

2(b)(i)	hydrogen bonding	1
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Page 3 of 7

Question	Answer	Marks
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May/June 2017 9701/21 · Q2 (b)(i)

4(a)(iii)	$sp^2 = 116^\circ - 124^\circ$	1
	$sp^3 = 106^\circ - 112^\circ$	1

May/June 2017 9701/21 · Q4 (a)(iii)

3(a)	(+) 103	1
3(b)(ii)	rate increases AND correct explanation in terms of 'more collisions'	1
	at higher T area above E_a is greater / more molecules with $E \geq E_a$	1
	higher frequency of successful collisions OR more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
3(b)(iv)	H-I bond strength less than H-Br OR less energy needed to break H-I <i>ora</i>	1
	I (atom) is big(ger) (than Br) OR I (atom) has more shielding (than Br) <i>ora</i>	1
	Br (atom) has greater (%) orbital / outer shell overlap OR attraction (of nucleus in iodine) for shared (pair of) electrons is weak(er) OR attraction (of nucleus in iodine) for bonding pair (or electrons) is weak(er) <i>ora</i>	1

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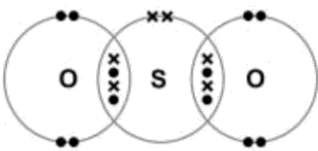
Page 5 of 9

Question	Answer	Marks
3(c)(i)	$H_2 = 0.015$ (mol)	1
	$HCl = 0.27$ (mol)	1
3(d)(ii)	equal number of moles (of gas) on either side (of equation) / (total) pressure cancels	1

May/June 2017 9701/22 · Q3 (a), (b)(ii), (b)(iv), (c)(i), (d)(ii)

4(a)(ii)	(A / straight chain) has strong(er) (temporary dipole-) induced dipole (attractions) <i>ora</i>	1
	(because A / straight chain has) bigger (surface) area / more (points of) contact (in unbranched isomer) <i>ora</i> OR (so) more energy required to break the intermolecular forces <i>ora</i>	1

May/June 2017 9701/22 · Q4 (a)(ii)

1(f)(i)		1
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May/June 2018 9701/21 · Q1 (f)(i)

2(b)(i)		
	4 shared pairs only (any symbols) (in NH ₄)	1
	3 × dot-and-cross bonds AND 1 × 2 crosses (in NH ₄)	1
2(b)(ii)	tetrahedral	1
	109–109.5° (inclusive)	1

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Page 5 of 10

Question	Answer	Marks
2c(i)	<i>in any order explain meaning of:</i> <i>weak</i> partially ionises / incompletely dissociates (into ions) <i>Bronsted-Lowry acid</i> is a proton donor / H ⁺ (ion) donor / hydrogen ion donor	2
2c(ii)	NH ₄ ⁺ (aq) + H ₂ O(l) = NH ₃ (aq or g) + H ₃ O ⁺ (aq)	
	all correct species and balancing	1
	correct state symbols	1

May/June 2018 9701/22 · Q2 (b)(i), (b)(ii)

4(d)(i)		
	lone pair on C of CN ⁻ and curly arrow to C of C=O	1
	correct dipole on C=O and curly arrow from = to O	1
	correct intermediate anion	1
	curly arrow from lone pair on O to H ⁺	1

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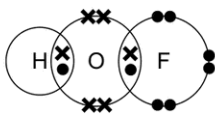
Page 9 of 10

Question	Answer	Marks
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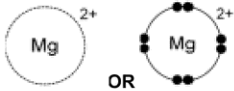
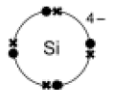
May/June 2018 9701/22 · Q4 (d)(i)

1(a)		4
	trigonal planar non-linear/bent/V-shaped/angular	
1(b)(i)	stronger attraction for O^{2-} / stronger ionic bonding / more energy needed to overcome ionic bonding / separate ions	1
	charge density of magnesium (ion) is greater (than sodium ion) ora	1
1(b)(ii)	Either: M1 SiO_2 has a giant (covalent) structure / giant molecular M2 Covalent bonds (much) stronger than VdW / id-id / IMFs in SO_3 OR M1 SO_3 has a (simple) molecular structure / (simple) molecule. M2 VdW / id-id / IMFs M2 IMF's are (much) weaker than covalent bonds (broken in SiO_2) OR M1 Covalent bonds are broken in SiO_2 AND VdW / id-id / IMFs in SO_3 M2 Covalent bonds are stronger (than VdW / id-id / IMFs)	2
1(c)(ii)	Decreasing reactant concentrations (at different time intervals / as reaction progresses)	1
	So rate decreases OR change in concentration ÷ time taken decreases	1
1(c)(iii)	(line becomes horizontal when) forward and reverse rates equal / equilibrium established	1
1(c)(iv)	2:1 ratio in equation / SO_2 used up more quickly (than O_2) / $2 \times SO_2$ react for every $1 \times O_2$	1
1(d)(ii)	$SO_2 = 0.02$ (mol)	1
	$O_2 = 1.01$ (mol)	1

May/June 2018 9701/23 · Q1 (a), (b)(i), (b)(ii), (c)(ii), (c)(iii), (c)(iv), (d)(ii)

2(a)(ii)	M1 identification of the IMF between F_2 molecules and between HCl molecules HCl has (permanent) dipoles and / or induced dipoles F_2 has induced dipoles M2 comparison of strength of IMF's in F_2 and HCl Intermolecular forces in HCl are stronger than F_2	2
2(a)(iii)	strong (electrostatic) forces of attraction between (oppositely charged) ions	1
2(c)(i)	 M1 bonding pairs correct M2 rest of molecule, incl. lone pairs.	2
2(c)(iv)	 M1 H-bond labelled / shown as distinct from $H-F$ bond M2 correct sequence of three correct dipoles M3 lone pair on F in line with H-bond	3

