
CHEMISTRY

9701/41

Paper 4 A Level Structured Questions

May/June 2017

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge will not enter into discussions about these mark schemes.

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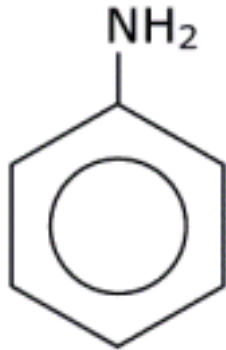
Question	Answer	Marks
1(a)	solubility increases down the group	1
	ΔH_{latt} and ΔH_{hyd} both decrease or ΔH_{latt} and ΔH_{hyd} both become less exothermic / more endothermic	1
	ΔH_{latt} decreases / changes more (than ΔH_{hyd} as OH^- being smaller than M^{2+})	1
	ΔH_{sol} becomes more exothermic / more negative / less endothermic / less positive	1
1(b)(i)	$\Delta H_{\text{r1}} - (538 + 2 \times 230 + 394) = -(1216 + 286)$ $\Delta H_{\text{r1}} - 1392 = -1502$	1
	$\Delta H_{\text{r1}} = \mathbf{-110}$	1
1(b)(ii)	let $\Delta H_{\text{f}}(\text{HCO}_3^-(\text{aq})) = y$ $2y - 538 = -1216 - 394 - 286 - 26$	1
	$y = \mathbf{-692}$	1
1(b)(iii)	$\Delta H_{\text{r3}} - 538 - 2(230 + 394) = -538 - 2(692)$ $\Delta H_{\text{r3}} = \mathbf{-136}$	1
1(b)(iv)	ΔH_{r3} will be identical to ΔH_{r4} , / unchanged	1
	as the reaction is the same, or: $2\text{OH}^-(\text{aq}) + 2\text{CO}_2(\text{g}) \longrightarrow 2\text{HCO}_3^-(\text{aq})$ or metal ions stay in solution/metal ions are unchanged / are spectators	1

Question	Answer	Marks
1(c)	more gaseous moles are being consumed (in reaction 3) or more CO₂ moles are being consumed (in reaction 3)	1
	ΔS is therefore expected to be more negative/less positive for reaction 3.	1
	Total:	13

Question	Answer	Marks
2(a)(i)		1 + 1
	16 electrons on each diagram	1
2(a)(ii)	HNC = 115–125° AND NCO = 180°	1
2(a)(iii)	cyanic acid, because it's a stronger / higher bond enthalpy / triple / C≡N / more electrons involved bond	1
2(b)(i)	$[H^+] = \sqrt{([HNCN]K_a)} = \sqrt{(0.1 \times 1.2 \times 10^{-4})}$ or 3.46×10^{-3}	1
	pH = log $[H^+] = 2.5$ (2.46)	1
2(b)(ii)	$Na_2CO_3 + 2(NH_2)_2CO \longrightarrow 2NaNCO + CO_2 + 2NH_3 + H_2O$	1
2(c)(i)	$n(OH^-)$ at start = $(2 \times 0.1 \times 30) / 1000 = 6 \times 10^{-3}$ mol $n(OH^-)$ reacted = $(0.1 \times 20) / 1000 = 2 \times 10^{-3}$ mol $n(OH^-)$ remaining = $(6-2) \times 10^{-3} = 4 \times 10^{-3}$ mol, (in 50 cm ³)	1
	so $[OH^-]_{end} = (4 \times 10^{-3} \times 1000) / 50 = 0.08 \text{ mol dm}^{-3}$	1

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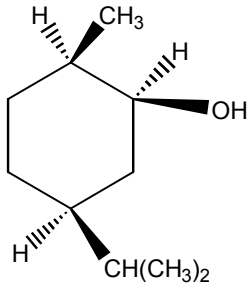
Question	Answer	Marks
2(c)(ii)	$[H^+] = K_w / [OH^-] = (1 \times 10^{-14}) / 0.08 = 1.25 \times 10^{-13} \text{ mol dm}^{-3}$	1
	so $\text{pH} = -\log(1.25 \times 10^{-13}) = \mathbf{12.9}$	1
2(c)(iii)	curve starts at 2.46 / 2.5	1
	vertical portion (end point) at vol added = 10.0 cm ³	1
	finishes at pH = 12.9	1
2(d)(i)	<i>monodentate</i> : (a species that) forms one dative / coordinate bond	1
	<i>ligand</i> : a species that uses a lone pair of electrons to form a dative / coordinate bond to a metal atom / metal ion	1
2(d)(ii)	$[Ag(NCO)_2]^-$ or $[Ag(OCN)_2]^-$ correct formula	1
	correct charge	1
2(e)(i)	$n(\text{BaCO}_3) = 1.66 / 197.3 = 8.4(1) \times 10^{-3} \text{ mol}$	1
2(e)(ii)	$n(\text{RNCO}) = 8.41 \times 10^{-3} \text{ mol}$, so $M_r = 1 / (8.41 \times 10^{-3}) = \mathbf{119}$	1
2(e)(iii)	molecular formula = C ₇ H ₅ NO	1

