

Cambridge International AS & A Level

CHEMISTRY**9701/41**

Paper 4 A Level Structured Questions

May/June 2024**MARK SCHEME**Maximum Mark: 100

Published

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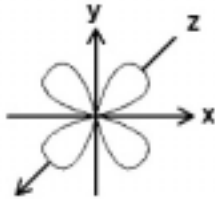
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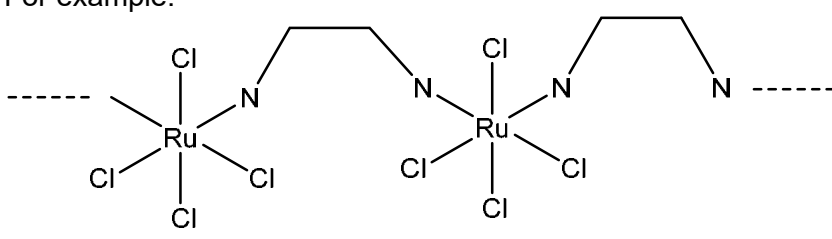
7 Guidance for chemical equations

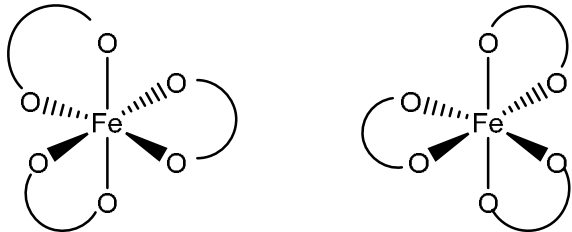
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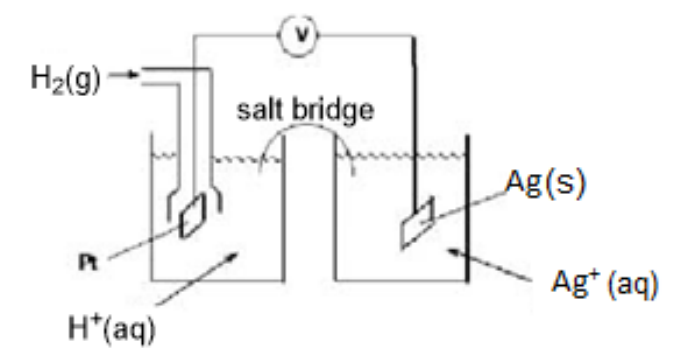
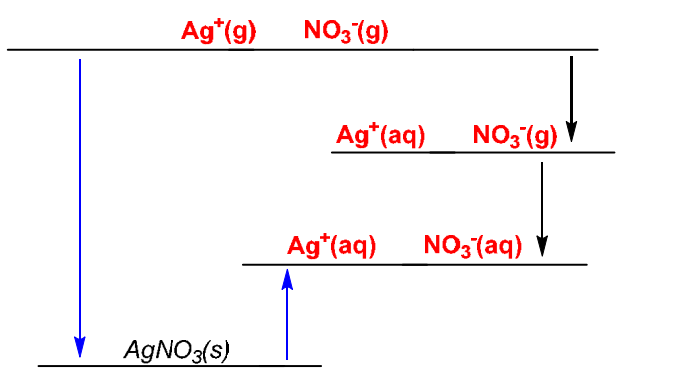
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Question	Answer	Marks
1(a)(i)	M1 strontium > calcium > magnesium M2 ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative M3 ΔH_{latt} changes more M4 ΔH_{sol} becomes more exothermic / more negative	4
1(a)(ii)	pH increases as the concentration of $[\text{OH}^-]$ ions increases	1
1(b)	M1 $[\text{H}^+] = 10^{-12.2}$ OR 6.31×10^{-13} M2 $[\text{OH}^-] = 0.0158 \text{ mol dm}^{-3}$ ecf M3 $[\text{Ba}(\text{OH})_2] = 0.01585 \div 2 = 7.92$ ecf M4 mol of $\text{Ba}(\text{OH})_2 = 0.00792 \div 4 = 1.98 \times 10^{-3}$ mass $\text{Ba}(\text{OH})_2 = 0.339 \text{ g}$ ecf	4
1(c)(i)	$K_{\text{sp}} = [\text{Fe}^{2+}][\text{OH}^-]^2$	1
1(c)(ii)	M1 $K_{\text{sp}} = 4 \times (5.85 \times 10^{-6})^3 = 8.01 \times 10^{-16}$ M2 $\text{mol}^3 \text{ dm}^{-9}$	2

Question	Answer	Marks
2(a)(i)	element which forms one or more stable ion with incomplete d orbitals	1
2(a)(ii)	they have vacant d orbitals that are energetically accessible	1
2(b)(i)	orbitals of the same energy	1
2(b)(ii)		1