March 2019 9701/22 · Q2 (a)(ii), (a)(iii), (c)(i), (c)(iv)

2(a)	M1 magnesium +2 charge on two Mg AND both with 0 or 8 electrons 	1
	M2 silicide -4 charge on one Si and 8 electrons 	1
2(b)	$\text{Mg}_2\text{Si(s)} + 4\text{H}_2\text{O(l)} \rightarrow 2\text{Mg(OH)}_2\text{(aq)} + \text{SiH}_4\text{(g)}$ M1 correct balancing and formulae M2 state symbols	1
		1
2(c)	M1 simple (covalent) / molecular / molecules	1
	M2 weak IMF / (temporary) induced dipole (forces)	1
2(d)(i)	$\text{C}^{5-}-\text{H}^{5+}$	1
	$\text{Si}^{5+}-\text{H}^{5-}$	1
2(d)(ii)	M1 tetrahedral (molecule)	1
	M2 (so individual bond) dipoles / partial charges cancel	1
2(e)	M1 Si—H bond is (much) weaker than C—H bond	1
	M2 low activation energy ORA	1

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Page 5 of 9

Question	Answer	Marks
2(f)(i)	M1 sodium silicate / Na_2SiO_3	1
	M2 water / H_2O	1
2(f)(ii)	acid(ic)	1

Question	Answer	Marks
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May/June 2019 9701/21 · Q2 (a), (b), (c), (d)(i), (d)(ii), (e), (f)(i), (f)(ii)

4(b)	$a = 109(.5)^\circ$	1
	$b = 120^\circ$	1

May/June 2019 9701/21 · Q4 (b)

2(c)(iv)	(triangular / trigonal) pyramid(al)	1
	107 ⁽⁰⁾	1

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Page 7 of 12

Question	Answer	Marks
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May/June 2019 9701/22 · Q2 (c)(iv)

3(a)(iv)	M1 statement correctly comparing the difference in electronegativity between Si and Cl AND Na and Cl OR Na is less electronegative than Si OR A	1
	M2 NaCl transfer of electrons	1
	M3 SiCl ₄ shared (pair of) electrons	1

May/June 2019 9701/22 · Q3 (a)(iv)

2(b)(i)	M1 SiO ₂ has a network of strong bonds / SiO ₂ has many strong bonds M2 SO ₃ has weak intermolecular forces OR weak VdW forces (between molecules) M3 high(er) / more energy required to break bonds than overcome forces (between molecules)	3
2(c)(i)	octahedral	1

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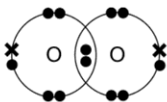
Page 5 of 9

Question	Answer	Marks
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Oct/Nov 2019 9701/21 · Q2 (b)(i), (c)(i)

4(a)(ii)	sp ²	1
4(b)(ii)	M1: A has H-bonding (between molecules) M2: B only has dipole–dipole / VdW forces (between molecules) M3: H-bonding is stronger / requires more energy to overcome	3

Oct/Nov 2019 9701/21 · Q4 (a)(ii), (b)(ii)

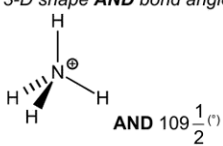
2(c)(iii)	 M1: bonding pair between the two O M2: total of 14 electrons distributed equally between the two O	2
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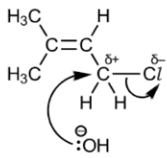
Page 6 of 10

Question	Answer	Marks
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Oct/Nov 2019 9701/22 · Q2 (c)(iii)

3(b)(ii)	3-D shape AND bond angle  AND $109\frac{1}{2}^\circ$	1
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Oct/Nov 2019 9701/22 · Q3 (b)(ii)

4(a)	 M1: curly arrow from lone pair on O of OH⁻ to C of C—Cl M2: correct dipole on C—Cl AND curly arrow from C—Cl bond to Cl^{δ-}	2
4(b)(ii)	(CH ₃) ₂ CHCH(OH)CH ₂ OH	1
4(d)(ii)	heterogeneous	1

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Page 9 of 10

Question	Answer	Marks
4(e)(ii)	potassium cyanide / KCN / sodium cyanide / NaCN	1
4(e)(iii)	(acidic) hydrolysis	1
4(e)(iv)	M1: recognise this reaction involves less stable intermediate 1° (carbo)cation (intermediate) is less stable (than 3°) M2: explain difference in reactivity in terms of positive inductive effect – comparative answer lower (positive) inductive effect / lower (+)I OR inductive effect of less alkyl groups	2

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Page 10 of 10

Oct/Nov 2019 9701/22 · Q4 (a), (b)(ii), (d)(ii), (e)(ii), (e)(iii), (e)(iv)

1(d)	180°	1
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March 2020 9701/22 · Q1 (d)

3(c)(iii)	M1 curly arrow from C=C double bond to Br M2 correct dipole in Br₂ AND curly arrow from Br—Br to Br^{δ-} M3 correct intermediate AND curly arrow from lone pair on Br⁻ to C⁺ M4 correct product	4
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Page 9 of 10

Question	Answer	Marks
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March 2020 9701/22 · Q3 (c)(iii)

4(c)	<table border="1"> <thead> <tr> <th></th><th>name of shape</th><th>bond angle / °</th></tr> </thead> <tbody> <tr> <td>CO₂</td><td>Linear</td><td>180</td></tr> <tr> <td>NH₃</td><td>Pyramid(al)</td><td>107</td></tr> <tr> <td>H₂O</td><td>non-linear / V / bent</td><td>104.5</td></tr> </tbody> </table> All 6 correct – 3 marks 4 or 5 correct – 2 marks 2 or 3 correct – 1 mark		name of shape	bond angle / °	CO ₂	Linear	180	NH ₃	Pyramid(al)	107	H ₂ O	non-linear / V / bent	104.5	3
	name of shape	bond angle / °												
CO ₂	Linear	180												
NH ₃	Pyramid(al)	107												
H ₂ O	non-linear / V / bent	104.5												

