PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 2: BONDING AND STRUCTURE

SCORE	PERCENTAGE
/196	%

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Q56.

This question is about dissolving different compounds.

* The solubility of two compounds in different solvents was investigated.
A summary of the findings is shown.

Compound	Soluble in water	Soluble in hexane
2-methylpentane	X	✓
potassium bromide	✓	X

Explain the findings of the investigation by considering the interactions between the compounds and each of the solvents.

(6)

(Total for question = 6 marks)

Q57.

Predict the shape and bond angles in a CH_3^- ion. Justify your answer.

(4)

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Mark Scheme

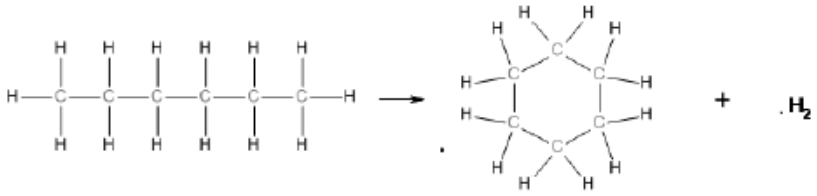
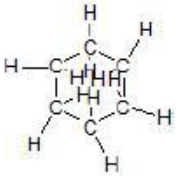
Q1.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to one of the following points • the loss of a hydrogen from the O–H group is made possible by the delocalisation of charge of/stabilisation on the carboxylate ion **or** the loss of a hydrogen from a methyl group would produce a carbanion with no stabilisation **or** similar electronegativies of carbon and hydrogen means that there is a lack of C–H bond polarity **or** the enthalpy of hydration of the ions outweighs the energy needed to break the O–H bond	Allow the C–H bond is not polar but the O–H bond is/ O–H bond is more polar Do not award the O–H bond is weaker than the C–H bond	(1)

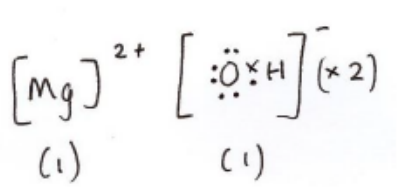
Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • different alkanes have different boiling temperatures/points **(1)** • because of (different) chain length/molar mass /strength of intermolecular forces/ number of electrons **(1)**	Allow Volatility for boiling temperature Allow Different alkanes condense at different temperatures Ignore melting temperatures if given with boiling temperatures Ignore densities Accept London /dispersion /van der Waals forces Allow reference to size A comparison such as 'longer alkanes have higher boiling points' scores 2 Ignore any reference to surface area Do not award references to cracking Do not award reference to just weight/mass Do not award incorrect trend	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	Correct equation	Example of equation: $C_8H_{18} \rightarrow C_2H_4 + C_6H_{14}$ OR $C_8H_{18} \rightarrow 2C_2H_4 + C_4H_{10}$ OR $C_8H_{18} \rightarrow 3C_2H_4 + C_2H_6$ Allow $CH_2=CH_2$ for C_2H_4 Products can be given in either order Do not award equations forming H_2	(1)

Question Number	Answer	Additional Guidance	Mark
(iii)	Correct equation	Example of equation:  Accept bonds to hydrogen atoms inside the ring, e.g.  Allow skeletal or structural formulae for hexane  or $CH_3(CH_2)_4CH_3$ and for cyclohexane  or $(CH_2)_6$ Ignore $C_6H_{14} \rightarrow C_6H_{12} + H_2$	(1)

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	 (1) (1)	For Mg allow 0 or 8 electrons in outermost shell Ignore inner shell electrons	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• amount of NaOH (1) • [NaOH] (1) • $[NaF]_{eq}$ (1) • K_c expression (1) • Value of K_c (1)	Example of calculation 11.7/1000 x 0.100 = 0.00117 / 1.17 x 10^{-3} 0.00117/(25/1000) = 0.0468 mol dm^{-3} 0.250 – 0.0468 = 0.2032 mol dm^{-3} $K_c = [NaOH]^2 / [NaF]^2$ 0.0530 (no units)	**5**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (ii)	An answer that makes reference to the following point: • No, as temperature is likely to be different on different days and this affects value of K_c	Allow 'yes, but only if the temperature is the same'	**1**

Q4.

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)**

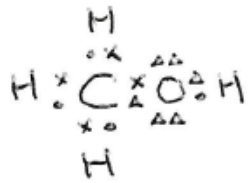
Q5.

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)**

Q6.

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'	

Q7.

Question Number	Answer	Additional Guidance	Mark
	• all bonding pairs of electrons correct **(1)** • 2 lone pairs of electrons on oxygen **(1)**	Example of diagram  Allow any symbols for electrons, including all dots or all crosses Allow electrons either side of a line for a bond e.g. x Electrons can be in overlapping circles, on the lines, inside the lines or in the gaps between the lines Non-bonding electrons on O can be shown as 2 pairs, all 4 together or as 3 and 1 Ignore inner shell electrons	**(2)**

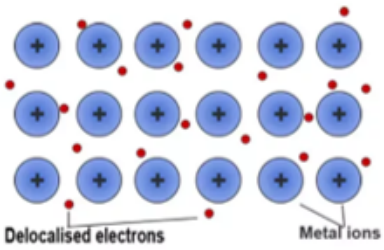
Q8.