Question	Answer	Marks
2(c)	M1 $2\text{AgNO}_3 + 2\text{NaOH} \rightarrow \text{Ag}_2\text{O} + 2\text{NaNO}_3 + \text{H}_2\text{O}$ OR $2\text{Ag}^+ + 2\text{OH}^- \rightarrow \text{Ag}_2\text{O} + \text{H}_2\text{O}$ M2 $\text{Ag}_2\text{O} + 4\text{NH}_3 + \text{H}_2\text{O} \rightarrow 2[\text{Ag}(\text{NH}_3)_2]\text{OH}$ OR $\text{Ag}^+ + 2\text{NH}_3 + \text{OH}^- \rightarrow [\text{Ag}(\text{NH}_3)_2]\text{OH}$	2
2(d)	M1 bond angle H–N–Ag is 109.5° M2 shape is linear AND bond angle for N–Ag–N is 180°	2
2(e)	M1 $\text{Ag}_2\text{O} + \text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{Ag} + 2\text{OH}^-$ M2 $\text{Zn} + 2\text{OH}^- \rightarrow \text{Zn}(\text{OH})_2 + 2\text{e}^-$	2
2(f)	For example:  M1 presence of <i>dps</i> ligand bonded to two Ru M2 the rest of the structure correct	2

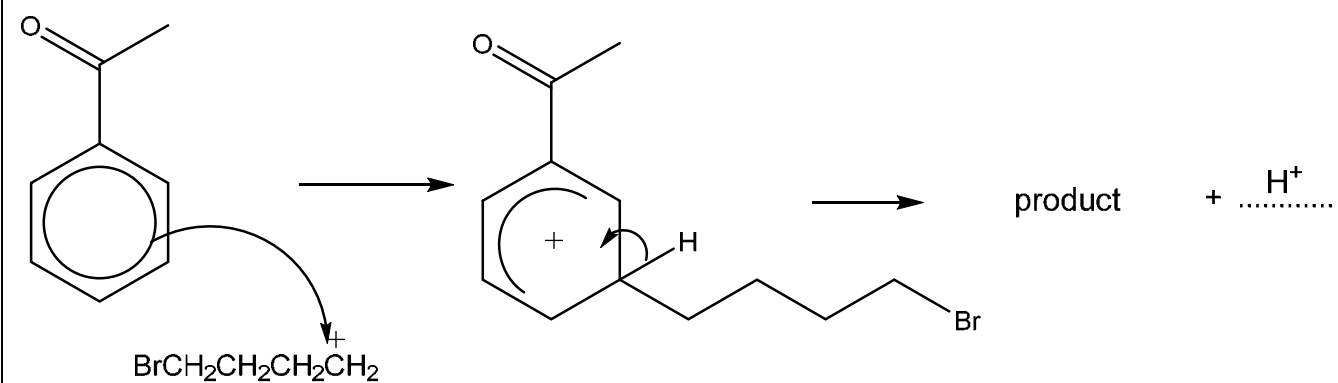
Question	Answer	Marks
3(a)	$\text{Li}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O} \rightarrow \text{Li}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}$	1
3(b)	M1 CaC_2O_4 AND Ca^{2+} has a smaller ionic radius / Ca^{2+} has a higher charge density M2 anion / $\text{C}_2\text{O}_4^{2-}$ becomes more polarised / distorted	2
3(c)	M1 d orbital(s) of different energy / d-d splitting occurs M2 electron(s) promoted / excited M3 light is absorbed AND colour seen is complementary	3
3(d)	$2\text{K}_3\text{Fe}(\text{C}_2\text{O}_4)_3 \rightarrow 2\text{K}_2\text{Fe}(\text{C}_2\text{O}_4)_2 + \text{K}_2\text{C}_2\text{O}_4 + 2\text{CO}_2$	1
3(e)		2
3(f)	M1 $\text{HC}_2\text{O}_4^- + \text{H}^+ \rightarrow \text{H}_2\text{C}_2\text{O}_4$ M2 $\text{HC}_2\text{O}_4^- + \text{OH}^- \rightarrow \text{C}_2\text{O}_4^{2-} + \text{H}_2\text{O}$	2
3(g)	M1 $2\text{C}_2\text{O}_4^{2-} + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{CO}_2(\text{g}) + 4\text{OH}^-(\text{aq})$ M2 $E_{\text{cell}} = 0.40 - (-0.59) = 0.99 \text{ V}$	2