Question	Answer	Marks
2(e)(iv)		1
	Total:	23

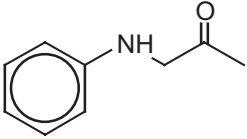
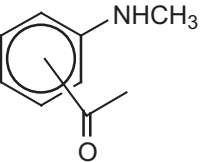
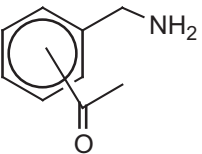
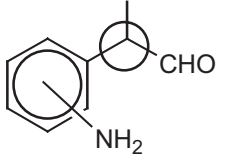
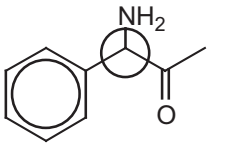
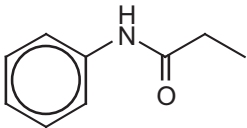
Question	Answer	Marks
3(a)(i)	+3 or Co^{3+}	1
3(a)(ii)	oxidation	1
	ligand displacement / replacement / exchange / substitution	1

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Question	Answer	Marks
4(a)(i)	optical, because it contains a / one chiral C-atom or chiral C-atoms or chiral atom / centre or C* indicated or C with 4 different groups	1
4(a)(ii)	$\text{C}_{10}\text{H}_{14}\text{O} + 3\text{H}_2 \longrightarrow \text{C}_{10}\text{H}_{20}\text{O}$ correct formulae	1
	balancing	1
4(b)(i)	electrophilic substitution	1
4(b)(ii)	step 3 reduction	1
	step 5 substitution / hydrolysis	1
4(b)(iii)	step 1 $(\text{CH}_3)_2\text{CHCl} + \text{AlCl}_3 / \text{AlBr}_3 / \text{FeCl}_3 / \text{FeBr}_3$	1 + 1
	step 2 $\text{HNO}_3 + \text{H}_2\text{SO}_4$ conc (T < 55 °C)	1
	step 3 $\text{Sn} + \text{HCl}$	1
	step 4 HNO_2 (or $\text{NaNO}_2 + \text{HCl}$) (at T < 10 °C)	1
	the two temperatures for steps 2 and 4	1
4(c)(i)	$\text{H}_2 + \text{Pt}$ or $\text{H}_2 + \text{Ni}$ + heat or pressure	1

Question	Answer	Marks
4(c)(ii)	 (CH₃)₂CH, CH₃ and OH on the correct ring atoms i.e. structure is correct	1
	all Hs on the same side of the ring	1
	Total:	15

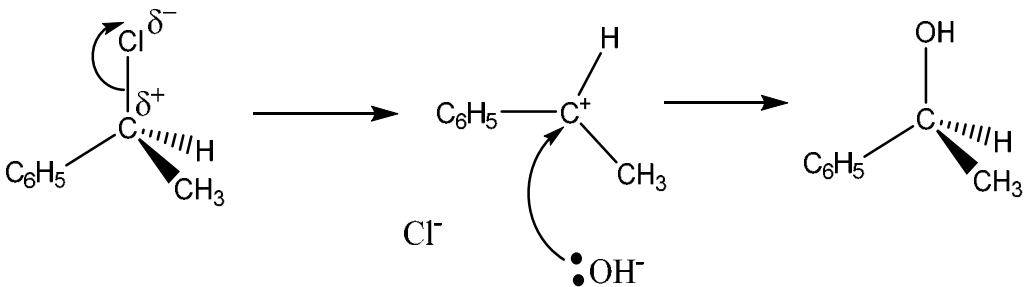
Question	Answer				Marks								
5(a)	<table><tr><td>J</td><td>K</td><td>L</td><td>M</td></tr><tr><td>amine methyl ketone</td><td>aromatic amine aldehyde</td><td>amine methyl ketone</td><td>amide</td></tr></table>				J	K	L	M	amine methyl ketone	aromatic amine aldehyde	amine methyl ketone	amide	
	J	K	L	M									
	amine methyl ketone	aromatic amine aldehyde	amine methyl ketone	amide									
	J and L correct				1 + 1								
K correct				1 + 1									
M correct				1									
5(b)(i)	hydrolysis				1								
5(b)(ii)	P is C ₆ H ₅ NH ₂				1								
	Q is CH ₃ CH ₂ CO ₂ Na				1								

Question	Answer	Marks
5(c)	J is  <i>or</i>  <i>or</i> 	1
	K is 	1
	L is 	1
	M is 	1
	K&L only: two chiral atoms shown	1
5(d)	W is $\text{C}_6\text{H}_5\text{CO}_2\text{Na}$	1
	Total:	14

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Question	Answer	Marks
6(a)	Any of the three methods possible. Any 4 of the 5 points for each method available for maximum 4 marks. Method 1 1 Ensure both solutions (A and B) at 40 °C before mixing 2 mix known volumes of A and B and start the clock 3 at known time take out a sample / X and add it to ice-cold solvent 4 titrate against HCl 5 repeat at time at known time intervals Method 2 1 Ensure both solutions (A and B) at 40 °C before mixing 2 mix known volumes of A and B and start the clock 3 at known time pour into ice-cold solvent or pour ice-cold solvent in 4 titrate against HCl 5 repeat with different concentrations of either A or B, or repeat using different times Method 3 1 Ensure both solutions (A and B) at 40 °C before mixing 2 mix known volumes of A and B and start the clock and add pH meter 3 at a known time 4 record the pH 5 repeat pH readings at known time intervals	4
6(b)(i)	from 1 and 3: when $[\text{RCI}]$ is trebled, so is rate, so order w.r.t. $[\text{RCI}] = 1$	1
	from 1 and 2: when both concentrations are doubled, rate doubles so $[\text{OH}^-]$ has no effect on rate, so order w.r.t. $[\text{OH}^-] = 0$	1
6(b)(ii)	rate = $k[\text{RCI}]$ AND units: $\text{sec}^{-1} \text{ 1 / s}$	1
6(b)(iii)	relative rate = 2.0	1

