6 Shapes of molecules and intermolecular forces
Answers to practice questions

<table>
<tr><th>Question number</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1 (a) (i)</td><td>HI, HBr, HCl, HF</td><td>B1</td><td></td></tr>
<tr><td>1 (a) (ii)</td><td>CF_4, CH_3I, CH_2Br_2, $CHCl_2F$</td><td>B1</td><td></td></tr>
<tr><td>1 (b) (i)</td><td>CO_2 and HCN: linear

H_2O and SCl_2: non-linear

BF_3 and SO_3: trigonal planar

NH_3 and H_3O^+: pyramidal

$AlCl_4^-$ and NH_4^+: tetrahedral</td><td>B1

B1

B1

B1

B1</td><td></td></tr>
<tr><td>1 (b) (ii)</td><td>CO_2, HCN, H_2O, SCl_2, BF_3, SO_3</td><td>B1</td><td></td></tr>
<tr><td>2 (a)</td><td><table><tr><th>molecule</th><th>bond angle</th><th>shape</th></tr><tr><td>CO_2</td><td>180º</td><td>linear</td></tr><tr><td>SF_6</td><td>90º</td><td>octahedral</td></tr><tr><td>CH_4</td><td>109.5º</td><td>tetrahedral</td></tr><tr><td>PF_3</td><td>107º</td><td>trigonal bipyramid</td></tr><tr><td>BF_3</td><td>120º</td><td>trigonal planar</td></tr></table>
1 mark for each bond angle</td><td>B1 x 5</td><td></td></tr>
<tr><td>2 (b)</td><td><table><tr><th>molecule</th><th>bond angle</th><th>shape</th></tr><tr><td>CO_2</td><td>180º</td><td>linear</td></tr><tr><td>SF_6</td><td>90º</td><td>octahedral</td></tr><tr><td>CH_4</td><td>109.5º</td><td>tetrahedral</td></tr><tr><td>PF_3</td><td>107º</td><td>trigonal bipyramid</td></tr><tr><td>BF_3</td><td>120º</td><td>trigonal planar</td></tr></table>
1 mark for each shape</td><td>B1 x 5</td><td></td></tr>
<tr><td>3 (a)</td><td>Shape: pyramidal

Sb has three bonding pairs and one lone pair of electrons

Electron pairs repel as far apart as possible and lone pairs repel more than bonding pairs</td><td>B1

B1

B1</td><td>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</td></tr>
<tr><td>3 (b)</td><td>Sb and Cl have different electronegativities OR Sb–Cl bonds are polar</td><td>B1</td><td>ALLOW Because Cl is more electronegative (than Sb) OR</td></tr>
</table>

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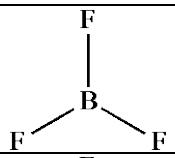
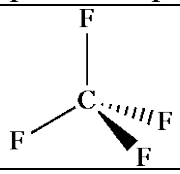
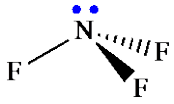
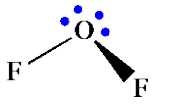
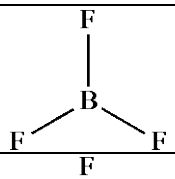
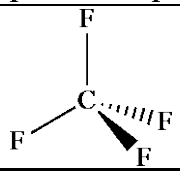
<tr><td></td><td>An $SbCl_3$ molecule is not symmetrical AND the dipoles do not cancel</td><td>B1</td><td>Because Sb is more electronegative (than Cl)
ALLOW description that electrons are drawn along a covalent bond