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Page 8 of 10

Question	Answer	Marks
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May/June 2020 9701/21 · Q4 (c)

5(a)(ii)	HCl AND H ₂ O	1
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May/June 2020 9701/21 · Q5 (a)(ii)

1(d)	M1 shape M2 bond angle 120(°)	2
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May/June 2020 9701/22 · Q1 (d)

2(b)		1
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May/June 2020 9701/22 · Q2 (b)

5(b)(i)	<i>mechanism for ethanal and HCN using CN^- (from KCN) as the catalyst</i> M1 arrow from lone pair of electrons on CN^- to C of $\text{C}=\text{O}$ M2 correct dipole on $\text{C}^{\delta+}=\text{O}^{\delta-}$ AND arrow from the double bond to or beyond the O of $\text{C}=\text{O}$ M3 arrow from lone pair of electrons on O of intermediate to H of HCN AND arrow from H-C bond to C of $\text{H}-\text{C}\equiv\text{N}$	3
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Page 11 of 12

Question	Answer	Marks
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May/June 2020 9701/22 · Q5 (b)(i)

4(d)(ii)	M1 only sigma / σ (bonds) in hexane / alkanes M2 B has sigma σ (bonds) and a / one pi / π (bond)	2
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Question	Answer	Marks
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May/June 2020 9701/23 · Q4 (d)(ii)

2(d)(i)		1
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Oct/Nov 2020 9701/21 · Q2 (d)(i)

3(a)(ii)	120	1
3(a)(iv)	(Lattice of) cations / positive ions surrounded by delocalised electrons	1

Oct/Nov 2020 9701/21 · Q3 (a)(ii), (a)(iv)

4(a)(iii)	M1: HF has permanent dipole(-dipole forces) AND HI has ((only)) instantaneous dipole / induced dipole (forces) / permanent dipole(-dipole forces) M2: IMF's in HI are weaker (than IMF's in HF)	2
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Oct/Nov 2020 9701/21 · Q4 (a)(iii)

2(d)	M1: identification of forces broken during melting of phosphorus(V) oxide intermolecular forces in phosphorus(V) oxide (are broken) M2: identification of force broken during melting of magnesium oxide electrostatic forces of attraction between (many oppositely charged) ions in magnesium oxide M3: statement linking difference in strength of appropriate forces described in M1 & M2 to explain difference in melting point (only) intermolecular forces weaker than forces (of attraction) between ions / ionic bonds	3
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Oct/Nov 2020 9701/22 · Q2 (d)

3(d)(i)	M1: (trigonal) pyramidal M2: 107	2
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Oct/Nov 2020 9701/22 · Q3 (d)(i)

2(e)(i)	M1: 2 × coordinate bonds in the right place M2: all other bonds	2
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March 2021 9701/22 · Q2 (e)(i)

4(a)	M1: $x = 108-110^\circ$ M2: $y = 118-122^\circ$	2
4(c)(ii)	M1: (excess dichromate and) heat under reflux M2: to allow full oxidation (of alcohol and aldehyde groups)	2
4(d)(i)	$\text{CH}_2\text{OHCHO} + 2[\text{H}] \rightarrow (\text{CH}_2\text{OH})_2$	1
4(d)(ii)	$\text{NaBH}_4 / \text{LiAlH}_4$	1
4(d)(iii)	ethene	1

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Page 9 of 9

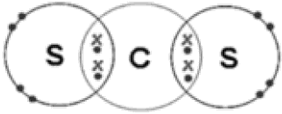
March 2021 9701/22 · Q4 (a), (c)(ii), (d)(i), (d)(ii), (d)(iii)

2(a)(ii)	<table border="1"> <tr> <td></td><td>N_2</td><td>CO</td></tr> <tr> <td>number of electrons per molecule</td><td>14</td><td>14</td></tr> <tr> <td>type of van der Waals'</td><td>temporary / instantaneous dipole-induced dipole</td><td>permanent dipoles—(permanent) dipoles (and temporary / induced / instantaneous dipoles)</td></tr> </table>		N_2	CO	number of electrons per molecule	14	14	type of van der Waals'	temporary / instantaneous dipole-induced dipole	permanent dipoles—(permanent) dipoles (and temporary / induced / instantaneous dipoles)	2
	N_2	CO									
number of electrons per molecule	14	14									
type of van der Waals'	temporary / instantaneous dipole-induced dipole	permanent dipoles—(permanent) dipoles (and temporary / induced / instantaneous dipoles)									
2(b)	CO / it is a polar molecule / it has a (permanent) dipole (but N_2 is non-polar)	1									

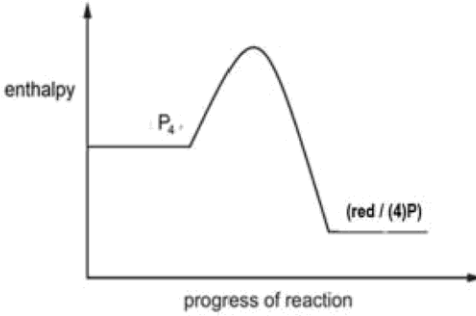
May/June 2021 9701/21 · Q2 (a)(ii), (b)