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Question	Answer	Marks
6(c)(i)	 C-Cl dipole and first curly arrow intermediate cation OH⁻ with lone pair and curly arrow	1 1 1
6(c)(ii)	Beginning with candidate's mechanism in (c)(i): If S_N1: racemate / mixture of / two optical isomers will be formed, because: the intermediate is planar / has a plane of symmetry / OH⁻ can approach from top or bottom or from any direction If S_N2: one optical isomer because attack always from fixed direction / from same side / the "configuration" always inverts / there is an asymmetric transition state	1

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Question	Answer					Marks																				
6(d)(i)	<table><tr><td>δ value</td><td>number of H atoms</td><td>group</td><td>splitting</td><td>result with D₂O</td></tr><tr><td>1.4</td><td>3</td><td>CH₃ / methyl</td><td>doublet</td><td>peak remains</td></tr><tr><td>2.7</td><td>1</td><td>OH / hydroxyl / alcohol</td><td>singlet</td><td>peak disappears</td></tr><tr><td>4.0</td><td>1</td><td>CH</td><td>quartet</td><td>peak remains</td></tr></table>					δ value	number of H atoms	group	splitting	result with D ₂ O	1.4	3	CH ₃ / methyl	doublet	peak remains	2.7	1	OH / hydroxyl / alcohol	singlet	peak disappears	4.0	1	CH	quartet	peak remains	
	δ value	number of H atoms	group	splitting	result with D ₂ O																					
	1.4	3	CH ₃ / methyl	doublet	peak remains																					
	2.7	1	OH / hydroxyl / alcohol	singlet	peak disappears																					
	4.0	1	CH	quartet	peak remains																					
	the three groups are in their correct places wrt the δ values					1																				
no. of H atoms for each peak agrees with group column					1																					
splitting patterns doublet, singlet and quartet are assigned to correct groups					1																					
peak identified as OH disappears with D ₂ O, no other peak disappears					1																					
	Total:					16																				

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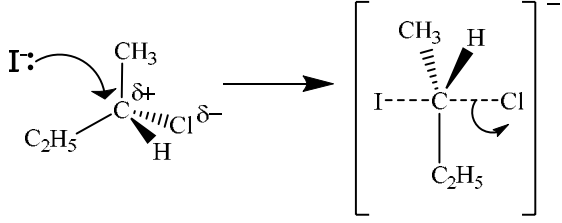
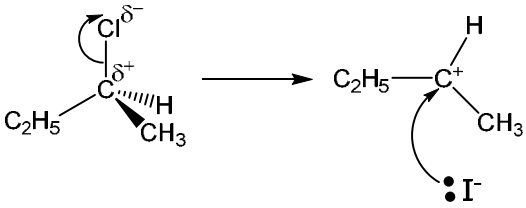
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Question	Answer	Marks
1(a)(i)	increases down the group	1
	radius / size of (cat)ion/M ²⁺ increases	1
	less polarisation / distortion of anion / carbonate ion / CO ₃ ²⁻	1
1(a)(ii)	Na ⁺ has smaller ionic charge and larger ionic radii OR the charge density of the Na ⁺ is lower	1
1(b)(i)	2KHCO ₃ —→ K ₂ CO ₃ + CO ₂ + H ₂ O	1
1(b)(ii)	NaHCO ₃ because Na ⁺ is smaller OR charge density Na ⁺ is larger	1
1(c)(i)	LE = $\Delta H_f - 2(\Delta H_{at} + IE) - \frac{1}{2}(O=O) - (EA_1 + EA_2)$ = $-361 - 2(89) - 2(418) - 496/2 - (-141+798)$ = -2280 (kJ mol ⁻¹) correct answer scores [3]	3 1 1 1
1(c)(ii)	LE of Na ₂ O will be more negative AND as Na ⁽⁺⁾ is smaller / larger charge density / smaller radii AND so greater attraction (between the ions) OR (ionic) bonds will be stronger	1
	Total:	10