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</td></tr>
<tr><td>4 (a) (i)</td><td>
<table>
<tr><th>molecule</th><th>bonded pairs</th><th>lone pairs</th><th>shape</th></tr>
<tr><td>BF_3</td><td>3</td><td>0</td><td>  </td></tr>
<tr><td>CF_4</td><td>4</td><td>0</td><td>  </td></tr>
<tr><td>NF_3</td><td>3</td><td>1</td><td>  </td></tr>
<tr><td>OF_2</td><td>2</td><td>2</td><td>  </td></tr>
</table>
1 mark for each molecule’s bonded and lone pairs</td><td>B1 x 4</td><td></td></tr>
<tr><td>4 (a) (ii)</td><td>
<table>
<tr><th>molecule</th><th>bonded pairs</th><th>lone pairs</th><th>shape</th></tr>
<tr><td>BF_3</td><td>3</td><td>0</td><td>  </td></tr>
<tr><td>CF_4</td><td>4</td><td>0</td><td>  </td></tr>
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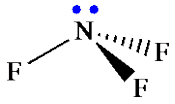
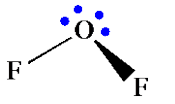
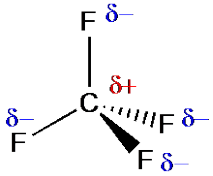
	<table><tr><td>NF_3</td><td>3</td><td>1</td><td>  </td></tr><tr><td>OF_2</td><td>2</td><td>2</td><td>  </td></tr></table> 1 mark for each shape		
4 (b)	Movement of electrons produces a changing dipole in a molecule, creating an instantaneous dipole The instantaneous dipole induces a dipole on a neighbouring molecule The induced dipole induces further dipoles on neighbouring molecules, which then attract one another	B1 B1 B1	
4 (c) (i)	The ability of an atom to attract electrons in a covalent bond	B1	
4 (c) (ii)		B1	
4 (d)	NF_3 and OF_2 are polar AND BF_3 and CF_4 are non-polar NF_3 and OF_2 are non-symmetrical AND BF_3 and CF_4 are symmetrical Dipoles cancel in symmetrical molecules	B1 B1 B1	
5 (a)	A hydrogen bond is an attraction between a lone pair of electrons on an electronegative atom in one molecule and a hydrogen atom in another molecule attached to an electronegative atom	B1	
5 (b)	O is more electronegative than H And O attracts the bonded pair of electrons in the covalent bond between O and H more than H	B1 B1	

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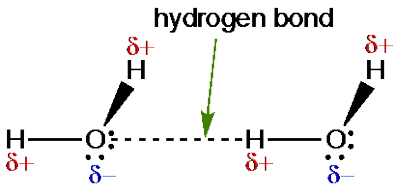
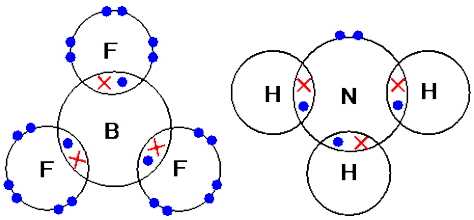
5 (c)	 1 mark for two water molecules shown with dipoles 1 mark for hydrogen bend between lone pair on O of one water molecule and H on another water molecule	B1 x 2	
5 (d)	104.5º	B1	
5 (e)	Ice is less dense than water Because H_2O molecules in ice are held apart by hydrogen bonds in open lattice structure Ice has a higher melting point than expected Because hydrogen bonds are stronger than other intermolecular forces so more energy is needed to break the hydrogen bonds	B1 B1 B1 B1	
6 (a)	The ability of an atom to attract electrons in a covalent bond	B1 B1	**ALLOW** 'attraction of an atom for electrons' **ALLOW** 'pull' for 'attract' **DO NOT ALLOW** 'element' for 'atom' **ALLOW** 'shared pair' or 'bond(ing) pair' for 'covalent bond'
6 (b)	$^{\delta+}$ N–F $^{\delta-}$ AND $^{\delta-}$N–B $^{\delta+}$	B1	**ALLOW** d+ / d **DO NOT ALLOW** + / –
6 (c) (i)	Octahedral	B1	
6 (c) (ii)	 1 mark for each drawing Electron pairs repel as far apart as possible NH_3 has one lone pair and three bonding pairs	B1 x 2 B1 B1	**ALLOW** diagrams without circles Must be 'dot-and-cross' **IGNORE** 'electrons repel' **DO NOT ALLOW** 'atoms repel' **ALLOW** 'bonds repel' **ALLOW** 'bonds' for 'bonding pairs' **ALLOW** 'four pairs' in place of 'one lone pair and three bonding pairs'