2(a)	M1 H-bond between an O and an H in OH groups in water and methanol molecules	1
	M2 minimum three partial charges (in sequence) over one water and one methanol molecule, <i>i.e.</i> :	1
	M3 either $\delta^-\text{O}-\text{H}^{\delta+}-\delta^-\text{O}$ or $\text{H}^{\delta+}-\delta^-\text{O}-\text{H}^{\delta+}$ lone pair of electrons on O of H-bond, in line with H-bond	1
2(b)(i)	M1 (methanol) gas (particles / molecules) in equilibrium with liquid	1
	M2 (methanol) gas (particles) exert a pressure (on the walls of a container / on the surface of the liquid)	1
2(b)(ii)	(liquid) particles (at the surface) have enough energy (to overcome attractive forces / evaporate / to become a vapour)	1
2(b)(iii)	M1 (liquid) H_2O molecules are held by stronger hydrogen bonding OR it takes more energy to break the hydrogen bonds between water molecules (in the liquid state) OR each water molecule forms two hydrogen bonds (whereas methanol can (only) form one per molecule)	1
	M2 fewer H_2O liquid molecules (able to) escape / become gaseous ora	1

May/June 2021 9701/23 · Q2 (a), (b)(i), (b)(ii), (b)(iii)

1(a)(ii)	 M1 bonding pairs M2 Correct number of remaining outer electrons	2
1(a)(iii)	180°	1

Oct/Nov 2021 9701/21 · Q1 (a)(ii), (a)(iii)

3(a)(i)	M1 simple molecular M2 giant molecular M3 weak IMFs (overcome) in P₄ AND strong (covalent) bonds (broken) in P	3
3(a)(ii)		1
3(b)(ii)	$\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 5\text{HCl}$ $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$	2
3(c)(ii)	stage 1 = reduction stage 2 = substitution	2

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Page 8 of 10

Question	Answer		Marks
3(c)(iii)	G = C ₂ H ₅ CH ₂ OH	H = C ₂ H ₅ CH=CHC ₂ H ₅	2
3(d)	CH ₃ CH ₂ CO ₂ H	CH ₃ COCH ₃	2

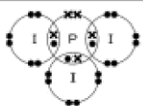
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Oct/Nov 2021 9701/21 · Q3 (a)(i), (a)(ii), (b)(ii), (c)(ii), (c)(iii), (d)

1(a)(i)	M1 (HI / I / iodine / hydrogen iodide has a) greater number of electrons M2 greater induced dipoles (between molecules)	2
1(a)(ii)	M1 bar at HF shows any boiling point above HI on graph M2 <i>explanation of difference in boiling point of a sample of HF in terms of strength</i> (sum of) hydrogen bonds (and induced dipoles in HF) are stronger than (sum of) induced dipoles (and permanent dipoles in HCl / HBr / HI)	2
1(c)(iii)	EITHER option 1 which assumes $\Delta H_{\text{reaction}}$ is (still) endothermic (using the value shown in (b)). M1 (K_p) decreases AND endothermic / ΔH_{f} = + / positive M2 reaction favours formation of reactants / hydrogen and iodine OR (product) yield / partial pressure of HI decreases / equilibrium shifts to the left OR option 2 which realises that $\Delta H_{\text{reaction}}$ is in fact exothermic (using bond energy data in Data Booklet) M1 (K_p) increases AND exothermic / ΔH_{f} = + / negative M2 reaction favours formation of products / hydrogen iodide yield increases / partial pressure of HI increases / equilibrium shifts to the right	2
1(d)(i)	$4\text{HI} + \text{O}_2 \rightarrow 2\text{I}_2 + 2\text{H}_2\text{O}$	1

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Page 5 of 11

Question	Answer	Marks
1(e)	M1 pressure increases M2 (pressure goes up as) number of moles/molecules increases in ratio 3 (gas) reactants to 5 (gas) products OR pressure is (directly) proportional to number of moles/molecules	2
1(f)(i)	 M1 correct bonding pairs M2 correct number of remaining outer electrons on each atom	2
1(f)(ii)	hydrolysis	1
1(f)(iii)	proton donor / H^+ donor fully dissociates / fully ionises	2
1(f)(iv)	H_2PO_3^-	1
1(g)(i)	M1 2-iodopropane – formed from a (more) stable (secondary) (carbo)cation/intermediate M2 (because of) greater (positive) inductive effect / (+)I of two alkyl groups OR (because of positive) inductive effect / (+)I of more R / more methyl / more alkyl groups	2

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Page 6 of 11

Question	Answer	Marks
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Oct/Nov 2021 9701/22 · Q1 (a)(i), (a)(ii), (c)(iii), (d)(i), (e), (f)(i), (f)(ii), (f)(iii), (f)(iv), (g)(i), (g)(ii) (continued ·)

1(g)(ii)	M1 curly arrow from = of C=C to H AND curly arrow from bond of H—I to I M2 curly arrow from lone pair of I⁻ to C⁽⁺⁾ of their intermediate M3 correct carbocation AND product for 2-iodopropane	3
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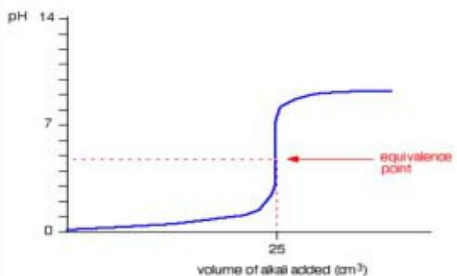
Page 7 of 11

Question	Answer	Marks
Oct/Nov 2021 9701/22 · Q1 (a)(i), (a)(ii), (c)(iii), (d)(i), (e), (f)(i), (f)(ii), (f)(iii), (f)(iv), (g)(i), (g)(ii) (cont.)		
3(c)(ii)	sp ²	1
Oct/Nov 2021 9701/22 · Q3 (c)(ii)		