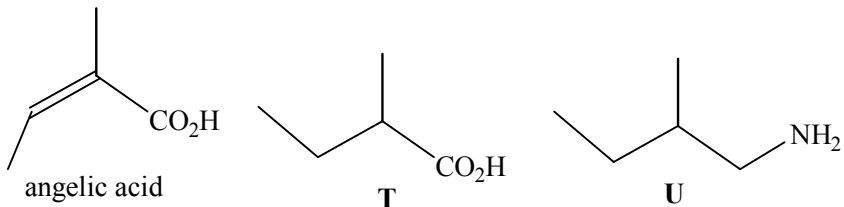
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Question	Answer	Marks
2(a)	Add AgNO ₃ Cl ⁻ gives a white ppt and I ⁻ gives a yellow ppt.	1
	Add NH ₃ (aq); ppt dissolves and ppt is insoluble	1
2(b)(i)	conductivity decreases during the reaction, AND number of Na ⁺ / I ⁻ / ions are decreased / used up (from solution)	1
2(b)(ii)	(Equilibrate) solutions at 40 °C / with a water bath (cannot be after mixing) mix known volumes and start the clock / timing clearly mentioned/implied measure conductance / conductivity at regular intervals / every measured time [method A] OR measure the time for conductance to go to zero / a specific value / to be constant [method B] prepare a curve of conductance vs. time [related to method A] OR prepare a curve of conductance vs. concentration [related to method A] OR repeating the experiment at different concentrations [related to method A and B] any 3 points	3
2(c)(i)	[R-Cl]: rate increases by 5 / 3 when concentration increases by 10 / 6 (5 / 3), so order = 1	1
	[I ⁻]: rate increases by 5 / 3 when concentration increases by 5 / 3, so order = 1	1
2(c)(ii)	rate = $k[I^-][CH_3CH_2CHClCH_3]$ AND units of $k = dm^3 mol^{-1} s^{-1}$	1
2(c)(iii)	relative rate = 5 / 5.3	1

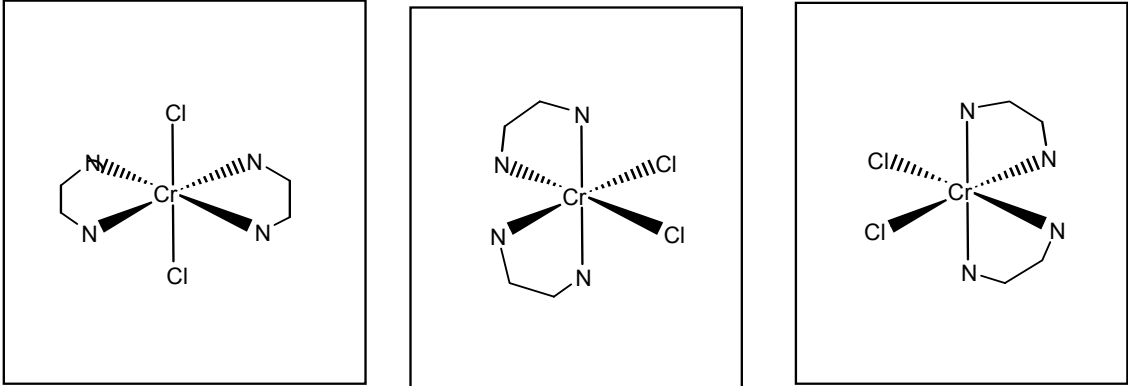
Question	Answer	Marks
2(d)(i)	either S_N1 or S_N2 mechanism S_N2  S_N1  C-Cl dipole AND C-Cl curly arrow intermediate cation OR 5-valent transition state (charge essential) I⁻ with lone pair AND other curly arrow	1 1 1
2(d)(ii)	If S_N1 in 2(d)(i) mixture of / two optical isomers will be formed, AND the intermediate can be formed by the I⁻ approaching from top or bottom plane If S_N2 in 2(d)(i) one optical isomer AND attack always from fixed direction / opposite side	1

Question	Answer	Marks
2(e)(i)	4 peaks	1
2(e)(ii)	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{Cl} \\ \\ \text{CH}_3 \end{array}$ $\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_2 - \text{Cl} \\ \\ \text{H} \end{array}$	1 + 1
	number of peaks = 2 number of peaks = 3	1
	Total:	18

Question	Answer	Marks
3(a)		
	four shared pairs: S=O and 2 × S-Cl	1
	all (9) lone pairs	1
3(b)(i)	$\text{NaOH} + \text{HCl} \longrightarrow \text{NaCl} + \text{H}_2\text{O}$	1
	$2\text{NaOH} + \text{SO}_2 \longrightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O}$	1

Question	Answer	Marks
3(b)(ii)	moles (at start) = $0.5 \times 60 / 1000 = 3 \times 10^{-2}$ AND moles (at end) = $0.5 \times 10.8 / 1000 = 5.4 \times 10^{-3}$	1
	moles reacted (= $(30 - 5.4) \times 10^{-3}$ =) 2.5×10^{-2} correct ans. scores [2]	1
3(b)(iii)	moles of $\text{RCO}_2\text{H} = 2.46 \times 10^{-2} / 3 = 8.2 - 8.3 \times 10^{-3}$ mole	1
3(b)(iv)	$M_r = 1.00 / (8.2 \times 10^{-3}) = 121.95$ (=122)	1
3(b)(v)	$\text{C}_7\text{H}_6\text{O}_2$ OR $\text{C}_6\text{H}_5\text{CO}_2\text{H}$	1
3(c)(i)	LiAlH_4	1
3(c)(ii)	 angelic acid T U	3
3(c)(iii)	angelic acid: geometrical OR cis-trans compound T : optical	1
	Total:	14

