Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • **(M1)** (a lower boiling temperature is expected) because water has fewer electrons than hydrogen sulfide **(1)** • **(M2)** water has weaker/less London forces **(1)** • **(M3)** (a higher boiling temperature occurs because) water has hydrogen bonding **(1)** • **(M4)** hydrogen bonding is stronger than London forces and requires more **energy** to break (and results in a higher boiling temperature) **(1)**	Accept water has 10 electrons but hydrogen sulfide has 18 electrons (per molecule) Ignore reference to Mr/size of atom Allow van der Waals'/dispersion forces/ instantaneous dipole-induced dipole Accept reverse arguments Ignore references to permanent dipole-dipole forces	**(4)**

Q2.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • **M1** London forces are greater in NCl_3 (1) • **M2** as NCl_3 has more electrons / as Cl (atom) has more electrons (than F atom) (1) • **M3** (permanent) dipole-dipole forces / "permanent dipoles" / "dipole forces" stronger in NF_3 (than NCl_3) (1) • **M4** as F is more electronegative than Cl (1) • **M5** **either** London forces predominate / London forces are more significant **or** more (heat) energy needed to overcome the intermolecular forces between NCl_3 molecules (than NF_3 molecules) (1)	Allow reverse arguments Award van der Waals' / induced dipole etc Award NCl_3 has 58 electrons whereas NF_3 has 34 electrons Ignore comparisons of M_r Do not award M2 if comparison of "**ionic** radii" Award for M3 (permanent) dipole-dipole forces only in NF_3 Electronegativity difference 1.0 between N and F / No electronegativity difference between N and Cl / N-F is a more polar bond than N-Cl Award (0) for M5 if any mention of: Ionic bonds breaking in either NF_3 or NCl_3 **Breaking of** N-F and / or N-Cl covalent bonds scores (0) for M5 Note If hydrogen bonding mentioned, can only award M1, M2 and M5 max Ignore polarisation of ions	**(5)**

Q3.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points:	An answer that states 'covalent bonds break' or 'bonds between atoms break' or refers to 'ions' scores (0) overall Allow reverse argument for M1 and M2	**(2)**
	• from chlorine to iodine / down the group, the number of electrons (in the molecule / atom) increases / changes from 34 to 106 / 17 to 53 **(1)**	Allow iodine has more / most electron shells (than chlorine and/or bromine) Ignore 'the size of the atoms /molecules increases from chlorine to iodine' Do not allow incorrect numbers of electrons	
	• so the strength of the London / instantaneous dipole-(induced) dipole forces increases / there are more London / instantaneous dipole-(induced) dipole forces **and** more energy is needed to separate the molecules **(1)**	Allow iodine has the strongest London force **and** most energy is needed to separate the molecules Allow more energy is need to overcome / break the London forces / bonds instead of separate the molecules Allow dispersion forces / van der Waals forces for London forces Ignore higher temperature needed to separate the molecules Do not award dipole-dipole forces / just 'intermolecular forces'	

Q4.

<table>
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Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

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</table>
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<td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning.

For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
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	The following table shows how the marks should be awarded for structure and lines of reasoning. **Number of marks awarded for structure of answer and sustained line of reasoning** Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. — 2 Answer is partially structured with some linkages and lines of reasoning. — 1 Answer has no linkages between points and is unstructured. — 0	In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).	