2(a)	M1 one sigma / σ bond and two pi / π bonds M2 sp hybridisation (in each N atom) M3 sigma / σ forms from direct / head-on / end-on overlap of orbitals AND pi / π forms sideways / lateral overlap of (p) orbitals	3
2(b)(i)	M1 react with (unburnt) hydrocarbons M2 (form) PAN / peroxyac(et)yl nitrate	2
2(b)(ii)	$2\text{NO} + 2\text{CO} \rightarrow 2\text{CO}_2 + \text{N}_2$ OR $\text{NO}_2 + 2\text{CO} \rightarrow \frac{1}{2}\text{N}_2 + 2\text{CO}_2$	1

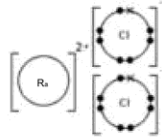
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Page 6 of 10

Question	Answer	Marks
2(c)	any Group 1 hydroxide or $\text{Ca}(\text{OH})_2$ / $\text{Sr}(\text{OH})_2$ / $\text{Ba}(\text{OH})_2$	1
2(d)(i)	M1 proton / H^+ donor M2 fully dissociates (in aqueous solution / water / solvent)	2
2(d)(ii)	$\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$	1
2(d)(iii)	M1 correct basic shape extending to $\sim 50\text{ cm}^3$ with vertical portion of curve at 25 cm^3 M2 initial pH at 0–2 (based on idea that HCl is a strong acid) AND final pH at between 8–12 (based on idea that NH_3 is a weak alkali) 	2

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Page 7 of 10

Question	Answer	Marks
May/June 2022 9701/21 · Q2 (a), (b)(i), (b)(ii), (c), (d)(i), (d)(ii), (d)(iii)		
2(b)	Ra^{2+} and $2 \times \text{Cl}^-$ 0 electrons surrounding 2Ra AND 8 electrons surrounding Cl 	1

May/June 2022 9701/22 · Q2 (b)

3(a)(i)		1
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Page 8 of 12

Question	Answer	Marks
3(a)(ii)	M1 expression OR value derived from using all bond energy values and ΔH correctly, ignoring stoichiometry $-7 = (n350 + m360 + p410) - (q410 + r350 + sC\equiv O)$. M2 correct calculation based on correct expression AND stoichiometry $[-7 = 2(350) + 2(360) + 10(410) - 10(410) - 350 - x] = (+)1077 \text{ kJ mol}^{-1}$	2
3(a)(iv)	M1 no change / none M2 I_2 is a catalyst AND does not affect position of equilibrium OR I_2 is a catalyst AND reduces time taken to reach (same) equilibrium	2
3(a)(v)	- start at origin and not crossing original until beyond the peak - peak to the right-hand side of original peak AND lower than original - line does not cross the original after the peak reached	2
3(b)(ii)	positional	1

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Page 9 of 12

Question	Answer	Marks
3(b)(iii)	 name: butan-2-ol name: butan-1-ol M1 correct structures M2 correct structures in correct boxes H and J M3 correct corresponding name of both H and J	3

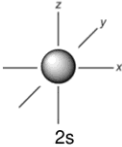
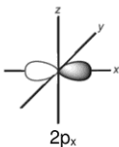
May/June 2022 9701/23 · Q3 (a)(i), (a)(ii), (a)(iv), (a)(v), (b)(ii), (b)(iii)

4(a)(i)	M1 curly arrow from = to H AND correct dipole on H-Cl M2 correct intermediate M3 curly arrow from H-Cl bond to Cl AND curly arrow from lp on: Cl- to C+	3
4(a)(ii)	- intermediate OR C+ OR carbocation (formed) is more stable - due to greater (positive) inductive effect. - caused by 3 methyl groups / 3 alkyl groups / more alkyl groups attached to C+ / central C	2
4(b)(iv)	C ₂ H ₅ COO ⁻ OR CH ₃ CH ₂ CO ₂ ⁻ or propanoate (an)ion	1

May/June 2022 9701/23 · Q4 (a)(i), (a)(ii), (b)(iv)

4(b)		1
	C1: M1 (m. & b. pts are low because) weak intermolecular forces / weak van der Waals	
	M2 (only) London / dispersion forces / instantaneous dipole-induced dipole	1

Oct/Nov 2022 9701/21 · Q4 (b)

1(a)	M1 ionic = oppositely charged ions / cations AND anions	1
	M2 covalent = shared pair(s) of electrons AND two nuclei	1
1(c)(ii)	ionic equation $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$	1
1(c)(iii)	 	2
1(d)(i)	phosphate(V)	1
1(d)(ii)	(molecular mass of NH_4MgPO_4) = 137.3	1
	$(245.3 - M(\text{NH}_4\text{MgPO}_4) \div 18.0)$ = 6	1

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Page 7 of 13

Question	Answer	Marks
1(e)(ii)	The C—Br carbon is bonded to three other carbon atoms <i>owtte</i>	1

Oct/Nov 2022 9701/22 · Q1 (a), (c)(ii), (c)(iii), (d)(i), (d)(ii), (e)(ii)

3(a)(i)	NaCl AND MgCl_2	1
3(a)(ii)	AlCl_3 AND SiCl_4 AND PCl_5	1
3(a)(iii)	NaCl	1
3(a)(iv)	SiCl_4	1
3(c)(ii)	$ \begin{array}{ccccccc} & \text{Cl} & \text{H} & & \text{H} & & \\ & & & & & & \\ \text{H}_3\text{C} & -\text{C}- & \text{C}- & \text{C}- & \text{Cl} \\ & & & & & & \\ & \text{H} & \text{H} & & \text{H} & & \end{array} $	1
3(d)(i)	M1 (structure =) simple / molecular, because it has a low melting / boiling point	1
	M2 (bonding =) covalent, because it is hydrolysed	1
3(d)(v)	M1 $90^\circ < \text{Cl}-\text{S}-\text{S} < 108^\circ$	1
	M2 sulfur has two lone pairs (of e^-) (and two bonding pairs) AND repulsion from lone pairs (greater)	1
3(d)(vi)	bonding electrons all other electrons correct	1