Question	Answer	Marks
4(a)(i)	$M_r = 52 + 6 \times 18 + 3 \times 35.5 = 266.5$	1
4(a)(ii)	$1.00\text{g} = 1 / 266.5$ OR 3.75×10^{-3} moles (of complex in 1g) for A , $n=2$ AND $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl} \cdot 2\text{H}_2\text{O}$ for B , $n=1$ AND $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl} \cdot \text{H}_2\text{O}$ for C , $n=0$; AND $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$	2
4(b)(i)	Geometric(al) / cis-trans	1
4(b)(ii)	$\begin{array}{c} \text{CN} \\ \\ \text{R}_3\text{P} - \text{Ni} - \text{PR}_3 \\ \\ \text{CN} \end{array}$ isomer 1 $\begin{array}{c} \text{CN} \\ \\ \text{R}_3\text{P} - \text{Ni} - \text{CN} \\ \\ \text{PR}_3 \end{array}$ isomer 2	1
4(b)(iii)	isomer 2 AND dipoles do not cancel OR CN^- are on the same side of the molecule	1
	Total:	6

Question	Answer	Marks
5(a)(i)	<i>bidentate</i> : (a species that) forms two dative bonds / donates two lone pairs	1
	<i>ligand</i> : a species that uses a lone pair to form a dative bond to a metal atom / metal ion	1
5(a)(ii)	 each structure [1] x 3	3
5(b)(i)	$K_{\text{stab1}} = [\text{Cu}(\text{NH}_3)_4^{2+}] / [\text{Cu}^{2+}][\text{NH}_3]^4$	1
	$K_{\text{stab2}} = [\text{Cu}(\text{en})_2^{2+}] / [\text{Cu}^{2+}][\text{en}]^2$	1
	$\text{mol}^{-4} \text{ dm}^{12}$ AND $\text{mol}^{-2} \text{ dm}^6$	1
5(b)(ii)	$K_{\text{eq3}} = K_{\text{stab2}} / K_{\text{stab1}}$	1
5(b)(iii)	$K_{\text{eq3}} = K_{\text{stab2}} / K_{\text{stab1}} = 4.4(2) \times 10^6$	1
	$\text{mol}^2 \text{ dm}^{-6}$	1
5(c)(i)	(ΔS_{eq1} is negative as) more / 5 moles of reactants are forming (one mole of) the complex OR (ΔS_{eq2} is positive as) fewer / 3 moles of reactants are forming (one mole of) the complex	1
5(c)(ii)	$\Delta G_{\text{eq2}} = -100 - 298 \times 40 / 1000$ OR $\Delta G = \Delta H - T\Delta S$ $= -112$ or $-111.9 \text{ (kJ mol}^{-1}\text{)}$ correct answer [2]	2 1 1

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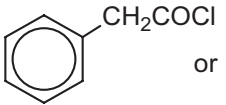
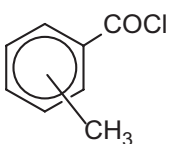
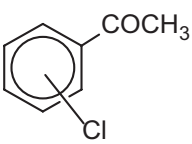
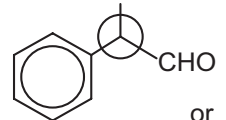
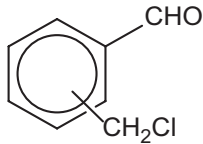
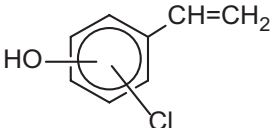
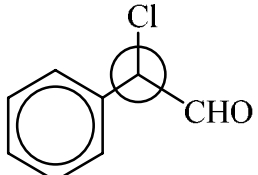
Question	Answer	Marks
5(c)(iii)	Since (ΔG_{eq2}) is more negative (than ΔG_{eq1}) AND equilibrium 2 is more feasible	1
5(c)(iv)	$\Delta H_{(3)} = -8 \text{ (kJ mol}^{-1}\text{)}$	1
5(c)(v)	ligand exchange / replacement / substitution / displacement	1
	Total:	17

Question	Answer	Marks
6(a)(i)	the lower / smaller the pK_a , the stronger the acid	1
6(a)(ii)	$pK_a = -\log(K_a)$ or $pK_a = -\lg(K_a)$ or $K_a = 10^{-pK_a}$	1
6(a)(iii)	(stronger than ethanoic acid because) Cl is electron-withdrawing	1
	and so stabilises the RCO_2^- anion / conjugate base or weakens O-H bond (so H^+ is more easily released)	1
6(b)(i)	$NH_3^+CH_2CO_2^- \longrightarrow NH_2CH_2CO_2^- + H^+$ OR $NH_3^+CH_2CO_2^- + H_2O \longrightarrow NH_2CH_2CO_2^- + H_3O^+$	1
6(b)(ii)	$K_a = 10^{-9.87} = 1.35 \times 10^{-10}$ $[H^+] = \sqrt{(K_a \cdot c)} = 3.67 \times 10^{-6}$	1
	pH = 5.4 (5.43–5.44) min 2sf	1