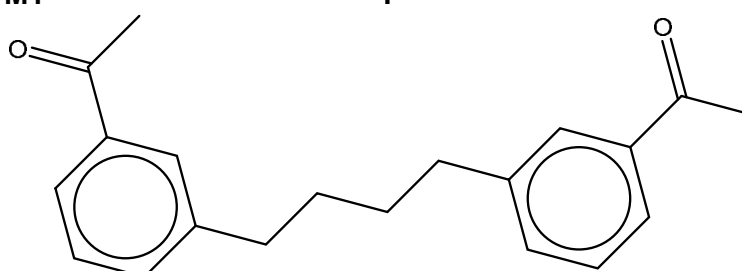
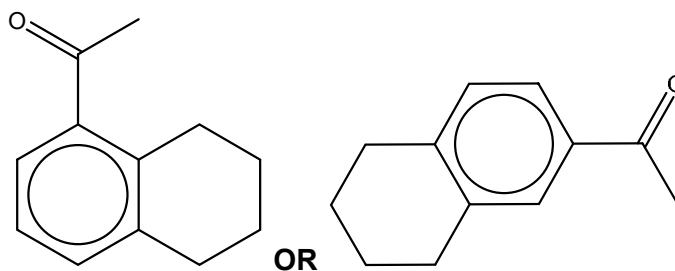
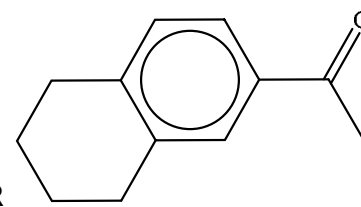
Question	Answer	Marks
4(a)	M1 voltage of a half-cell compared to SHE M2 1 mol dm ⁻³ AND 101 kPa AND 298 K	2
4(b)(i)	 M1 Pt Ag Ag⁺ M2 gas delivery system H₂ H⁺ M3 voltmeter salt bridge wiring Pt to V to Ag	3
4b(ii)	<i>E</i> value would be more negative AND shifts Ag ⁺ (+ e ⁻) ⇌ Ag to the left	1
4(c)	enthalpy change when one mole of a solute dissolves in water	1
4(d)(i)	 M1 two arrows in blue M2 correct species in red with all state symbols	2

Question	Answer	Marks
4(d)(ii)	$\Delta H_{\text{latt}} = -811.6 \text{ (kJ mol}^{-1}\text{)}$	1
4(e)	M1 $\text{Mg(NO}_3)_2(\text{s})$, $\text{NaNO}_3(\text{s})$, $\text{RbNO}_3(\text{s})$ M2 Mg^{2+} has a higher charge than Na^+ OR Rb^+ AND Na^+ has a smaller radius than Rb^+ M3 correct statement relating magnitude of LE to attraction between ions OR strength of ionic bonds	3

Question	Answer	Marks
5(a)(i)	tangent drawn at $t = 0$ AND gradient of tangent calculated at $t = 0$ answer between 0.016 to 0.040	1
5(a)(ii)	$[\text{I}^-]$ stays constant / $[\text{I}^-]$ does not change OR the overall order is one under these conditions	1
5(b)	M1 equation 1: $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$ M2 equation 2: $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$	2
5(c)	the rate constant and rate of reaction 1 will both increase	1
5(d)	$k = 0.693 \div t_{1/2}$ $t_{1/2} = 0.693 \div 0.0158 = 43.9 \text{ s}$	1
5(e)	$\text{NO} + \text{Br}_2 \rightarrow \text{NOBr}_2$ OR $\text{NO} + \text{Br}_2 \rightarrow \text{NOBr} + \text{Br}$ $\text{NOBr}_2 + \text{NO} \rightarrow 2\text{NOBr}$ OR $\text{Br} + \text{NO} \rightarrow \text{NOBr}$ M1 two equations adding up to the overall equation M2 step 1 has one NO and one Br_2 only and is identified as slow step	2

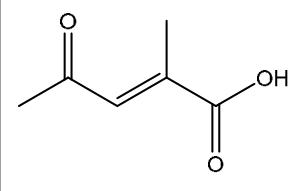
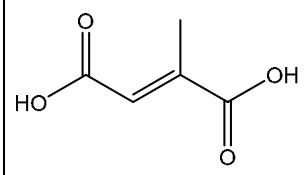
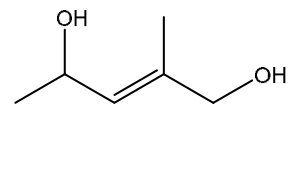
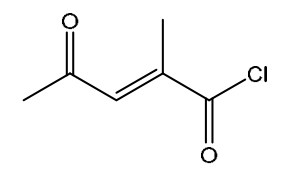
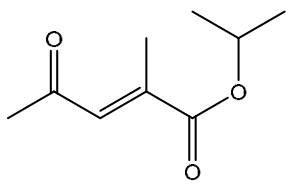
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6(a)(i)	ratio of the concentrations of solute in two solvents	1																
6(a)(ii)	M1 $10.5 = (y \div 25) \div ((0.74 - y) \div 40)$ M2 $y = 0.642 \text{ g}$	2																
6(b)	<table><tr><td></td><td>sp</td><td>sp²</td><td>sp³</td></tr><tr><td>Kekulé benzene</td><td>0</td><td>6</td><td>0</td></tr><tr><td>Dewar benzene</td><td>0</td><td>4</td><td>2</td></tr><tr><td>Ladenburg benzene</td><td>0</td><td>0</td><td>6</td></tr></table> M1 row 1 and 2 correct M2 row 3 correct		sp	sp ²	sp ³	Kekulé benzene	0	6	0	Dewar benzene	0	4	2	Ladenburg benzene	0	0	6	2
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6(c)	M1 120° AND hexagonal/trigonal planar M2 C-C has π -bonds and σ -bonds AND C-H have σ -bonds only	2																
6(d)	bond strain OR ring strain	1																
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6(f)(i)	$\text{BrCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{FeBr}_3 \rightarrow \text{BrCH}_2\text{CH}_2\text{CH}_2\text{CH}_2^+ + \text{FeBr}_4^-$	1																