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Page 8 of 11

Question	Answer	Marks
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Oct/Nov 2022 9701/23 · Q3 (a)(i), (a)(ii), (a)(iii), (a)(iv), (c)(ii), (d)(i), (d)(v), (d)(vi)

1(e)	M1 6 bonding pairs (of electrons and 0 lone pairs) OR coordination number = 6 OR $x = 6$ M2 bonding pairs repel (equally)	2
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May/June 2023 9701/21 · Q1 (e)

4(b)(iii)	type of hybridisation	sp^2	sp^3	2
	number of carbon atoms in V	3	1	

May/June 2023 9701/21 · Q4 (b)(iii)

1(a)(ii)	bonds in NaCl are stronger than bonds in Mg	1
1(a)(iii)	M1 S ₈ / molecules of sulfur have more electrons (than P ₄ / molecules of phosphorus) M2 S has stronger instantaneous dipole–induced dipole forces (than phosphorus / P)	2
1(b)(ii)	(across a period) • increase in nuclear charge • similar shielding • (so) increase in nuclear attraction for bonding / outer / valence electrons OR bonding / outer / valence electron(s) are more strongly attracted to nucleus Two correct for one mark, three correct for two marks	2
1(b)(iii)	hydrogen bond	1
1(b)(iv)	M1 link shown as a dashed line between the lone pair of electrons from N of one NH ₃ to one H on other NH ₃ M2 minimum 3 correct partial charges (on adjacent atoms) over two NH ₃ molecules EITHER $\delta^- \text{N} - \delta^+ \text{H} \cdots \delta^- \text{N}$ OR $\delta^+ \text{H} \cdots \delta^- \text{N} - \delta^+ \text{H}$	2
1(b)(v)	M1 O is more electronegative than N M2 two H-bonds per water molecule : 1 per ammonia molecule.	2

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Page 6 of 12

Question	Answer	Marks
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May/June 2023 9701/22 · Q1 (a)(ii), (a)(iii), (b)(ii), (b)(iii), (b)(iv), (b)(v)

3(c)

type of bond in X	number of bonds in X
sigma σ	8
pi π	2

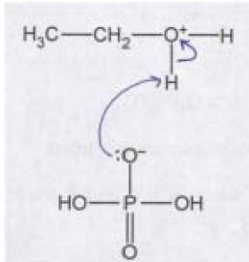
2

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Page 8 of 12

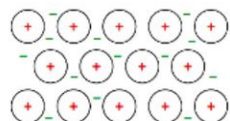
Question	Answer	Marks
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May/June 2023 9701/22 · Q3 (c)

4(a)	Method 1 - identification of number and type of bonds when all are broken $2\text{O-H} + 4\text{C-H} + \text{C}=\text{C}$ OR $(2 \times 460) + (4 \times 410) + 610$ - identification of number and type of bonds when all are made $\text{O-H} + 5\text{C-H} + \text{C-C} + \text{C-O}$ OR $(460 + (5 \times 410) + 350 + 360)$ - calculation of energy to break bonds – energy to make bonds $3170 - 3220 = -50 \text{ (kJ mol}^{-1}\text{)}$ Two correct for one mark, three correct for two marks. OR Method 2 - identification of number and type of relevant bonds broken (including the new C-H only) $2\text{O-H} + \text{C}=\text{C}$ OR $(2 \times 460) + 610$ - identification of number and type of relevant bonds made (including the new C-H only) $\text{O-H} + \text{C-H} + \text{C-C} + \text{C-O}$ OR $(460 + 410 + 350 + 360)$ - calculation using energy to break bonds – energy to make bonds $1530 - 1580 = -50 \text{ (kJ mol}^{-1}\text{)}$ Two correct for one mark, three correct for two marks.	2									
4(c)(iii)	 M1 arrow from bond of one of the O-H to O of the cation M2 arrow from lone pair on O of the anion to between H of H-O	2									
4(c)(iv)	M1 a catalyst increases rate of reaction M2 by producing an alternative reaction pathway with lower activation energy	2									
4(c)(v)	it is regenerated OR it is reformed	1									
4(d)	<table border="1"> <tr> <td></td><td>sigma</td><td>pi</td></tr> <tr> <td>type of orbitals involved in bond</td><td>$\text{sp}^2(-\text{sp}^2)$</td><td>$(2)\text{p}(-2)\text{p}$</td></tr> <tr> <td>how the orbitals overlap</td><td>direct</td><td>sideways</td></tr> </table> Two correct for one mark, four correct for two marks.		sigma	pi	type of orbitals involved in bond	$\text{sp}^2(-\text{sp}^2)$	$(2)\text{p}(-2)\text{p}$	how the orbitals overlap	direct	sideways	2
	sigma	pi									
type of orbitals involved in bond	$\text{sp}^2(-\text{sp}^2)$	$(2)\text{p}(-2)\text{p}$									
how the orbitals overlap	direct	sideways									

Question	Answer	Marks
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May/June 2023 9701/22 · Q4 (a), (c)(iii), (c)(iv), (c)(v), (d)

1(a)	 labelled diagram shows: - regular arrangement of positive ions AND surrounded by / (sea of) delocalised electrons	1
1(b)(ii)	giant AND has a high melting point	1
	ionic AND conducts electricity (only) when molten	1
1(d)(ii)	(KMnO_4 is) cold and dilute	1

March 2024 9701/22 · Q1 (a), (b)(ii), (d)(ii)

2(c)(i)	• trigonal bipyramidal • octahedral	2
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March 2024 9701/22 · Q2 (c)(i)

3(d)(i)	correct bonding pairs lone pairs	1
3(d)(ii)	sp^2	1
3(d)(iii)	M1 shows the π (π) orbital M2 refers to overlap of (two) (2)p orbitals side-on / above and below the plane	1