Question Number	Answer	Additional Guidance	Mark
	• O–H	Allow this shown on diagram in (a) Allow OH Do not award –O–H	**(1)**

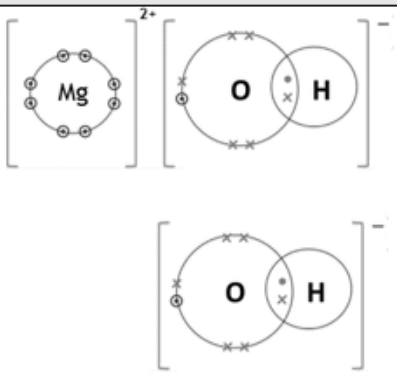
Q9.

Question number	Answer	Additional guidance	Marks
(a)	B		**1**
(b)	B		**1**
(c)	C		**1**

Q10.

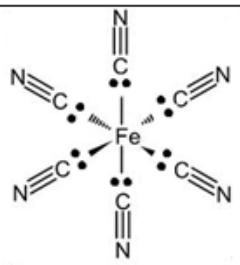
Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points (Structure consisting of) • lattice of positive ions / regular arrangement of positive ions **(1)** • (in sea of) delocalised electrons **(1)** • strong forces of attraction between ions and delocalised electrons (so high melting temperature) **(1)** • so lots of (heat) energy needed to break attraction between ions and delocalised electrons / metallic bonds **(1)**	M1 and M2 can be scored by use of a labelled diagram, but if both given both must be correct For example  Allow charge on ion of 2+ or 3+ Diagram should show at least 4 ions (for M1) a number of electrons roughly consistent with charge on ions and random (for M2) The attraction between ions and delocalised electrons only needs to be mentioned once in M3 and M4 Allow 'lots of energy needed to separate the ions'	**(4)**

Q11.

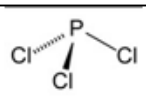
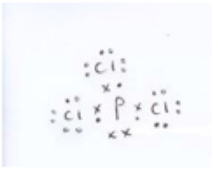
Question Number	Answer	Additional Guidance	Mark
(i)	• magnesium ion (1) • hydroxide ion (1)	 Allow all dots or all crosses Allow M1 for magnesium ion outer shell shown with no electrons Allow M2 even if only 1 hydroxide ion is shown Ignore inner shells Ignore absence of square brackets and circles Ignore any indication of 2 hydroxide ions e.g. 1 hydroxide ion with '2' preceding it Penalise missing charges once only	(2)

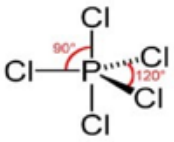
Question Number	Answer	Additional Guidance	Mark
(ii)		Example of calculation	(5)
	• calculation of moles of $Mg(OH)_2$ **(1)**	0.174 ÷ 58.3 = 2.98456 x 10^{-3} (mol)	
	• calculation of mass of $Mg(NO_3)_2$ **(1)**	2.98456 x 10^{-3} x 148.3 = 0.44261 (g)	
	• calculation of mass of H_2O **(1)**	0.765 - 0.44261 = 0.32239 (g)	
	• calculation of moles of H_2O **(1)**	0.32239÷18 = 0.017911 (mol)	
	• deduction of $Mg(NO_3)_2$: H_2O ratio (and hence formula) **(1)**	0.017911÷ 2.98456 x 10^{-3} = 6.0011 1:6, (so $Mg(NO_3)_2.6H_2O$)	
	OR		
	• Calculation of moles of $Mg(OH)_2$ **(1)**	0.174 ÷ 58.3 = 2.98456 x 10^{-3} (mol)	
	• deduction of moles of $Mg(NO_3)_2.xH_2O$ **(1)**	1:1 so = 2.98456 x 10^{-3} (mol)	
	• expression for / calculation of molar mass of $Mg(NO_3)_2.xH_2O$ **(1)**	148.3 + 18x / 0.765 ÷ 2.98456 x 10^{-3} = 256.3	
	• expression for moles of $Mg(NO_3)_2.xH_2O$ in terms of mass and molar mass / calculation mass of water in 1 mole **(1)**	0.765÷(148.3 + 18x) = 2.98456 x 10^{-3} (mol) / 256.3 - 148.3 = 108 0.32239 = 0.0537x, so x = 0.32239÷0.0537 = 6.0035 / 108÷18 so x = 6 ; (so $Mg(NO_3)_2.6H_2O$)	
	• calculation of x (and hence formula) **(1)**	Correct answer with no working scores M5 only. Ignore SF from M1 to M4, allow TE throughout	

Q12.