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6(f)(ii)	 product + ...H⁺ M1 curly arrow from inside the hexagon towards C⁺ M2 structure of the intermediate M3 curly arrow from C–H bond into the ring AND H⁺	3

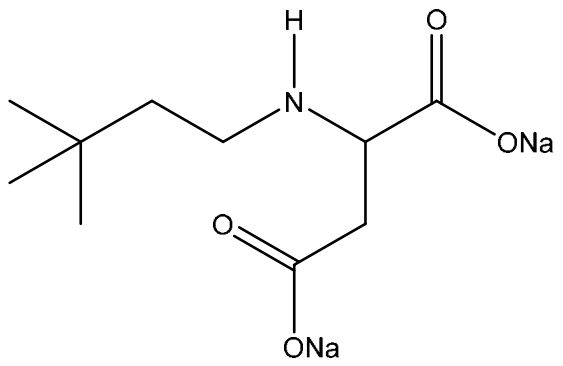
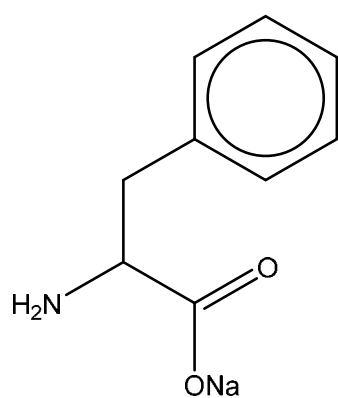
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6(f)(iii)	M1 Y  M2 Z  OR 	2

Question	Answer	Marks
7(a)	methyl pentanoate	1
7(b)(i)	time between injection and detection	1
7(b)(ii)	29.5%	1

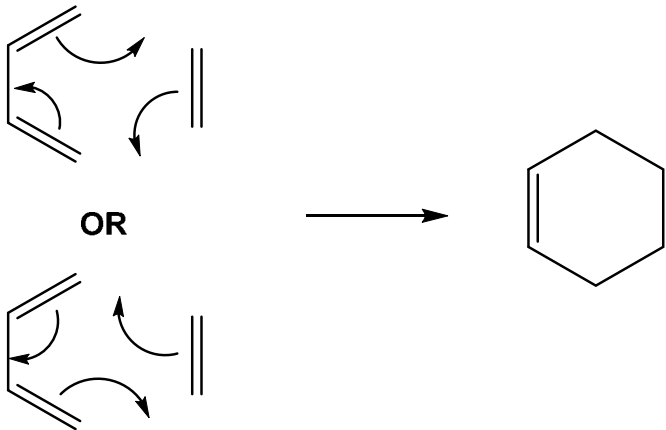
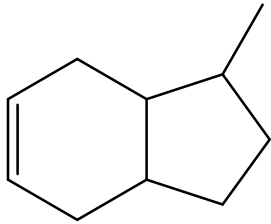
Question	Answer			Marks
7(c)(i)	ester	number of peaks seen in proton (¹ H) NMR	number of peaks seen in carbon-13 NMR	2
	B	5	6	
	C	4	5	
	M1 row 1 correct M2 row 2 correct			
7(c)(ii)	A and B			1

Question	Answer	Marks
7(d)	F, C₆H₈O₃  G CHI₃ H  alkaline I₂(aq) → J, C₆H₁₂O₂  K, C₆H₈O₂Cl  LiAlH₄ ↓ SOCl₂ ↘ propan-2-ol ↓ L  one mark for each structure: F, G, H, J, K and L	6

Question	Answer	Marks
7(d)	six alternatives for F Chemical structures showing six alternatives for F: - Structure 1: A branched molecule with a methyl ketone, a double bond, and a carboxylic acid group. - Structure 2: A branched molecule with a methyl ketone, a double bond, and a carboxylic acid group. - Structure 3: A branched molecule with a methyl ketone, a double bond, and a carboxylic acid group. - Structure 4: A branched molecule with a methyl ketone, a double bond, and a carboxylic acid group. - Structure 5: A cyclopropane ring with a carboxylic acid group and a methyl ketone group. - Structure 6: A branched molecule with a methyl ketone, a double bond, and a carboxylic acid group.	