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Page 8 of 10

Question	Answer	Marks
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March 2024 9701/22 · Q3 (d)(i), (d)(ii), (d)(iii)

2(b)(i)	M1 1 shared pair of electrons between each S-Cl shown as •• M2 6 non-bonding electrons around each Cl shown as • AND 4 non-bonding electrons around S shown as •	2
2(b)(ii)	M1 shape non-linear M2 bond angle 103–105(°)	2
2(d)(i)	BN	1

May/June 2024 9701/21 · Q2 (b)(i), (b)(ii), (d)(i)

5(a)	(electrostatic) attraction between nuclei of two atoms and shared pair of electrons	1
5(b)(i)	sp^2	1
5(b)(ii)	M1 σ bond – diagram showing how σ bond is made from direct overlap of orbitals i.e. OR M2 π bond - diagram showing how π bond is made from sideways overlap of 2× p– orbitals i.e. OR	2

May/June 2024 9701/21 · Q5 (a), (b)(i), (b)(ii)

3(d)	M1 6 electrons between C and N AND 2 electrons between C and S M2 3 lone pairs around S AND none around C AND 1 lone pair around N	2
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Question	Answer	Marks
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May/June 2024 9701/22 · Q3 (d)

4(e)(ii)	M1 presence of a π bond M2 limited rotation of C=C bond M3 EITHER two different groups on each / both double bonded carbon atoms OR two different atoms on each / both double bonded carbon atom OR one H / atom and one alkyl group on each / both double bonded carbon atom	3
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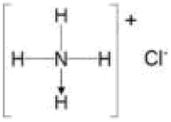
Question	Answer	Marks
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May/June 2024 9701/22 · Q4 (e)(ii)

1(a)(ii)	<table border="1"> <tr> <td></td><td>σ bond</td><td>π bond</td></tr> <tr> <td>no of bonds</td><td>1</td><td>2</td></tr> <tr> <td>how orbitals overlap</td><td>direct (orbital overlap)</td><td>sideways (overlap of adjacent p orbitals)</td></tr> </table>		σ bond	π bond	no of bonds	1	2	how orbitals overlap	direct (orbital overlap)	sideways (overlap of adjacent p orbitals)	4
	σ bond	π bond									
no of bonds	1	2									
how orbitals overlap	direct (orbital overlap)	sideways (overlap of adjacent p orbitals)									
1(c)(i)	both states shown as solid	1									
1(c)(ii)	M1 correctly balanced equation for aluminium oxide $\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$ M2 correctly balanced equation for P_4O_{10} and an excess of NaOH $\text{P}_4\text{O}_{10} + 12\text{NaOH} \rightarrow 4\text{Na}_3\text{PO}_4 + 6\text{H}_2\text{O}$	2									
1(d)(ii)	thermal decomposition	1									

Question	Answer	Marks
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May/June 2024 9701/23 · Q1 (a)(ii), (c)(i), (c)(ii), (d)(ii)

4(a)	 OR Correct representation or label showing M1 (ionic bond between) NH_4^+ and Cl^- AND 4 N—H covalent bonds OR 4 shared pairs of electrons in NH_4 M2 1 N—H coordinate bond OR arrow on bond/line in correct direction or only 1 bonding pair using the same symbol for electrons¹	2
4(b)(i)	acid–base reaction	1
4(b)(ii)	$\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$	1
4(c)(ii)	OH^- (more reactive because) negatively charged species more attracted to halogenoalkane and / or $\text{C}^{\delta+}$ and / or intermediate and / or C^+ OR NH_3 (more reactive because) N electrons less tightly held OR N is more able to donate (lp) electrons (to make the covalent bond) OR N is less electronegative ORA	1

Question	Answer	Marks
4(e)(iii)	butan-2-amine OR butyl-2-amine	1

3(a)(i)	element	C (graphite)	Sn	3
	state and appearance	grey shiny solid	silvery solid	
	electrical conductivity	• good/ conductor	good	
	type of bonding	• covalent	metallic	
	type of structure	giant	• giant	
3(a)(ii)	giant molecular			1
3(a)(iii)	its delocalised electrons are free to move			1
3(b)(iii)	M1 NH_4^+ / ammonium ion / ammonium cation is a proton / H^+ donor M2 OH^- is a proton / H^+ acceptor OR the OH^- / NaOH is a stronger base than NH_3			2
3(d)(i)	M1 molecules CH_4 to PbH_4 have greater number of electrons / number of electrons increase M2 greater / stronger instantaneous dipole–induced forces / London forces / dispersion forces OR more energy required to overcome the instantaneous dipole–induced forces / London forces / dispersion forces			1
				1
3(d)(ii)	tetrahedral			1
3(e)(i)	$\text{Si} + 2\text{Cl}_2 \rightarrow \text{SiCl}_4$			1
3(e)(ii)	effervescence / misty / steamy fumes			1
3(e)(iii)	M1 SiO_2 is giant covalent AND SiCl_4 is simple covalent / simple molecular / molecular M2 so need less energy to overcome IMF's in SiCl_4 , compared to the bonds in SiO_2 ora			2
3(f)	$\text{Sn}(\text{SO}_4)_2$			1

Question	Answer	Marks
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Oct/Nov 2024 9701/21 · Q3 (a)(i), (a)(ii), (a)(iii), (b)(iii), (d)(i), (d)(ii), (e)(i), (e)(ii), (e)(iii), (f)