Question number	Answer	Additional guidance	Marks
(a)(i)	A		1
(a)(ii)	 • 3D shape correctly shown (1) • electron pairs shown OR all six bonds shown clearly to the carbons (1)	Charge and square brackets not required Allow dotted lines for the wedges going backwards Allow arrows to represent dative covalent bonds instead of electron pairs	2
(b)	• step 1 – ligand substitution/ligand exchange (1) • step 2 – redox (1)	Allow reduction **and** oxidation Allow oxidation	2
(c)	• identification: green precipitate is iron(II) hydroxide (1) Explanation: • precipitate turns brown because iron(II) hydroxide is oxidised by oxygen (and water) in the air (1) • to form iron(III) hydroxide (1)	$Fe(OH)_2$ / $Fe(H_2O)_4(OH)_2$ $Fe(OH)_3$ / $Fe(H_2O)_3(OH)_3$	3

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to • **M1** PCl_3 is (trigonal) pyramidal (1) • **M2** has 3 bond pairs and 1 lone pair (around central P atom) (1) • **M3** electron pairs repel to positions of minimum repulsion / maximum separation (1)	Marking points 1 and 2 may be shown on diagrams (see below) Award M1 for correct name of shape even if diagram(s) incorrect Ignore lone pair – bond pair repulsions > bond pair – bond pair repulsions Answer must state or imply somewhere that (electron) pairs repel Do not award if specifically stated that 'bonds repel' or 'atoms repel' Ignore any references to bond angles even if incorrect	(3)
Example of diagram for award of M1 (a lone pair may also be shown on the P atom) 			
Example of diagram for award of M2 (must show 3 bond pairs and 1 lone pair) 			

Question Number	Answer	Additional Guidance	Mark
(ii)	• **M1** Diagram showing trigonal bipyramidal shape, with 3D emphasised by use of two wedges or one hatch and one wedge in the central plane (1) • **M2** 90˚ and 120˚ angles labelled (1) • **M3** trigonal bipyramidal (1)	 M2 dependent on correct M1 Ignore 180° Do not award M2 if any incorrect bond angle is shown M3 stand alone mark Both words required Award "trigonal bipyramid"	(3)

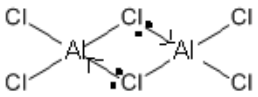
Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • phosphorus can expand its octet / can expand its (outer) shell / can accommodate more than 8 electrons / can accommodate 10 electrons / has available (3d-) orbitals (for promotion of electrons) (1) • nitrogen does not have (2)d-orbitals / can only accommodate eight electrons (in its outer shell) (1)	**Comment** Award reference to P accommodating 18 electrons Ignore comparisons of size / radius of P and N atoms	(2)

Q14.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH_2OH) withdraws / attracts electrons **(1)** • stabilises the anion / CH_2OHCOO^- ion **or** weakens O-H bond in acid so hydrogen **ion** / H^+ lost more easily **(1)**	Allow reference to intramolecular hydrogen bonding Allow hydrogen **ion** / H^+ more easily dissociates	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	($CH_2OHCOOH + CH_3COOH \rightarrow$) • $CH_2OHCOO^- + CH_3COOH_2^+$	Both correct for the mark Allow formulae in either order Allow formulae in brackets with charge outside Allow displayed formulae Do not allow $CH_3C(OH)_2^+$	**(1)**

Q15.

Question Number	Answer	Additional Guidance	Mark
(i)	• diagram showing two $AlCl_3$ molecules joined through two chlorine atoms	Example of diagram  Allow dot-and-cross diagram Ignore missing arrows / direction of arrows Ignore missing lone pairs	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• dative (covalent) bonds **or** coordinate bonds	Allow this labelled on diagram in (i) Do not award this mark if dative bonds shown as arrows starting from aluminium in (c)(i)	(1)

Q16.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points • amino acids exist as zwitterions **(1)** • so ionic bonds form between the zwitterions / amino acids **(1)**	maybe shown on a diagram allow (a single molecule of an amino acid) forms positive and negative ions Allow 'strong electrostatic forces' if ions clearly referenced in response Ignore reference to hydrogen bonds	**(2)**

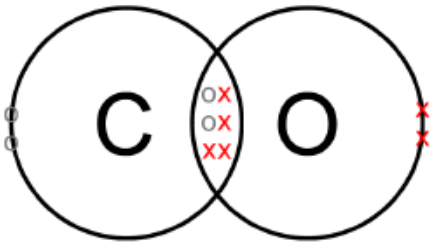
Q17.

Question Number	Answer	Additional guidance	Mark
	An answer that makes reference to the following: • suitable volumes of ethanol and water (1) • evidence of calculation to show one component of mixture in excess (1) • mixed together in simple calorimeter / polystyrene cup with lid (1) • stir and measure maximum temperature change (1) • calculate energy change using $Q=mc\Delta T$ (1) • calculate strength of hydrogen bond per mole by scaling up from the amount of limiting component of mixture (i.e. component not in excess) (1)		**6**

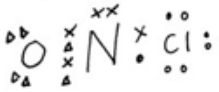
Q18.