	Indicative content: • IP1 Electrons Same number of electrons so similar / the	Read all of the answer first as IPs can be found anywhere in the answer Allow high electronegativity of F and O (compared to H) Allow HF and H_2O (highly) polar **and** CH_4 non polar	

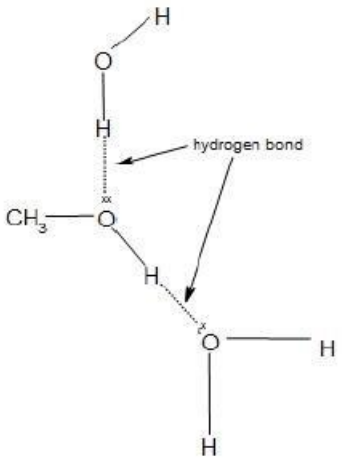
	same London forces / van der Waals' forces / dispersion forces • IP2 Electronegativity Large electronegativity differences in HF and H_2O **and** small in CH_4 / quoting all electronegativity values of differences / combination of previous three alternatives covering all three bonds • IP3 Intermolecular forces in methane **Only** (weak) London forces / van der Waals' forces / dispersion forces in CH_4	Allow IP2 for any three of: F=4.0, O=3.5, H=2.1, C=2.5 Allow IP2 for any two of: HF=1.9, HO=1.4, HC=0.4 These values may be seen anywhere Allow no dipole-dipole forces / no hydrogen bonds in CH_4 Award IP3 if London forces are the only intermolecular forces mentioned in CH_4 May be shown in a diagram	

	• IP4 Intermolecular forces in water and hydrogen fluoride Hydrogen bonding in both HF and H_2O (but not CH_4) • IP5 Relative numbers of hydrogen bonds More hydrogen bonds / (average of) twice as many hydrogen bonds in H_2O than in HF • IP6 Energy More energy needed to break stronger intermolecular forces / less needed to break weaker intermolecular forces.	Do not award IP6 for any clear indication of covalent bond breaking or ionic bond breaking	

Q5.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • (only) ethanol has hydrogen bonding (and dipole-dipole and London forces) **(1)** • ethene (only) has (weaker) London/ instantaneous dipole –induced dipole forces **(1)** • more **energy** required to break the (stronger) intermolecular forces/hydrogen bonds in alcohols **(1)**	Ignore references to ethanol having stronger London forces Accept dispersion /van der Waals forces A comparison is needed Allow overcome for break Allow 'heat' for energy Accept reverse argument Do not award if the more energy required is given in response to just breaking stronger London forces for ethanol Do not award M3 for covalent bonds breaking	**(3)**

Q6.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • methanol hydrogen bonds to water (1) • at least one lone pair on an oxygen atom and an approximate 180° OHO bond angle (1) • strength of (all) intermolecular forces between methanol and water is approximately the same as those in water and methanol or strength/extent of H-bonding between methanol and water is same/> that between water/methanol molecules (1)	<u>Example of diagram</u>  Accept one labelled hydrogen bond (min) between the O or H of methanol and a correct atom in water. Minimum of one lone pair must be shown on the relevant O atom Ignore reference to the methyl group Allow any mention of H-bond between methanol and water for M11720 – 1700 cm^{-1}	(3)

Q7.

Question Number	Answer	Additional Guidance	Mark
	An explanation which makes reference to the following points: • branching results in fewer/weaker London forces **(1)** • due to less surface area/points of contact **(1)**	Accept reverse argument Allow van der Waals / instantaneous dipole-induced dipole / dispersion forces Ignore just intermolecular forces Do not award 'fewer electrons' Do not award if **covalent** bonds broken Allow reference to less close packing of molecules together	**(2)**

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: **setting up of the dipole** • uneven distribution of **electrons**/ (random) movement of **electrons** / (random) fluctuations of **electrons** **(1)** **type of dipole** • (results in an) instantaneous dipole / temporary dipole (in the first molecule) **(1)** **induction of a second dipole** • causes/induces a (second) dipole on another molecule **(1)**	M1 & M3 could be scored for an appropriate diagram Allow "Change in **electron** density" Allow "transient dipole" / "oscillating dipole" Do not award for "permanent dipole" Allow neighbouring molecule / adjacent molecule Do not award for "permanent dipole"	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: **relative number of electrons** • bromine has more **electrons** (than chlorine) / bromine has one more shell of **electrons** (than chlorine) **(1)** **relative strength of intermolecular forces** • (so) bromine has stronger (London) forces (between molecules) / more (heat) energy is needed to overcome the London forces between bromine molecules / greater temporary dipole – induced dipole forces **(1)**	Allow reverse arguments Allow correct formulae Bromine has 35/70 electrons and chlorine has 17/34 electrons Ignore comments about protons, molecular mass etc Do not award "more outer shells" Ignore comments about 'points of contact' Allow more (London) forces Allow "bonds between molecules" Award **(0)** marks overall if any implication that **covalent** bonds are broken (on boiling)	(2)