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	of electrons AND lone pair of electrons repels more than bonding pairs BF_3 has three bonding pairs of electrons which repel equally	 B1	The third marking point can be gained from statements seen in fourth or fifth marking points
6 (c) (iii)	A BF_3 molecule is symmetrical The dipoles cancel out	B1 B1	**IGNORE** 'polar bonds cancel' **IGNORE** 'charges cancel'
7 (a)	A covalent bond is the strong electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms	B1	**DO NOT ALLOW** 'shared electrons'
7 (b) (i)	Pairs of electrons surrounding a central atom repel The shape is determined by the number of bond pairs AND the number of lone pairs of electrons	B1 B1	**ALLOW** alternative phrases/words to repel eg 'push apart' **ALLOW** lone pairs repel **OR** bond(ing) pairs repel **ALLOW** 'the number of bonding pairs and number of lone pairs decides the orientation of the surrounding atoms' **ALLOW** 'how many' for 'number of' **ALLOW** the second mark for a response which has 2 of the following **including at least one** shape involving lone pairs (of electrons) BUT mark incorrect responses first 2 bonding pairs = linear 3 bonding pairs = trigonal planar 4 bonding pairs = tetrahedral 6 bonding pairs = hexagonal 3 bonding pairs and 1 lone pair = pyramidal 2 bonding pairs and 2 lone pairs = non-linear **IGNORE** 'number of electron pairs decides shape of molecule' as this is in the question
7 (b) (ii)	O–B–O: 120º B–O–H: 104.5º	B1 B1	**ALLOW** 104–105°
7 (c)	SF_6	B1	**ALLOW** XeF_4 **DO NOT ALLOW** SCl_6 **DO NOT ALLOW** stated complexes (simple molecule is asked for)

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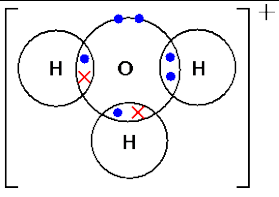
8 (a)	F_2 has London (or van der Waals') forces between molecules HCl also has permanent dipole–dipole interactions between molecules In HCl, the intermolecular forces are stronger and require more energy to break	B1 B1 B1 B1	**ALLOW** vdWs for van der Waals' **IGNORE** F_2 has covalent bond for this mark **IGNORE** F_2 has 'intermolecular forces' *Quality of written communication*: 'dipole(s)' spelled correctly and used in context for the **second** marking point **IGNORE** HCl has 'intermolecular forces' **IGNORE** van der Waals' forces in HCl **DO NOT ALLOW** hydrogen bonding **DO NOT ALLOW** ionic bonding Look for strength of force comparison anywhere in the answer **ALLOW** ECF for hydrogen bonding in HCl being stronger than the stated intermolecular forces in F_2 BUT **DO NOT ALLOW** this mark if HCl or F_2 has covalent bonds broken **OR** if HCl has ionic bonds broken (the question asks for forces between molecules) **IGNORE** HCl has stronger van der Waals' (forces) than F_2 (as they both have the same number of electrons) **DO NOT ALLOW** fourth mark if covalent bonds are broken in HCl or F_2 **OR** if ionic bonds are broken in HCl **IGNORE** 'heat' but **ALLOW** 'heat energy'
8 (b)	 1 mark for correct bonds from O to 3 H atoms, including one dative covalent bond. 1 mark for other O lone pair shown correctly	B1 x 2	Must be 'dot-and-cross' Must be H_3O for either mark Circles for shells **not** needed **IGNORE** inner shells **IGNORE** lack of positive charge and square brackets **DO NOT ALLOW** second marking point if negative charge is shown on the ion Non-bonding electrons do **not** have to be seen as a pair

Question number	Answer	Marks	Guidance
			ALLOW second mark for one non-bonding pair of electrons and three *dot-and-cross* bonding pairs of electrons
9 (a)	NH_3 London forces hydrogen bonds PF_3, and SF_6 and NH_3 London forces	B1 B1 B1	
9 (b)	Hydrogen bonds are far stronger than London forces. More energy is required to break hydrogen bonds in NH_3	B1 B1	
9 (c)	NH_3: pyramidal NH_3: 107º SF_6: octahedral SF_6: 90º	B1 B1 B1 B1	