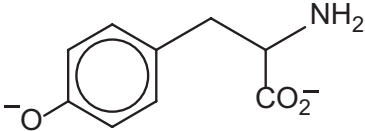
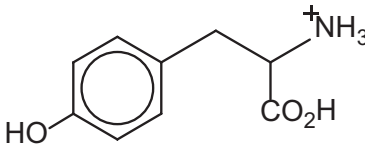
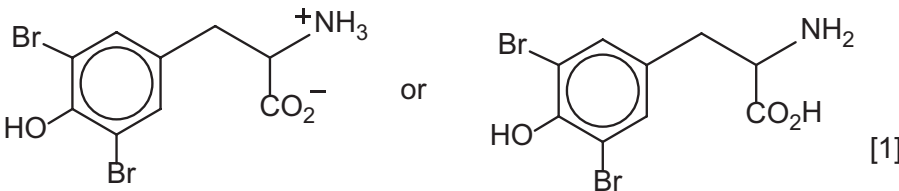
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Question	Answer	Marks
6(b)(iii)	curve starts at 5.4 and continuous	1
	vertical portion (end point) at vol added = 10.0 cm ³	1
	finishes at pH = 12.5 at 20 cm³ (and does not increase in pH)	1
	Total:	10

Question	Answer				Marks
7(a)	W	X	Y	Z	5
	acyl chloride / COCl/	methyl ketone / CH3CO group aryl chloride	aldehyde / CHO chloro(alkane) / RCl	Alkene / C=C phenol / C6H5OH aryl chloride	
	0–1 [0]; 2 [1]; 3 [2]; 4 [3]; 5 [4]; 6–8 [5]				

Question	Answer	Marks
7(b)(i)	W  or  X  Cl	1 + 1
	Y  or  Z  HO	1 + 1
7(b)(ii)	Y  OR any chiral atom correctly labelled	1
	Total:	10

Question	Answer	Marks
8(a)(i)	step 1 electrophilic substitution	1
	step 2 nucleophilic addition	1
8(a)(ii)	hydrolysis	1

Question	Answer	Marks
8(a)(iii)	step 1 ClCH_2CHO (allow Br, I for Cl)	1
	AlCl_3	1
	step 2 $\text{HCN} + \text{NaCN}$	1
	step 3 heat in H_3O^+ / heat $\text{H}^+(\text{aq})$	1
	step 5 NH_3 under pressure (+ heat) or heat NH_3 in a sealed tube	1
8(a)(iv)	with $\text{NaOH}(\text{aq})$  [2]	1 + 1
	with $\text{HCl}(\text{aq})$  [1]	1
	with $\text{Br}_2(\text{aq})$  or [1]	1
8(b)(i)	P is tyr	1
	tyr is 2- AND it is small / has a small Mr	1

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Question	Answer	Marks
8(b)(ii)	(<i>dipeptide / phe-tyr</i>) 2– is about double the M_r / mass of (<i>phe</i>) 1 OR mass / charge ratios are about the same for each (for dipeptide / phe-tyr and phe)	1
	Total:	15

CHEMISTRY

9701/43

Paper 4 A Level Structured Questions

May/June 2017

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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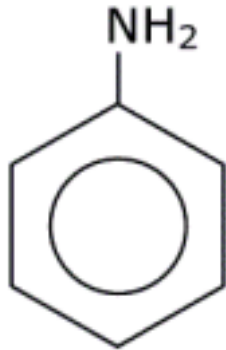
Question	Answer	Marks
1(a)	solubility increases down the group	1
	ΔH_{latt} and ΔH_{hyd} both decrease or ΔH_{latt} and ΔH_{hyd} both become less exothermic / more endothermic	1
	ΔH_{latt} decreases / changes more (than ΔH_{hyd} as OH^- being smaller than M^{2+})	1
	ΔH_{sol} becomes more exothermic / more negative / less endothermic / less positive	1
1(b)(i)	$\Delta H_{\text{r1}} - (538 + 2 \times 230 + 394) = -(1216 + 286)$ $\Delta H_{\text{r1}} - 1392 = -1502$	1
	$\Delta H_{\text{r1}} = \mathbf{-110}$	1
1(b)(ii)	let $\Delta H_{\text{f}}(\text{HCO}_3^-(\text{aq})) = y$ $2y - 538 = -1216 - 394 - 286 - 26$	1
	$y = \mathbf{-692}$	1
1(b)(iii)	$\Delta H_{\text{r3}} - 538 - 2(230 + 394) = -538 - 2(692)$ $\Delta H_{\text{r3}} = \mathbf{-136}$	1
1(b)(iv)	ΔH_{r3} will be identical to ΔH_{r4} , / unchanged	1
	as the reaction is the same, or: $2\text{OH}^-(\text{aq}) + 2\text{CO}_2(\text{g}) \longrightarrow 2\text{HCO}_3^-(\text{aq})$ or metal ions stay in solution/metal ions are unchanged / are spectators	1

Question	Answer	Marks
1(c)	more gaseous moles are being consumed (in reaction 3) or more CO₂ moles are being consumed (in reaction 3)	1
	ΔS is therefore expected to be more negative/less positive for reaction 3.	1
	Total:	13