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• 222 (K)	allow answers in the range 200 to 240 (K)	(1)

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Choose an item. This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.	(6)

1	1
0	0

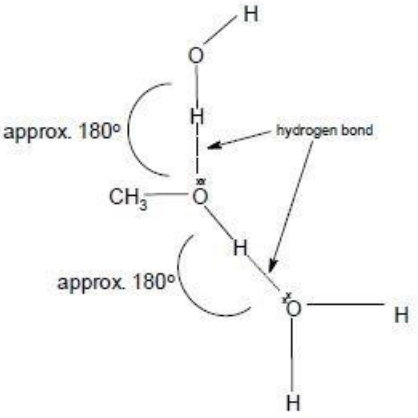
The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure and sustained lines of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Example of suitable diagram



Allow either/both hydrogen bond(s).

Allow any number of hydrogen bonds, if all correct.
O-H-O bond angle must be approx. 180° (either in diagram or mentioned in text)
Ignore lone pair and dipole

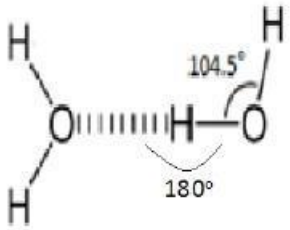
Indicative content:

- IP1 **hydrogen bonding** between water/solvent and methanol/solute
- IP2 suitable diagram
- IP3 same strength/comparable to the bonding in either component on its own

	Or hydrogen bonding is present in methanol and in water • IP4 hydration of Na^+ and Cl^- • IP5 suitable diagram of at least one ion • IP6 the ionic bonding is stronger than the bonding between sodium and/or chloride ions and methanol	Allow 'solvation/hydration of the ions', provided it is clear that both ions are included. Example of suitable diagram  allow solvation/hydration by any number of water molecules ⩾1 If dipole shown on water, must be correct	

Q11.

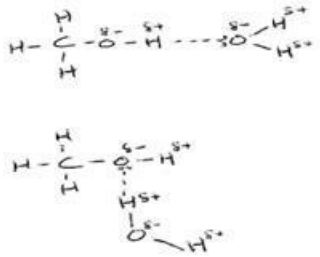
Question Number	Answer	Mark
(i)	**The only correct answer is C** ***A*** *is not correct because oxygen does have a higher mass number but it is not the cause of polarity* ***B*** *is not correct because oxygen does have a larger atomic radius but it is not the cause of polarity* ***D*** *is not correct because oxygen does have more electrons but this is not the cause of polarity*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	 • correct shape of two water molecules and hydrogen bond show at about 180 ° but not necessarily labelled **(1)** • HOH bond angle 104.5° and OHO angle 180° **(1)**	Allow about 10° tolerance by eye. Allow 104 – 105°	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to two of the following points: • more open / more space between molecules (making it less dense) **(1)** • due to (3 Dimensional) lattice / ring structure in ice **(1)** • hydrogen bonds longer than the covalent bonds **(1)**	Do not award MP1 if the gaps are full of air molecules May be shown as a diagram Allow reverse arguments for liquid water	**(2)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	• hydrogen bonding		**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• at least one lone pair shown on the oxygen atom in water or methanol **and** involved in the hydrogen bond **(1)** • hydrogen bond shown between an H in one molecule and an O on the other molecule **and** O–H---O / O---H–O bond angle at (about) 180° **(1)** • at least one δ+ shown on either H atom in water or attached to O in methanol **and** at least one δ– shown on any O atom **(1)**	Examples of diagrams  Any bond angle labelled as 180° must be between the correct bonds 180° must be drawn at about 180°, not just labelled Ignore all other bond angles Only 1 correct dipole needs to be shown No TE on (i) If 2 hydrogen bonds shown, 1 with correct bond angle and 1 incorrect, do not award M2	**(3)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • the electron density of the (benzene) ring is greater in phenol (than in benzene) **(1)** • because the lone pair (of electrons) on oxygen **and** overlaps with the pi cloud / delocalised electrons / delocalised system **(1)**	Allow lone pair (of electrons) on oxygen feeds into / donates into / interacts with the delocalised electrons / system Ignore electron pushing effect of OH	**(2)**