2(a)(ii)	Al^{3+} 	1
2(b)(ii)	$\text{CH}_3\text{CN} + 2\text{H}_2\text{O} + (1)\text{H}^+ \rightarrow \text{CH}_3\text{COOH} + \text{NH}_4^+$	1
2(b)(iii)	 	2
2(b)(iv)	alkyl groups are electron donating / have positive inductive effect.	1
	strengthens the O—H bond / makes H^+ less likely to be donated	1
2(c)(i)	(molecules) H_2S to H_2Te / they have greater number of electrons	1
	stronger instantaneous dipole–induced dipole / London dispersion forces OR more energy required to overcome the instantaneous dipole–induced dipole / London dispersion forces	1
2(c)(ii)	(only) H_2O has hydrogen bonding AND hydrogen bonding (much) stronger than the other intermolecular forces OR H_2O has hydrogen bonding AND because of higher electronegativity of O compared to S OR stronger van der Waals' forces because (only) H_2O has hydrogen bonding OR hydrogen bond AND increased strength of permanent dipoles in H_2O outweighs the increase in strength of id-id in the others	1

Question	Answer	Marks
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Oct/Nov 2024 9701/22 · Q2 (a)(ii), (b)(ii), (b)(iii), (b)(iv), (c)(i), (c)(ii)

3(b)(iii)	M1 NH_4^+ / ammonium ion / ammonium cation is a proton / H^+ donor M2 OH^- is a proton / H^+ acceptor OR the OH^- / NaOH is a stronger base than NH_3	2
3(d)(ii)	tetrahedral	1
3(f)	$\text{Sn}(\text{SO}_4)_2$	1

Question	Answer	Marks
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Oct/Nov 2024 9701/23 · Q3 (b)(iii), (d)(ii), (f)

1(b)(ii)	trigonal bipyramid(al)	1
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March 2025 9701/22 · Q1 (b)(ii)

3(a)(ii)	- atoms larger (down the group) - distance between electron pair and nucleus greater / longer bond length / lesser orbital overlap - weaker attraction	2
3(b)	$\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HOCl}$ $\text{ClO}^- / \text{HOCl}$ kills bacteria	2
3(c)(i)	sodium iodide / NaI	1
3(c)(iii)	cream(-coloured) / off-white precipitate / solid forms	1
3(d)(i)	instantaneous dipole—induced dipole / id—id / London / dispersion (forces) AND permanent dipole—permanent dipole / pd—pd (forces)	1

March 2025 9701/22 · Q3 (a)(ii), (b), (c)(i), (c)(iii), (d)(i)

1(a)(i)	(both) giant molecular	1															
1(a)(ii)	delocalised electrons move through the structure OR delocalised electrons move through / between the layers	1															
1(a)(iii)	no delocalised electrons (to carry charge through the structure) OR <u>all</u> (4) outer electrons are used in bonding	1															
1(b)(i)	$\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 5\text{HCl}$	1															
	$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$	1															
1(b)(ii)	M1 phosphorus(V) chloride white / yellow solid M2 silicon(IV) chloride colourless liquid	2															
1(b)(iii)	M1 (phosphorus(V) chloride) produces colourless solution M2 silicon(IV) chloride produces white suspension / white precipitate (in a colorless liquid / mixture / solution)	2															
1(c)(i)	species behaves as acid and base OR species reacts with (both) acid and base	1															
1(d)(i)	<table border="1"> <tr> <td>SO_2</td><td>-73</td><td>pd</td></tr> <tr> <td>H_2O</td><td>0</td><td>H</td></tr> <tr> <td>SiO_2</td><td>1600</td><td>C</td></tr> <tr> <td>Na_2O</td><td>1132</td><td>I</td></tr> <tr> <td>MgO</td><td>2852</td><td>I</td></tr> </table>	SO_2	-73	pd	H_2O	0	H	SiO_2	1600	C	Na_2O	1132	I	MgO	2852	I	3
SO_2	-73	pd															
H_2O	0	H															
SiO_2	1600	C															
Na_2O	1132	I															
MgO	2852	I															

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Page 7 of 14

Question	Answer	Marks
1(d)(ii)	<i>Evaluate hypotheses based on the information candidates have given in the table</i> M1 not enough information M2 SO_2 and / or H_2O break intermolecular forces OR SO_2 and / or H_2O does not break covalent bonds OR only SiO_2 breaks covalent bonds	2

Question	Answer	Marks
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May/June 2025 9701/22 · Q1 (a)(i), (a)(ii), (a)(iii), (b)(i), (b)(ii), (b)(iii), (c)(i), (d)(i), (d)(ii)

4(b)(i)	M1 non-linear M2 bond angle – $120^\circ > x \geq 116^\circ$	2
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May/June 2025 9701/23 · Q4 (b)(i)

5(b)(i)	number of σ bonds = 14 number of π bonds = 2	2
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Page 9 of 11

Question	Answer	Marks
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May/June 2025 9701/23 · Q5 (b)(i)

2(a)(i)	non-linear	1
2(a)(ii)	104.5°	1
2(b)(i)	<i>In any order:</i> M1 (solution / liquid) (red) to colourless M2 yellow solid appears	2
2(b)(iii)	hydrolysis	1

Question	Answer	Marks
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May/June 2025 9701/24 · Q2 (a)(i), (a)(ii), (b)(i), (b)(iii)

1(b)(v)	M1 (trigonal) pyramidal M2 three bonding pairs AND one lone pair (of electrons)	2
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Oct/Nov 2025 9701/24 · Q1 (b)(v)

2(a)	M1 Al ₂ O ₃ is ionic M2 P ₄ O ₁₀ is a (simple) molecule M3 ionic bonds are stronger than intermolecular forces	3
2(b)(iii)	no effect AND K _c is not affected by pressure	1
2(c)(i)	increases rate by providing a different mechanism with a lower activation energy	1
2(c)(ii)	2CH ₃ OH → CH ₃ OCH ₃ + H ₂ O	1

Oct/Nov 2025 9701/24 · Q2 (a), (b)(iii), (c)(i), (c)(ii)