules of Ba_3N_2 either directly or by indirect reference to intermolecular forces.
		iii		1	Ba must have a 2+ charge Ba can be with or without octet. **IGNORE** lack of charge on O_2^{2-} ion

			 **OR**  **OR**  **OR** 		O_2^{2-} ion to have 12 electrons belonging to O atoms + 2 other electrons of another symbol. The 2 other electrons must match Ba if Ba has an octet. If O electrons are shown as 6 of one symbol and 6 of another, each O must have six electrons of the same symbol **ALLOW**  **OR**  **Examiner's Comments** This question was designed to be difficult, but many candidates rose to the challenge. Weaker candidates simply drew a *'dot-and-cross'* diagram for BaO_2 in which they treated each oxygen species as an oxide ion each having a single negative charge. Many stronger candidates did realise from the structure given in the question that there was only a single bond between the two oxygen atoms, as was clear from their suggested diagram. Only the stronger candidates managed to incorporate correctly the electrons from barium, to arrive at a correct version of the bonding of BaO_2.
			Total	**5**	
20	a	i	*The Dipole Mark* At least one $H^{\delta+}$ **AND** one $O^{\delta-}$ shown correctly on each water molecule (see diagram) ✓  *The Hydrogen bonding Mark*	2	**DO NOT ALLOW** $H^{\delta-}$ **OR** $O^{\delta+}$ **IGNORE** lone pairs for first marking point

			One Hydrogen bond between H in one water molecule and a lone pair of O in an adjacent water molecule ✓		All Hydrogen bonds must hit a lone pair Hydrogen bond does NOT need to be labelled but it must be different from the covalent bond if it is not labelled **ALLOW** H-bond as label **ALLOW** only one lone pair on O atom **ALLOW** additional, correctly drawn Hydrogen bonded water molecules with correct dipoles **DO NOT ALLOW** more than two lone pairs on O atom **Examiner's Comments** Nearly all candidates answered this familiar question very well. Failure to show full dipoles on both molecules was the most common omission by some margin, whilst omitting to show a lone pair or not showing it involved in the hydrogen bond was seen comparatively more rarely.
		ii	*Property 1* Ice is less dense than water ✓ *Explanation 1* The molecules in ice are held apart by hydrogen bonds ✓ **OR** ice has an open lattice **OR** structure *Property 2* Ice has a relatively high melting point ✓ *Explanation 2* Hydrogen bonds are relatively strong OR Hydrogen bonds are stronger (than other intermolecular attractions or forces) OR More energy is needed to overcome hydrogen bonding	4	**ALLOW** ice floats (on water) **ALLOW** ice contracts when it melts **ALLOW** ice (water) has a higher melting point than expected **OR** predicted **ALLOW** other expressions which convey that the melting point is anomalously high e.g. 'Ice has an unusually high melting point' **IGNORE** boiling point **IGNORE** the following unqualified statements 'Ice has a higher melting point' or 'Ice has a high melting point' **IGNORE** references to surface tension as a property **IGNORE** explanations of surface tension **ALLOW** hydrogen bonds are the strongest intermolecular attraction or force **DO NOT ALLOW** 'hydrogen bonds are strong' but **ALLOW** this as part of a qualified statement (e.g. 'hydrogen bonds are strong compared with weak van der Waals forces') **Examiner's Comments** This question proved to be one of the more challenging ones on this paper. Of the possible properties of ice, the fact that ice is less dense than water was quoted often and was then supported by the correct explanation. It was when it came to discussing the anomalous melting point of water that candidates found it more difficult. Weaker candidates were content to give a very brief account, simply saying that ice's melting point was high (0°C is not a particularly high temperature) because hydrogen bonds are strong (a hydrogen bond is not a strong bond in comparison to a typical ionic bond). Such answers lacked the required comparison in terms of this property relative to other small molecules or of the strength of the hydrogen bonds in relation to other intermolecular forces.

	b		 '*dot-and-cross*' of CO_2 ✓	1	Lone pairs on O must be seen Lone pairs may be seen as 4 individual electrons **ALLOW** correct use of three different symbols **Examiner's Comments** The *'dot-and-cross'* diagram of the bonding in CO_2 was well known.
			Total	**7**	
21		i	(Trigonal) Pyramidal ✓ (Sb has) three bonding pairs **AND** one lone pair of electrons ✓ **Pairs** of electrons repel ✓	3	**ALLOW** alternative phrases / words to repel eg 'push apart' **ALLOW** lone pairs repel more than bonding pairs **ALLOW** bonds for bonded pairs **ALLOW** lp and bp **IGNORE** electrons repel **DO NOT ALLOW** atoms repel **Examiner's Comments** This question was well answered. Many candidates approached this question in a systematic manner and consequently gained marks for stating the number of bonding and lone pairs around the nitrogen atom and used this to determine the molecular shape. Centres are advised to demonstrate this method of addressing this type of question.
		ii	There is a difference in electronegativities (between Sb and C*l*) **OR** (Sb-Cl) bonds are polar **OR** have a dipole **OR** Dipoles seen on the diagram ✓ The molecule is not symmetrical **AND** dipoles do not cancel ✓	2	**ALLOW** Because C*l* is more electronegative (than Sb) **OR** Because Sb is more electronegative (than C*l*) **ALLOW** description that electrons are drawn along a covalent bond **IGNORE** single δ + or single δ- for dipole **IGNORE** diagram if M1 awarded in text **ALLOW** partial charges do not cancel **IGNORE** references to lone pair causing dipoles **Examiner's Comments** This question was relatively challenging with the need for the candidate first to refer to the polar nature of the Sb—Cl bond and then to note that the shape of the molecule prevents these individual dipoles from cancelling out. It was rare for candidates picked up both marks.

			Total	**5**	
22	a	i	**Boiling point of H_2S lower than H_2O** H_2O has hydrogen bonding (1) Hydrogen bonding is stronger **OR** more energy required to overcome hydrogen bonding (1) **Boiling point of H_2S lower than H_2Se** induced dipole–dipole interactions / London forces in H_2S are weaker (1) H_2S has fewer electrons **OR** less energy required to overcome induced dipole–dipole interactions (1)	4	**ora** throughout **do not allow** covalent bonds break **allow** instantaneous–induced dipole interactions **allow** dispersion forces **allow** van der Waals' / vdW **ignore** permanent dipole–dipole **do not allow** covalent bonds break
		ii	Any value between 285 and 335 (K) (1)	1	Graph must show an extrapolation line
	b		MgO: giant ionic (1) SO_2: simple molecular (1) ionic bonds (in MgO) are (much) stronger than intermolecular bonds (in SO_2) (1) ionic bonds (in MgO) need more energy to overcome / break (than intermolecular forces in SO_2) (1)	4	**ora** throughout For intermolecular bonds **allow** induced dipole–dipole interactions / London forces / permanent dipole–dipole interactions / van der Waals' forces **do not allow** hydrogen bonds **ignore** covalent bonds in SO_2 unless statement that they break: **CON**
			Total	**9**	
23			 three shared electron pairs plus a lone pair on C and O (1) one of the shared pairs shown as dative – i.e. both with the same type of dot / cross as the other electrons around the O (1)	2	mark can be awarded if either lone pair is missing, but there must be three shared pairs
			Total	**2**	

2.2.2 Bonding and Structure