Question	Answer	Marks
2(a)(i)		1 + 1
	16 electrons on each diagram	1
2(a)(ii)	HNC = 115–125° AND NCO = 180°	1
2(a)(iii)	cyanic acid, because it's a stronger / higher bond enthalpy / triple / C≡N / more electrons involved bond	1
2(b)(i)	$[H^+] = \sqrt{([HNCN]K_a)} = \sqrt{(0.1 \times 1.2 \times 10^{-4})}$ or 3.46×10^{-3}	1
	pH = log $[H^+] = 2.5$ (2.46)	1
2(b)(ii)	$Na_2CO_3 + 2(NH_2)_2CO \longrightarrow 2NaNCO + CO_2 + 2NH_3 + H_2O$	1
2(c)(i)	$n(OH^-)$ at start = $(2 \times 0.1 \times 30) / 1000 = 6 \times 10^{-3}$ mol $n(OH^-)$ reacted = $(0.1 \times 20) / 1000 = 2 \times 10^{-3}$ mol $n(OH^-)$ remaining = $(6-2) \times 10^{-3} = 4 \times 10^{-3}$ mol, (in 50 cm ³)	1
	so $[OH^-]_{end} = (4 \times 10^{-3} \times 1000) / 50 = 0.08 \text{ mol dm}^{-3}$	1

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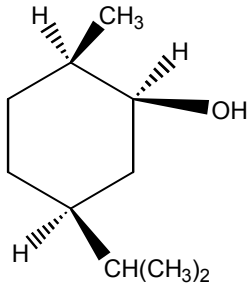
Question	Answer	Marks
2(c)(ii)	$[H^+] = K_w / [OH^-] = (1 \times 10^{-14}) / 0.08 = 1.25 \times 10^{-13} \text{ mol dm}^{-3}$	1
	so $\text{pH} = -\log(1.25 \times 10^{-13}) = \mathbf{12.9}$	1
2(c)(iii)	curve starts at 2.46 / 2.5	1
	vertical portion (end point) at vol added = 10.0 cm ³	1
	finishes at pH = 12.9	1
2(d)(i)	<i>monodentate</i> : (a species that) forms one dative / coordinate bond	1
	<i>ligand</i> : a species that uses a lone pair of electrons to form a dative / coordinate bond to a metal atom / metal ion	1
2(d)(ii)	$[Ag(NCO)_2]^-$ or $[Ag(OCN)_2]^-$ correct formula	1
	correct charge	1
2(e)(i)	$n(\text{BaCO}_3) = 1.66 / 197.3 = 8.4(1) \times 10^{-3} \text{ mol}$	1
2(e)(ii)	$n(\text{RNCO}) = 8.41 \times 10^{-3} \text{ mol}$, so $M_r = 1 / (8.41 \times 10^{-3}) = \mathbf{119}$	1
2(e)(iii)	molecular formula = C ₇ H ₅ NO	1

Question	Answer	Marks
2(e)(iv)		1
	Total:	23

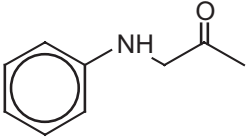
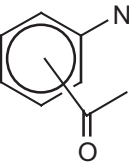
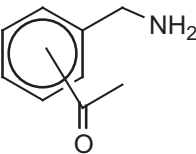
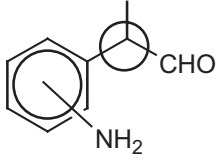
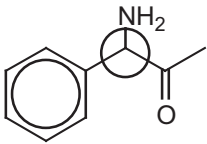
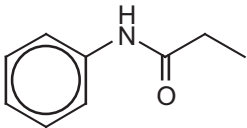
Question	Answer	Marks
3(a)(i)	+3 or Co^{3+}	1
3(a)(ii)	oxidation	1
	ligand displacement / replacement / exchange / substitution	1

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Question	Answer	Marks
4(a)(i)	optical, because it contains a / one chiral C-atom or chiral C-atoms or chiral atom / centre or C* indicated or C with 4 different groups	1
4(a)(ii)	$\text{C}_{10}\text{H}_{14}\text{O} + 3\text{H}_2 \longrightarrow \text{C}_{10}\text{H}_{20}\text{O}$ correct formulae	1
	balancing	1
4(b)(i)	electrophilic substitution	1
4(b)(ii)	step 3 reduction	1
	step 5 substitution / hydrolysis	1
4(b)(iii)	step 1 $(\text{CH}_3)_2\text{CHCl} + \text{AlCl}_3 / \text{AlBr}_3 / \text{FeCl}_3 / \text{FeBr}_3$	1 + 1
	step 2 $\text{HNO}_3 + \text{H}_2\text{SO}_4$ conc (T < 55 °C)	1
	step 3 $\text{Sn} + \text{HCl}$	1
	step 4 HNO_2 (or $\text{NaNO}_2 + \text{HCl}$) (at T < 10 °C)	1
	the two temperatures for steps 2 and 4	1
4(c)(i)	$\text{H}_2 + \text{Pt}$ or $\text{H}_2 + \text{Ni}$ + heat or pressure	1

Question	Answer	Marks
4(c)(ii)	 (CH₃)₂CH, CH₃ and OH on the correct ring atoms i.e. structure is correct	1
	all Hs on the same side of the ring	1
	Total:	15