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8(a)(i)	two	1
8(a)(ii)	amide amine ester carboxylic acid / carboxyl any two [1] all four [2]	2
8(b)(i)	M1 hydrolysis M2 acid–base	2
8(b)(ii)	  $\text{H}_3\text{C}-\text{OH}$ one mark for each structure	3

Question	Answer	Marks
9(a)(i)	$\text{C}_6\text{H}_5\text{OH} + \text{Na} \rightarrow \text{C}_6\text{H}_5\text{ONa} + \frac{1}{2}\text{H}_2$	1
9(a)(ii)	both structures for one mark	1
9(b)	M1 correct dipole AND curly arrow from inside the hexagon to the carbon atom M2 structure of the intermediate M3 curly arrow from C-H bond into the ring AND H^+	3

Question	Answer	Marks
9(c)(i)	 OR All three curly arrows for one mark	1
9(c)(ii)		1

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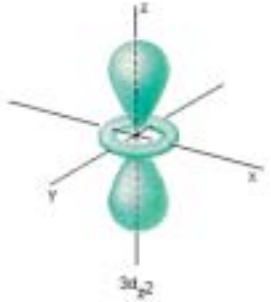
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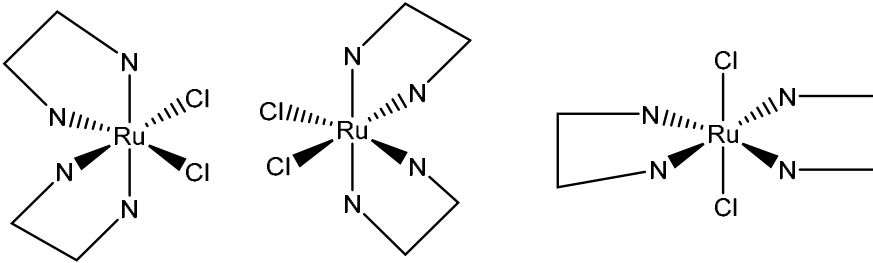
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1(b)	M1 ΔH / energy change when 1 mole of an ionic solid / compound is formed M2 from gaseous ions (under standard conditions)	2
1(c)	M1 as ionic radii increases AND ΔH_{latt} less exothermic M2 as ionic charge increases AND ΔH_{latt} increases/more exothermic	2
1(d)(i)	any two [1] any three [2] all four [3]	3

Question	Answer	Marks
1(d)(ii)	M1 selection of ONLY six correct values (–381, 89, 419, 279, –200, 640) AND use of $\times 2$ as only multiplier with K M2 correct evaluation of data used ecf $-381 = (89 \times 2) + (419 \times 2) + 279 + (-200) + 640 + \Delta H^\circ_{\text{latt}}$ $\Delta H^\circ_{\text{latt}} = -2116 \text{ (kJ mol}^{-1}\text{)}$	2

Question	Answer	Marks
2(a)(i)	$2\text{LiNO}_3 \rightarrow \text{Li}_2\text{O} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$	1
2(a)(ii)	M1 radius / size of cation / M^+ increases OR charge density of ion decreases M2 less polarisation / distortion of anion / nitrate ion / NO_3^- / less weakening of NO bond	2
2(b)	M1 M2 any two for one mark or all four for two marks: - mol total $\text{MnO}_4^- = 0.125 \times 0.0500 = 6.25 \times 10^{-3}$ - mol $\text{Fe}^{2+} = 0.0400 \times 0.0225 = 9.00 \times 10^{-4}$ - mol unreacted $\text{MnO}_4^- = 9.00 \times 10^{-4} \div 5 = 1.80 \times 10^{-4}$ ecf - mol reacted $\text{MnO}_4^- = 6.25 \times 10^{-3} - 1.80 \times 10^{-4} = 6.07 \times 10^{-3}$ ecf M3 mol $\text{NO}_2^- = 2.5 \times 6.07 \times 10^{-3} = 1.5175 \times 10^{-2}$ conc $\text{NaNO}_2 = 4 \times 1.5175 \times 10^{-2} = 6.07\text{--}6.08 \times 10^{-2} \text{ mol dm}^{-3}$ ecf min 2sf	3
2(c)(i)	$3\text{MnO}_4^{2-} + 4\text{H}^+ \rightarrow 2\text{MnO}_4^- + \text{MnO}_2 + 2\text{H}_2\text{O}$ M1 MnO_4^{2-} as a reactant and $\text{MnO}_4^- + \text{MnO}_2$ products identified M2 correct equation	2
2(c)(ii)	(E_{cell}) decreases / becomes less positive AND as $[\text{H}^+]$ decreases AND equilibrium shifts to the left OR in alkali the $E_{\text{cell}} = 0.60 - 0.56 = 0.04 \text{ V}$ (working required)	1

Question	Answer	Marks
3(a)	M1 $\Delta S^\circ = (213.8 + 2 \times 248.2) - (237.8 + 3 \times 205.2)$ $\Delta S^\circ = -143.2 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ M2 $\Delta H^\circ = (-393.5 + 2 \times -296.8) - (116.7)$ $\Delta H^\circ = -1103.8 \text{ (kJ mol}^{-1}\text{)}$ M3 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G^\circ = -1103.8 - (298 \times -0.1432) = -1061.1 \text{ to } -1061.4 \text{ (kJ mol}^{-1}\text{) ecf min 3sf}$	3
3(b)	M1 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ AND $\Delta G^\circ = 0$ OR $T = \Delta H^\circ / \Delta S^\circ$ [1] M2 $T = 261.6 \div 0.3655 = 715.7 / 716 / 715 \text{ K min 3sf}$	2