Question Number	Answer	Mark
	The only correct answer is C (poor electrical conductivity) ***A*** *is not correct because both graphene and graphite are similar to diamond in having a high melting temperature* ***B*** *is not correct because neither graphene nor graphite nor diamond have a precise molecular formula since they are giant molecular structures* ***C*** *is not correct because graphene, graphite and diamond are all giant molecular structures*	**(1)**

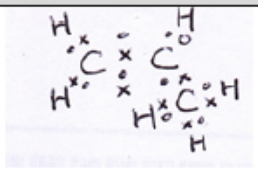
Q19.

Question Number	Answer	Additional Guidance	Mark
	• 3 bond pairs showing triple bond, one of which must be a dative bond (1) • both lone pairs on C and O (1)	Example of dot and cross diagram:  Allow 1 mark if correct number of electrons shown, but all as crosses or all as dots Ignore lines showing covalent bonds	(2)

Q20.

Question Number	Answer	Additional Guidance	Mark
	• electrons for double bond, single bond and lone pair around N (1) • rest of electrons on Cl and O (1)	Example of dot-and-cross diagram  Allow any combination of dots/crosses/triangles for electrons Allow bond pairs in double bond shown horizontally Ignore lines drawn between atoms to show covalent bonds	(2)

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
	 • 2 pairs of electrons between 2 carbon atoms and 1 pair of electrons between the other 2 carbon atoms (1) • rest of diagram correct (1)	Allow dots or crosses for any atoms or all dots or all crosses Allow diagrams with overlapping circles Ignore inner shell electrons shown on carbon atoms	**2**

Q22.

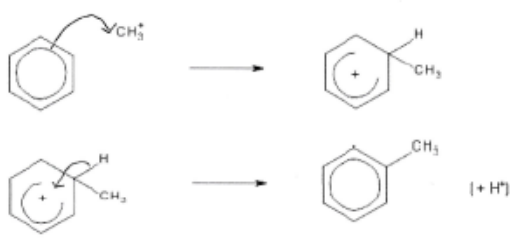
Question Number	Answer	Additional Guidance	Mark
(i)	• dot-and-cross diagram **and** charges	Example of diagram  Circles are not needed Allow no electrons or 8 electrons on outer shell of Mg Allow dots or crosses for all electrons Allow diagrams without square brackets, provided charges are shown Allow alternative ways of showing that there are 2 bromide ions Ignore inner shell electrons	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• (conducts electricity when) molten / liquid **and** dissolved in water / (in) aqueous (solution)	Both needed for the mark Ignore gaseous Allow 'in solution / dissolved'	**(1)**

Q23.

Question Number	Answer	Additional Guidance	Mark
(i)	• dot-and-cross diagram	Example of diagram  Allow electrons in overlapping circles Allow all dots / all crosses Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. x • Do not award diagram with lone pair on Al	(1)

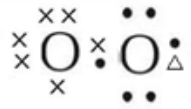
Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • shape – trigonal planar (1) • bond angle - 120° (1)	Mark independently Both words needed Allow triangular for trigonal – but not just tri Allow marks for labelled diagram **Note** If shape is pyramidal, no mark for M1 but allow (1) for 107° No TE for any other shape	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	• equation for the formation of the electrophile (1) • curly arrow from on or within the circle to CH_3^+ (1) • structure of intermediate including charge with some part of the charge within the horseshoe **and** horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon (1) • curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure (1)	Example of mechanism $CH_3Cl + AlCl_3 \rightarrow CH_3^+ + [AlCl_4]^-$  Allow $AlCl_4^-$ / $^{\delta+}CH_3\text{-}AlCl_4^{\delta-}$ Allow curly arrow from anywhere within the hexagon Allow curly arrow to any part of CH_3^+, including the + charge Do not award curly arrow from outside the hexagon Allow dotted / dashed lines for horseshoe Do not award dotted bonds to H and CH_3 unless clearly part of a 3D structure Ignore any involvement of $AlCl_4^-$ in the final step /HCl **Note** Correct Kekulé structures score full marks	(4)

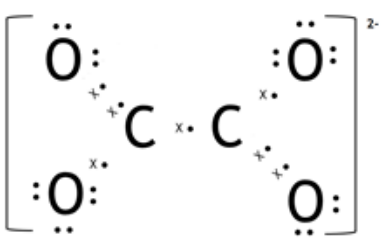
Q24.

Question number	Answer	Additional guidance	Marks
(i)	An explanation that makes reference to the following points: • the shape is V-shaped/bent (1) • because the three electron pairs on Sn repel one another (1)	First marking point can be awarded for a correctly drawn diagram	2
(ii)	• prediction: any value between 95 and 119° (1) • justification: lone pair – bond pair repulsion is greater than bond pair – bond pair repulsion (and hence the angle is less than 120°) (1)		2

Q25.

Question number	Answer	Additional guidance	Marks
	An explanation that makes reference to the following points:  (1) • it is a radical because it has an unpaired electron (1)	Accept any other symbols in place of dots and crosses, including a minus sign to replace the triangle	2

Q26.