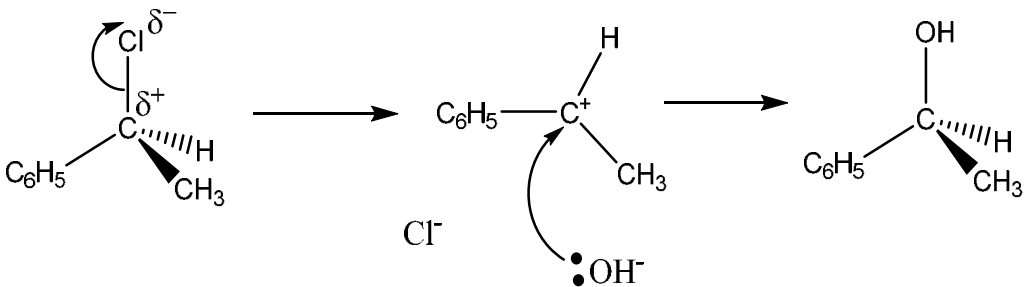
Question	Answer				Marks								
5(a)	<table><tr><td>J</td><td>K</td><td>L</td><td>M</td></tr><tr><td>amine methyl ketone</td><td>aromatic amine aldehyde</td><td>amine methyl ketone</td><td>amide</td></tr></table>				J	K	L	M	amine methyl ketone	aromatic amine aldehyde	amine methyl ketone	amide	
	J	K	L	M									
	amine methyl ketone	aromatic amine aldehyde	amine methyl ketone	amide									
	J and L correct				1 + 1								
	K correct				1 + 1								
M correct				1									
5(b)(i)	hydrolysis				1								
5(b)(ii)	P is C ₆ H ₅ NH ₂				1								
	Q is CH ₃ CH ₂ CO ₂ Na				1								

Question	Answer	Marks
5(c)	J is  <i>or</i>  <i>or</i> 	1
	K is 	1
	L is 	1
	M is 	1
	K&L only: two chiral atoms shown	1
5(d)	W is $\text{C}_6\text{H}_5\text{CO}_2\text{Na}$	1
	Total:	14

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Question	Answer	Marks
6(a)	Any of the three methods possible. Any 4 of the 5 points for each method available for maximum 4 marks. Method 1 1 Ensure both solutions (A and B) at 40 °C before mixing 2 mix known volumes of A and B and start the clock 3 at known time take out a sample / X and add it to ice-cold solvent 4 titrate against HCl 5 repeat at time at known time intervals Method 2 1 Ensure both solutions (A and B) at 40 °C before mixing 2 mix known volumes of A and B and start the clock 3 at known time pour into ice-cold solvent or pour ice-cold solvent in 4 titrate against HCl 5 repeat with different concentrations of either A or B, or repeat using different times Method 3 1 Ensure both solutions (A and B) at 40 °C before mixing 2 mix known volumes of A and B and start the clock and add pH meter 3 at a known time 4 record the pH 5 repeat pH readings at known time intervals	4
6(b)(i)	from 1 and 3: when $[\text{RCI}]$ is trebled, so is rate, so order w.r.t. $[\text{RCI}] = 1$	1
	from 1 and 2: when both concentrations are doubled, rate doubles so $[\text{OH}^-]$ has no effect on rate, so order w.r.t. $[\text{OH}^-] = 0$	1
6(b)(ii)	rate = $k[\text{RCI}]$ AND units: $\text{sec}^{-1} \text{ 1 / s}$	1
6(b)(iii)	relative rate = 2.0	1

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Question	Answer	Marks
6(c)(i)	 C-Cl dipole and first curly arrow intermediate cation OH⁻ with lone pair and curly arrow	1 1 1
6(c)(ii)	Beginning with candidate's mechanism in (c)(i): If S_N1: racemate / mixture of / two optical isomers will be formed, because: the intermediate is planar / has a plane of symmetry / OH⁻ can approach from top or bottom or from any direction If S_N2: one optical isomer because attack always from fixed direction / from same side / the "configuration" always inverts / there is an asymmetric transition state	1

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Question	Answer					Marks																				
6(d)(i)	<table><tr><td>δ value</td><td>number of H atoms</td><td>group</td><td>splitting</td><td>result with D₂O</td></tr><tr><td>1.4</td><td>3</td><td>CH₃ / methyl</td><td>doublet</td><td>peak remains</td></tr><tr><td>2.7</td><td>1</td><td>OH / hydroxyl / alcohol</td><td>singlet</td><td>peak disappears</td></tr><tr><td>4.0</td><td>1</td><td>CH</td><td>quartet</td><td>peak remains</td></tr></table>					δ value	number of H atoms	group	splitting	result with D ₂ O	1.4	3	CH ₃ / methyl	doublet	peak remains	2.7	1	OH / hydroxyl / alcohol	singlet	peak disappears	4.0	1	CH	quartet	peak remains	
	δ value	number of H atoms	group	splitting	result with D ₂ O																					
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	4.0	1	CH	quartet	peak remains																					
	the three groups are in their correct places wrt the δ values					1																				
no. of H atoms for each peak agrees with group column					1																					
splitting patterns doublet, singlet and quartet are assigned to correct groups					1																					
peak identified as OH disappears with D ₂ O, no other peak disappears					1																					
	Total:					16																				