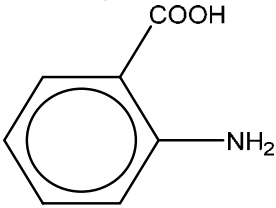
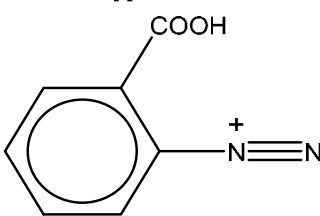
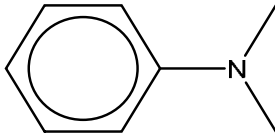
Question	Answer	Marks
4(a)(i)	the (3)d and (4)s (sub-shells/orbitals) are close/similar in energy	1
4(a)(ii)		1

Question	Answer	Marks
4(b)	- precipitation solution A: e.g. NaOH / OH⁻ - observations: (pale) blue ppt. / solid - product: Cu(OH)₂ OR [Cu(OH)₂(H₂O)₄] ecf from A - ligand substitution solution B: e.g. HCl / Cl⁻, NH₃ - observations: dark/deep blue solution (with NH₃) OR yellow solution (with Cl⁻) - product: [Cu(NH₃)₄(H₂O)₂]²⁺ OR [CuCl₄]²⁻ any two [1] any four [2] all six [3]	3
4(c)	M1 (Ag⁺) d-subshell is full / complete OR d¹⁰ OR d-orbitals are full M2 no d-d(*) transition OR no d electrons promoted/excited	2
4(d)	M1 species with two lone pairs (of electrons) M2 that form dative (covalent) / co-ordinate bond(s) to a (central) metal atom / ion	2
4(e)(i)		3
4(e)(ii)	optical AND cis-trans / geometrical	1
4(e)(iii)	trans isomer / trans isomer correctly identified AND dipoles cancel / partial charges cancel / ion dipoles cancel	1

Question	Answer	Marks
5(a)(i)	M1 (using exp 1 and 2) $[\text{NO}] \times 3$, rate $\times 9$ so 2nd order to NO M2 (using exp 1 and 3) $[\text{NO}] \times 2$, $[\text{Cl}_2] \times 4$, rate $\times 16$ so 1st order to Cl_2 OR (using exp 2 and 3) $[\text{NO}] \times 2/3$, $[\text{Cl}_2] \times 4$, rate $\times 1.8$ so 1st order to Cl_2 M3 (rate $=$) $k [\text{NO}]^2 [\text{Cl}_2]$ ecf	3
5(a)(ii)	M1 rate $= k [\text{NO}]^2 [\text{Cl}_2]$ $k = (3.68 \times 10^{-2}) \div (0.025^2 \times 0.015) = 3925.33$ ecf (a)(i) min 2sf M2 $\text{dm}^6 \text{mol}^{-2} \text{min}^{-1}$ ecf (a)(i)	2
5(b)	initiation $\text{NO}_2\text{Cl} \rightarrow \text{Cl}\cdot + \text{NO}_2\cdot$ step 1 $\text{Cl}\cdot + \text{O}_3 \rightarrow \text{ClO}\cdot + \text{O}_2$ step 2 $\text{ClO}\cdot + \text{O}_3 \rightarrow \text{Cl}\cdot + 2\text{O}_2$ Any two [1] all three [2]	2
5(c)	M1 $\text{O}_3 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{O}_2$ ALLOW $\text{O}_3 + \text{NO}_2 \rightarrow \text{NO}_5$ M2 $\text{NO}_3 + \text{NO}_2 \rightarrow \text{N}_2\text{O}_5$ ALLOW $\text{NO}_5 + \text{NO}_2 \rightarrow \text{N}_2\text{O}_5 + \text{O}_2$	2

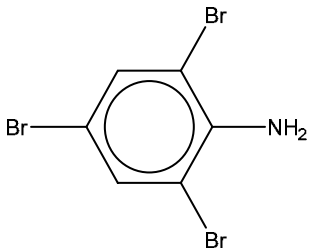
Question	Answer	Marks
6(a)(i)	species / molecules / pair that differ (by the presence or absence) of a H^+ ion / proton	1
6(a)(ii)	$\text{HCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HCOO}^-$	1
6(b)(i)	$K_a = \frac{[\text{H}^+][\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-]}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}]}$	1