Question Number	Answer	Additional Guidance	Mark
(i)	• double C=O bond on left and right hand side **(1)** • rest of diagram **(1)**		(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+) 3	Allow 3+ / +III / III+ / III / three Ignore working out Do not award ±3	(1)

Q27.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • fewer protons (in nitrogen) **(1)** • result in a weaker **nuclear** attraction because shielding is the same/electrons are in the same (sub)shell (in oxygen)/same number of electron shells **(1)**	Reference to molecule scores **(0)** Accept reverse arguments in terms of oxygen Allow weaker (effective) nuclear charge Allow smaller atomic number Do not award if incorrect numbers of protons stated or if ions referred to Do not award 'charge density' Ignore references to electron repulsion and electronegativity	**(2)**

Q28.

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)**

Q29.

Question Number	Correct Answer	Reject	Mark
	B		**1**

Q30.

Question Number	Answer	Mark
	The only correct answer is C (hexagonal rings within a layer) ***A*** *is not correct because in the layers of graphite and graphene the carbon atoms are bonded to three other carbon atoms and not four* ***B*** *is not correct because graphite and graphene do not have pentagonal rings within their layers* ***D*** *is not correct because graphene is a two-dimensional structure consisting of a single layer*	**(1)**

Q31.

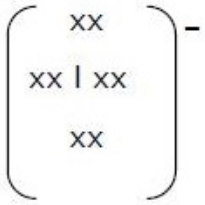
Question Number	Answer	Additional Guidance	Mark
	• N^{3-} / O^{2-} / F^{-} / Na^{+} / Al^{3+}	Do not award Ne, C^{4-}, Si^{4+}	(1)

Q32.

Question Number	Answer	Mark
(i)	**The only correct answer is C** (fractional distillation) ***A*** *is incorrect because the process is used to produce smaller hydrocarbons* ***B*** *is incorrect because the process is used to produce branched and cyclic hydrocarbons* ***D*** *is incorrect because the process is used to heat reaction mixtures*	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to one of the following pairs of points Either • the OH groups (in compound **X**) can form hydrogen bonds (1) • so more energy is needed to vaporise compound **X** / break intermolecular forces in compound X (1) Or • hydrocarbons have only London forces, but compound **X** has hydrogen bonds (as well) (1) • hydrogen bonds are stronger (than London forces) (1)	Ignore references to dipole-dipole interactions Allow 'the oxygen (in compound X) can form hydrogen bonds') Allow 'more energy is needed to break bonds in compound **X**' if H bonds discussed Any reference to the breaking of **covalent** bonds loses M2 only	(2)

Q33.

Question Number	Acceptable Answers	Reject	Mark
(a)	$[:Li]^+$ (1)  (1) Accept all or mixture of dots and crosses **Check inner electrons present on lithium** If no element symbols but fully correct with Li first give **1 max** If no / incorrect charge(s) if the electrons are correct **1 max** If arrow drawn from third / outer shell electron on lithium to join electrons in iodine / iodide with correct charges scores **1 max** Brackets are not essential		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	Li(s) **and** $Li^+(g)$ **and** $I^-(g)$ **(1)** $\frac{1}{2}I_2(s)$ **and** I(g) **(1)** (ΔH_{at}) **[**$\frac{1}{2}I_2(s)$**]** **(1)** Notice the square brackets are essential for this mark If wrong state for iodine element ie if $\frac{1}{2}I_2(g/l)$ and consistent (ΔH_{at})[$\frac{1}{2}I_2(g/l)$] allow third mark If I(s) given for element and (ΔH_{at}) [I(s)] allow third mark If wrong state with monatomic iodine both the last two marks lost If $Li^+(g)$ + e appears ignore electron		**3**

Question Number	Acceptable Answers	Reject	Mark
(c)	**First mark for one of:** −270 = + 159 + 107 + 520 + electron affinity − 759 Or Electron affinity = −270 − (159 + 520 + 107 − 759) **(1)** OR Electron affinity = −270 - 159 - 520 - 107 + 759 **(1)** **Second mark for:** (Electron affinity =) −297 (kJ mol^{-1}) **(1)** −297 (kJ mol^{-1}) alone scores **(2)** NB providing method is recognisable with one transcription error eg 795 for 759 and the final answer is consistent **1 max** NB (+) 297 (kJ mol^{-1}) **1 max**	Wrong unit e.g. J	**2**

Question Number	Acceptable Answers	Reject	Mark
(d)	(Experimental lattice energy is) more negative / exothermic **(1)** OR Theoretical lattice energy is less negative / exothermic **(1)** OR Recognition that more energy **released** **(1)** Irrespective of first answer then, any two from: Due to a degree of covalency **(1)** Deviation from pure ionic model (in experimental value) OR The theoretical model is pure ionic bonding **(1)** **Polarization / distortion** of the iod**ide** / negative ions (by the lithium ion). Can be shown by diagram **(1)** Iodine/ I / I_2 ion is not acceptable but iodine / I **anion** is allowed Note I_2 anion is not allowed	Greater / less Increase / decrease alone	**3**

Question Number	Acceptable Answers	Reject	Mark
(e)	Electron affinities become less negative / less exothermic / more positive (going down Group 7) **(1)** As (added) **electron** further from the nucleus OR **More** shielding / shielded (from the nucleus) **(1)** Second mark stands alone Ignore larger (ionic) radius / atom / ion / charge density	Greater / less / Increase / decrease alone Any indication of ionization/ removing an electron	**2**

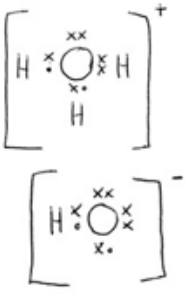
Q34.