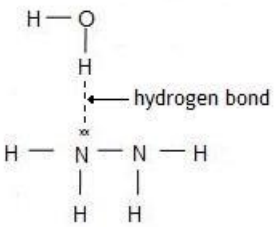
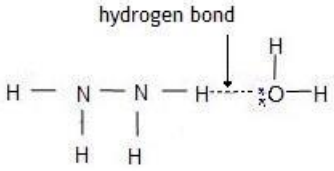
Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • they both form hydrogen bonds (1) • in 4-nitrophenol the hydrogen bonds join molecules in a straight chain / at both ends / at opposite ends (of the molecule so are stronger) or 2-nitrophenol forms intramolecular hydrogen bonds / forces / interactions (so fewer intermolecular hydrogen bonds) (1)	Allow M1 and M2 shown in diagrams Ignore reference to other specific types of intermolecular forces Allow 4-nitrophenol forms stronger intermolecular hydrogen bonds / forces / interactions Allow in 2-nitrophenol the hydrogen bonds join 2 molecules together / form a dimer (so there are fewer / weaker hydrogen bonds) Allow in 2-nitrophenol the hydrogen bonds are on the same side (of the molecule)	(2)

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	A description that makes reference to the following points: • diagram showing **both** Na^+ ion **and** ClO^- ion surrounded by water molecules/solvated **(1)** • correct orientation of the water molecules around **both** ions with a relevant dipole shown on at least one water molecule for each ion, (i.e. δ– on O for a water molecule next to Na+ and a δ+ on at least one H atom on a water molecule next to a ClO^-) **(1)**	Allow any number of water molecules **(>1)** for **both** ions For M1 to be awarded there must be more than one H_2O molecule around each ion M2 can be awarded even if only one H_2O molecule is shown next to each ion Allow one mark for one ion surrounded by correctly orientated water molecules. Written description only, covering the same two marking points scores one mark max **Mention of hydrogen bonding or water drawn as "HO_2" or NaClO shown as covalent scores (0) overall**	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • ethanol forms hydrogen bonds (with water) **(1)** • chloroethane forms (permanent) dipole-dipole attractions **and** London forces (with water) **(1)**	 Allow "London forces and dipole forces" Ignore 'chloroethane does not form hydrogen bonds with water	**(2)**

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
	A diagram and description showing the following points: • any mention of hydrogen bonding /H –bonds in water, hydrazine or the mixture, in text or diagram **(1)** • diagram showing hydrogen bond between the correct atoms **(1)** • lone pair on either nitrogen or oxygen and bond angle shown on diagram as approximately 180° **(1)**	Examples of suitable diagrams: Do not award if H bonding clearly within the molecule, e.g. the O-H / N-H bond is a hydrogen bond   Allow more than one H bond Allow description of atoms connected by H-bond Ignore any dipoles Allow bonds involving lone pair on the hydrazine or the water, and hydrogen atoms in hydrazine or water.	**(3)**

Q16.

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If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

In general, an answer with 5 or 6 IPs would score 2 reasoning marks, 3 or 4 IPs would score 1 reasoning mark, 0, 1 or 2 IPs would score 0 reasoning marks.