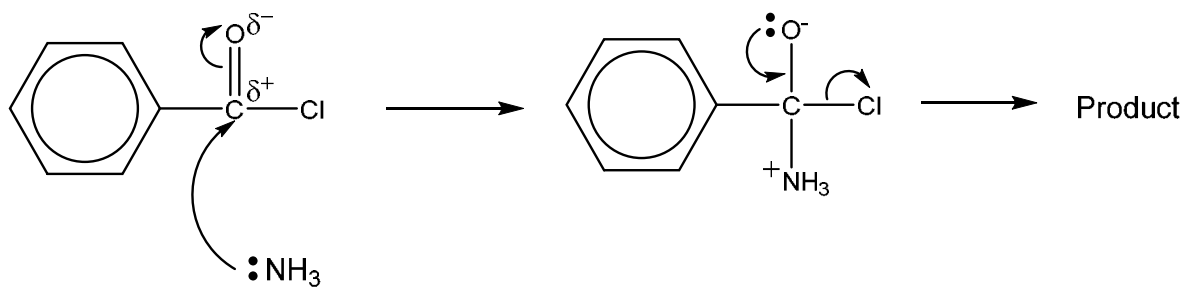
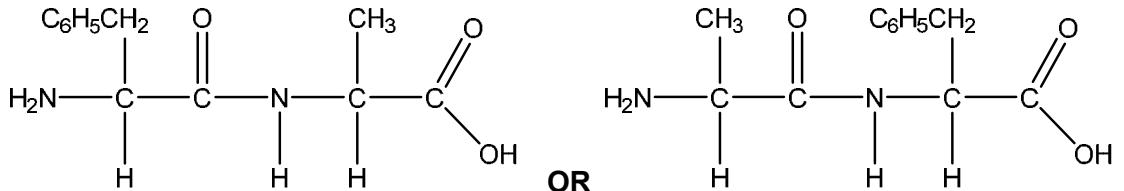
Question	Answer	Marks
6(b)(ii)	M1 $K_a = 10^{-4.82} = 1.51 \times 10^{-5}$ OR $[H^+] = 10^{-3.25} = 5.62 \times 10^{-4}$ M2 $[HA] = (10^{-3.25})^2 \div 1.51 \times 10^{-5} = 0.021 / 0.0209 / 0.02089$ (mol dm ⁻³) ecf min 2sf	2
6(c)(i)	M1 a solution that resists / opposes / minimises changes in pH M2 when small amounts of acid / H ⁺ and base / alkali / OH ⁻ are added to it	2
6(c)(ii)	<u>Method 1</u> M1 $[H^+] = 10^{-5.70}$ OR 2.00×10^{-6} OR 1.99526×10^{-6} M2 moles CH ₃ COONa = $0.400 \times 0.125 = 5.00 \times 10^{-2}$ moles CH ₃ COOH _{eqm} = $(5.00 \times 10^{-2} \times 2.00 \times 10^{-6}) \div 1.78 \times 10^{-5}$ OR 5.60×10^{-3} M3 $[CH_3COOH]_{initial} = 5.60 \times 10^{-3} \times 1000 / 600$ $[CH_3COOH]_{initial} = 0.00933-0.00936$ (mol dm ⁻³) ecf min 2sf <u>Method 2</u> M1 $pK_a = -\log(1.78 \times 10^{-5})$ OR 4.75 M2 $pH = pK_a + \log[B^-] / [HA]$ $5.7 = 4.75 + \log(0.05 / (0.6x))$ $0.95 = \log(0.05 / (0.6x))$ M3 $10^{0.95} = (0.05 / (0.6x))$ $5.348x = 0.05$ $x = 0.00935-0.00937$ (mol dm ⁻³) ecf min 2sf	3
6(d)(i)	$HCOOH \rightarrow CO_2 + 2H^+ + 2e^-$	1
6(d)(ii)	M1 $Q = 3.75 \times 40 \times 60$ OR 9000 C AND use of 96500 OR $1.6 \times 10^{-19} \times 6.02 \times 10^{23}$ M2 moles of oxygen = $9000 \div 386000 = 0.0233$ volume of O ₂ = $0.0233 \times 24000 = 559.6 / 559.8 / 560$ cm ³ ecf min 2sf ALLOW [use of $Q \div (1.6 \times 10^{-19} \times 6.02 \times 10^{23}) = 560.6$ cm ³]	2

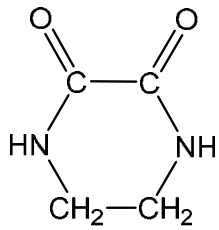
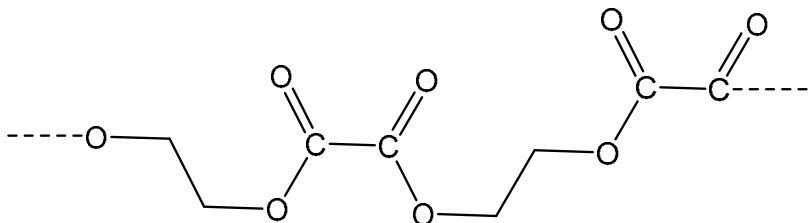
Question	Answer	Marks
7(a)(i)	2-nitrobenzoic acid OR 2-nitrobenzenecarboxylic acid	1
7(a)(ii)	hot / reflux / heat AND (alkaline / acidified / neutral) MnO_4^- / KMnO_4	1
7(a)(iii)	COOH / carboxyl group is electron-withdrawing / electronegative AND 3- and 5- / meta- directing	1
7(b)(i)	Q  R  S 	3
7(b)(ii)	M1 step 1: Fe / Sn , conc. HCl M2 step 2: HNO_2 OR NaNO_2 AND HCl M3 step 1: heat / reflux / hot AND step 2: $\leq 10^\circ\text{C}$	3