Question Number	Correct Answer	Reject	Mark
	C		1

Q35.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • pentane has the lowest melting temperature because it only has London forces (1) • butan-1-ol and glycine have (similar) London forces (due to similar number of electrons) (1) • butan-1-ol has higher / less negative melting temperature than pentane as it has hydrogen bonds (1) • glycine has the highest melting temperature as it is an ionic solid (lattice) / consists of zwitterions (1)	Accept van der Waals as alternative to London If marking points 2 and 3 are not scored then allow 1 mark for the idea that butan-1-ol has higher melting temperature (than pentane) due to stronger intermolecular forces	4

Q36.

Question Number	Answer	Additional Guidance	Mark
	Two diagrams • oxonium ion **(1)** • hydroxide ion **(1)**	Examples of suitable diagrams  Ignore inner 'shell' of two electrons Ignore missing brackets Ignore covalent circles Penalise all dots or all crosses or use of other symbols for electrons once only Penalise omission of charges once only	(2)

Q37.

Question Number	Answer	Mark
	The only correct answer is B ***A*** *is incorrect because covalent bonds are within molecules not between molecules* ***C*** *is incorrect because there are no ionic bonds* ***D*** *is incorrect because London forces are not the strongest force*	**(1)**

Q38.

Question Number	Answer	Mark
	The only correct answer is D (Na^+ and Mg^{2+}) **A** *is not correct because the chloride ion has an extra shell of electrons compared to the nitride ion* **B** *is not correct because the sulfide ion has an extra shell of electrons compared to the oxide ion* **C** *is not correct because the potassium ion has an extra shell of electrons compared to the sodium ion*	(1)

Q39.

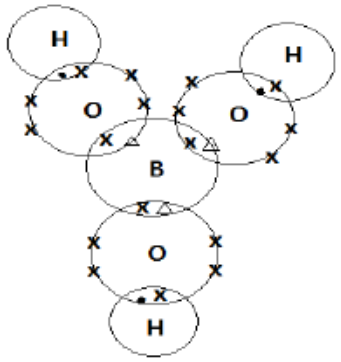
Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: **setting up of the dipole** • uneven distribution of **electrons**/ (random) movement of **electrons /** (random) fluctuations of **electrons** **(1)** **type of dipole** • (results 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)**

Q40.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points • metal cations in a 'sea' of delocalised electrons (1) • (metallic bonding is the strong) **electrostatic** attraction between (cations and electrons) (1)	ACCEPT suitable annotated diagram ALLOW reference to metal ions IGNORE 'free' electrons/positive nucleus Do not award reference to molecules Example diagram  Approximately equal numbers of positive ions and negative electrons	(2)

Q41.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• all 6 bonding pairs correct **(1)** • 2 lone pairs on each O and no additional electrons on boron or hydrogen **(1)**	<u>Example of diagram</u>  Non-bonding electrons on O can be shown as pairs, all 4 together or as 3 and 1 Electrons in overlap regions can be on the lines or the gaps between the lines Allow (1) for electrons in correct places but incorrect symbols for electrons Ignore inner shell electrons shown on B and/or O **Note** If any double bonds are shown the answer scores (0)	(2)

Question Number	Answer	Mark
(ii)	**The only correct answer is C** ***A*** *is incorrect because 109.5° is incorrect* ***B*** *is incorrect because 109.5° and 180° are incorrect* ***D*** *is incorrect because 180° is incorrect*	**(1)**

Q42.

Question Number	Answer	Additional Guidance	Mark
(i)	A		1
(ii)	D		1

Q43.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • the lone pair of electrons on the O overlap with the π/delocalised electrons in the benzene ring (1) • so (increased electron density) makes the ring more susceptible to electrophilic attack (1)	second mark is conditional on a reasonable explanation	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • 2-nitrophenol forms intramolecular hydrogen bonding <u>and</u> 4-nitrophenol only forms intermolecular hydrogen bonding **(1)** • so the hydrogen in the 2-nitrophenol cannot form hydrogen bonds with water (so less soluble) **(1)**		**2**

Q44.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • **(M1)** oxygen is more electronegative than hydrogen **and** carbon **(1)** • **(M2)** which results in a polar bond with oxygen δ– so carbon **and** hydrogen δ+ **(1)** • **(M3)** carbon dioxide is a symmetrical/linear molecule and so the dipole moments/vectors cancel **(1)** • **(M4)** the lone pairs of electrons of oxygen/ the V-shape of the water molecule mean that the dipole moments/ vectors do not cancel **(1)**	Accept supporting diagrams which illustrate the following: Accept electronegativity values stated Allow oxygen has a greater force of attraction for the bonded electron pairs than hydrogen **or** carbon Penalise the failure to refer to carbon and hydrogen once only Allow 'symmetrical so dipoles/ polar bonds cancel' Allow angular/bent for V-shape Penalise reference to just 'charges' once only in M3 and M4 if dipoles not stated or shown in the answer	**(4)**

Q45.