Reasoning marks may be reduced for extra incorrect chemistry.
</td>
<td>(6)</td>
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	linkages and lines of reasoning			
	Answer has no linkages between points and is unstructured	0		
	Indicative content • 2-methylpentane is insoluble in water as it cannot hydrogen bond to water (as none of the hydrogen atoms are electropositive) • 2-methylpentane is soluble in hexane as London forces in both compounds (are similar in strength / size) • so (resultant) forces in mixture are similar in magnitude to those in each liquid • potassium bromide is soluble in water as its ions are hydrated when dissolved • the enthalpy change of hydration is greater than / close to / compensates for the energy needed to break apart the lattice • potassium bromide is insoluble in hexane as any (London) forces that form between it and hexane would be smaller in magnitude than the forces between the ions		If there is no specific reference to types of intermolecular forces / interaction in IPs 1 and 2 then allow 1 IP for idea of 'like dissolves like' e.g. 2-methylpentane dissolves in hexane as they are both non-polar / does not dissolve in water as water is polar scores 1IP if both IP1 and IP2 not awarded Allow van der Waals / dispersion forces / instantaneous dipole-induced dipole Allow both form only London forces Ignore references to entropy Do not award if water is shown as split into ions	

Q17.

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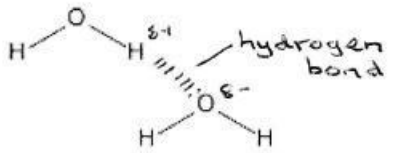
In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

	Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning **Indicative content** • **IP1 –** lone pair and dipole lone pair on oxygen in hydrogen bond **and** dipole shown with δ+ on any one H and δ– on any one O • **IP2 –** shape hydrogen bond labelled / or shown as a dotted line **and** hydrogen bond(s) shown as approximately linear or O-H-O bond angle labelled 180° • **IP3 –** London forces hydrogen sulfide has stronger London forces/ dispersion forces / van der Waals' forces (because it has more electrons)	**General points to note** If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Example of incorrect chemistry Reference to ionic bonding/ions Ignore reference to intermolecular forces other than London forces in H_2S  Example of diagram Comment: allow bond angles drawn between 170^0 and 190^0 if labelled 180^0 If multiple hydrogen bonds are drawn the majority must be within this tolerance Allow / attractions between temporary dipoles and induced dipoles / instantaneous dipole - induced dipole for London forces	

	• **IP4 –** comparison hydrogen bonding is stronger than London forces / is the strongest intermolecular force / requires more energy to break/ requires more energy to overcome	Do not award breaking of covalent bonds Allow hydrogen bonds take a lot of energy to break as long as hydrogen bonds are only mentioned as being present in the water	
	• **IP5 –** ice at 0^0C (water molecules are arranged) in a lattice / hexagon **or** hydrogen bonds are longer than covalent bonds	Allow this shown in a diagram Allow rings (of 6 for hexagonal) Allow there are spaces / air / gaps in the structure	
	• **IP6 –** water at 0^0C (water) molecules get closer / have less distance between them / more molecules in the same volume	Allow (water) molecules fill the spaces/gaps Allow reverse argument	

Q18.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • silicon – giant atomic / giant covalent / giant molecular / macromolecular **and** contains covalent bonds **(1)** • chlorine - (simple) molecular / molecules / diatomic / Cl_2 **and** contains London forces **(1)** • (covalent) bonds in silicon are stronger than London forces/ intermolecular forces in chlorine **or** covalent bonds take more energy to break than London forces / intermolecular forces **(1)**	Do not allow just 'silicon is a covalent molecule' Do not allow reference to ions or metallic bonding Allow dispersion forces / van der Waals' / attractions between temporary dipole and induced dipole/ attractions between instantaneous dipole (- induced dipole) for London forces Do not award covalent bonds being broken in chlorine Ignore silicone for silicon as correct spelling is given in the paper	**(3)**