Question Number	Correct Answer	Reject	Mark
(a)	B		1

Question number	Correct Answer	Rejecct	Mark
(b)	D		1

Question Number	Correct Answer	Reject	Mark
(c)	D		1

Question Number	Correct Answer	Reject	Mark
(d)	A		1

Q46.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	C		1

Question Number	Correct Answer	Reject	Mark
(c)	A		1

Question Number	Correct Answer	Reject	Mark
(d)	C		1

Question Number	Correct Answer	Reject	Mark
(e)	B		1

Q47.

Question Number	Answer	Additional guidance	Mark
(i)	An explanation that makes reference to the following points: • copper forms an ion with an incomplete d-sub-shell / with a configuration of $3d^9$ (1) • but the only ion formed by zinc has a completely filled d-sub-shell (1)		2
(ii)	An explanation that makes reference to the following points: • (in brass) the layers of positive ions can slide over one another (1) • and there are (always) electrons between the layers preventing repulsion between the ions in one layer and those in another layer (1) • (in sodium chloride) when a layer of ions is displaced, ions with the same charge become close to one another and repel (1)		3

Q48.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • (pyramidal / this shape) because there are 4 pairs / 3 bond pairs and one lone pair of electrons (around central / P atom) **and** these are arranged to minimise repulsion **(1)** • (bond angle less than 109.5°) as lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion **(1)**	'ions' scores (0) overall Allow the electron pairs are arranged to minimise repulsion Allow (4) pairs of electrons with maximum separation / as far apart as possible Ignore reference to 'bonds' Ignore wrong shape Ignore repel equally Ignore repulsion between electrons There must be a comparison in M2 Allow lone pairs have greater repulsion than bond pairs Ignore just 'the lone pairs repel more' Ignore repetition of the question e.g. 'reduces the bond angle' Ignore incorrect bond angle stated (Data book value is 100.1°) Do not allow bond angle >109.5°	**(2)**

Question Number	Answer	Mark
(ii)	**The only correct answer is D** ***A*** *is not correct because both incorrect* ***B*** *is not correct because non-polar bond is incorrect* ***C*** *is not correct because non-polar molecule is incorrect*	**(1)**

Q49.

Question Number	Answer	Mark
	The only correct answer is A ***B*** *is not correct because oxygen has more protons to exert an attractive force to reduce the ionic radius* ***C*** *is not correct because sodium has more protons to exert an attractive force to reduce the ionic radius* ***D*** *is not correct because aluminium has more protons to exert an attractive force to reduce the ionic radius*	**(1)**

Q50.

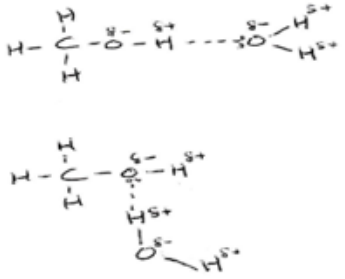
Question Number	Answer	Mark
(i)	**The only correct answer is C** (120° and 109.5°) ***A*** *is incorrect because both angles are incorrect* ***B*** *is incorrect because 90° is incorrect* ***D*** *is incorrect because 109.5° is incorrect for the left hand O–C–H angle*	**(1)**

Question Number	Answer	Mark
(ii)	**The only correct answer is D** (atm^{-1}) ***A*** *is incorrect because it is the inverse of the units for* K_C ***B*** *is incorrect because it is the units for* K_C ***C*** *is incorrect because it is the inverse of the units for* K_p	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points • K_p will remain unchanged **(1)** • equilibrium moves to right-hand side (to keep K_p constant) / only temperature affects K_p **(1)**	Allow answers in terms of quotient Do not award M2 if K_p is described as changing Ignore comments related to rate	**(2)**

Q51.

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

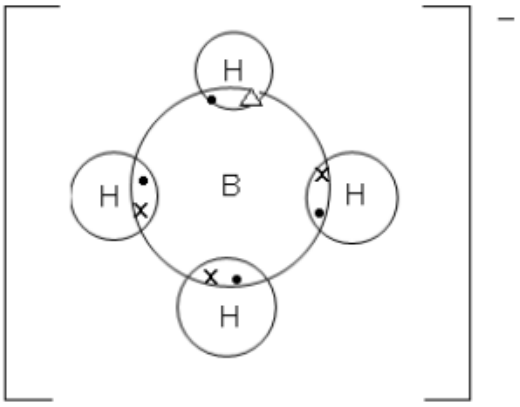
Question Number	Answer	Additional Guidance	Mark
(ii)	• at least one lone pair shown on the oxygen atom in water or methanol **and** involved in the hydrogen bond **(1)** • hydrogen bond shown between an H in one molecule and an O on the other molecule **and** O–H---O / O---H–O bond angle at (about) 180° **(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)**

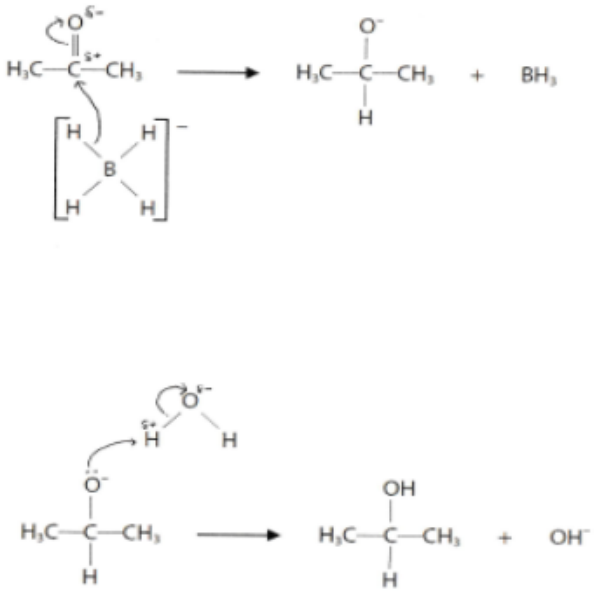
Q52.

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** (1) overlaps with the pi cloud / delocalised electrons / delocalised system	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)	Allow M1 and M2 shown in diagrams Ignore reference to other specific types of intermolecular forces	(2)
	• 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** (1) 2-nitrophenol forms intramolecular hydrogen bonds / forces / interactions (so fewer intermolecular hydrogen bonds)	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)	

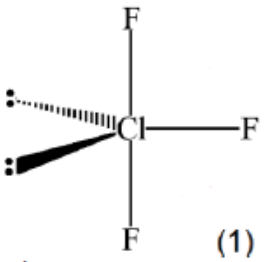
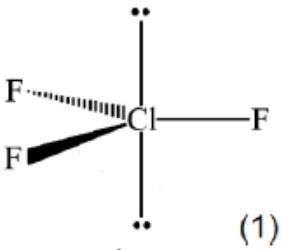
Q53.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• dot-and-cross diagram	Example of diagram  Electrons must have the correct symbols i.e. 3 bonds with • and x and 1 bond with • and Δ Circles do not need to be shown Allow missing brackets but charge needs to be shown Allow charge anywhere on or close to diagram Ignore lines representing covalent bonds e.g. x • Ignore missing atom labels / inner shell of 2 electrons on B	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• curly arrow from B-H bond to C of C=O **(1)** Allow curly arrow from B-H bond to H **and** curly arrow from H to C • dipole on C=O **(1)** **and** curly arrow from C=O bond to or just beyond O • lone pair on O^- **(1)** **and** curly arrow from lone pair to H of H_2O • curly arrow from O-H bond to O **(1)** **and** dipole on H-O bond	Example of mechanism  Allow curly arrow from any B-H bond Ignore lone pair on O in H_2O Penalise half-headed curly arrow once only	**(4)**

Q54.

Question number	Answer	Additional Guidance	Marks
(i)	**A** ($AlCl_3$ and BCl_3)		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(ii)	 (1) Shape 1  (1) Shape 2	Allow other indications of 3D shapes Allow shapes in either order	**2**

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Question number	Acceptable Answer	Additional Guidance	Marks
(iii)	An explanation that makes reference to the following points: Shape 2 because • lone pair-lone pair repulsion is greater (than both lone pair-bond pair repulsion and bond pair-bond pair repulsion) (1) • hence having the lone pairs as far apart as possible (will result in less repulsion between them) **OR** • Lone pair-lone pair bond angle is 180º rather than 120º (1)		**2**

Q55.

Question Number	Answer	Additional Guidance	Mark
(a)	**C** (iodine)		**1**

Question Number	Answer	Additional Guidance	Mark
(b)	**C** (P_4O_{10})		**1**

Question Number	Answer	Additional Guidance	Mark
(c)	**D** (ice has a lower density than water at 0ºC)		**1**

Q56.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>
This question assesses the 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.

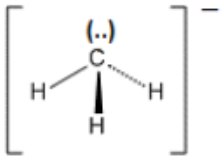
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some</td><td>1</td></tr>
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</td>
<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, a response with four 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 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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</table>

	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	

Q57.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • shape: (trigonal) pyramidal/ drawn as (trigonal) pyramidal (1) • bond angle: 107° (1) • justification: 4 pairs of electrons arranged as far apart as possible to minimise repulsion/maximum separation (1) • 1 pair of electrons is a lone pair and causes more repulsion than the bonding pairs (so the bond angle is less than a normal tetrahedral shape) (1)	Example of shape drawn:  Allow any bond angle in the range 105-108°	**4**