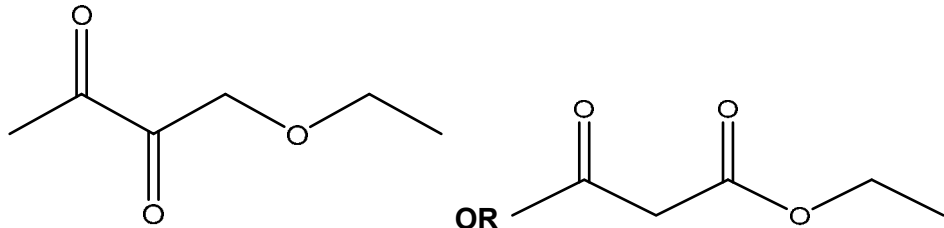
Question	Answer	Marks
8(a)	M1 benzylamine > ammonia > phenylamine M1 M2 Any two for one mark, all three for two marks: (basicity linked to) p orbital of N / lone pair on N AND being able to bond / accept / donate to / coordinate to a proton / H^+ (benzylamine) R / alkyl / CH_2 group AND is electron donating / positive inductive effect / has + I effect (phenylamine) p orbital of N / lone pair on N is overlaps / incorporated / delocalised in the ring / π-bond system	3

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Question	Answer	Marks
8(b)(i)	M1 white ppt. M2 structure 	2
8(b)(ii)	M1 lone pair / p-orbital / electrons on the nitrogen / NH_2 AND overlap / delocalised / incorporated AND with the (π-electrons) ring / π system M2 increasing its electron density (of the ring) OR it can polarise the electrophile / Br_2 better	2
8(c)	lone pair / p-orbital on N is delocalised AND into $\text{C}=\text{O}$ group / across the two electronegative O and N	1

Question	Answer	Marks
8(d)	 M1 / M2 any two for one mark, all four for two marks: • lone pair on N • correct arrow from lone pair N to C (of C=O) • correct dipole on C=O • correct arrow from the C=O bond to O atom M3 correct intermediate M4 arrow from O⁽⁻⁾ to C–O bond AND arrow from C–Cl bond to Cl ALLOW arrow from anywhere on O⁻ to C–O bond	4
8(e)(i)	pH at which a molecule has no overall charge / is neutral / exist as a zwitterion	1
8(e)(ii)	<chem>C6H5CH2CH(NH2)COO^-</chem>	1
8(f)	 M1 correct peptide bond displayed (there must be a saturated carbon attached to either side of the peptide group) M2 rest of the dipeptide correct	2

Question	Answer	Marks
9(a)	due to the electron-withdrawing effect/electronegative / –I effect of chlorine AND stabilising the anion / carboxylate ion OR weakening the O-H bond	1
9(b)(i)	$(\text{COOH})_2 + 2\text{SOCl}_2 \rightarrow (\text{COCl})_2 + 2\text{HCl} + 2\text{SO}_2$	1
9(b)(ii)	CO₂ [1]  [1]	2
9(b)(iii)	 M1 one correct repeat unit (within their structure) M2 the rest of the structure correct ecf on one incorrect monomer used [If structure partly or fully skeletal: continuation bonds must be dashed / wavy / different or have through brackets]	2
9(c)(i)	CHI ₃ / triiodomethane	1

Question	Answer				Marks
9(c)(ii)	chemical shift (δ)	splitting pattern	number of ^1H atoms responsible for the peak	number of protons on adjacent carbon atoms	4
	1.15	triplet	3	2	
	2.25	singlet	3	0	
	3.60	singlet	2	0	
	3.95	quartet / quadruplet	2	3	
	mark as any three [1] any six [2] any nine [3] all twelve [4]				
9(c)(iii)					1

Cambridge International AS & A Level

CHEMISTRY**9701/43**

Paper 4 A Level Structured Questions

May/June 2024**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 International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2024 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

This document consists of **18** printed pages.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptions for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1 Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.

2 The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.

3 Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).

4 The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.

5 'List rule' guidance

For questions that require ***n*** responses (e.g. State **two** reasons ...):

- The response should be read as continuous prose, even when numbered answer spaces are provided.
- Any response marked *ignore* in the mark scheme should not count towards ***n***.
- Incorrect responses should not be awarded credit but will still count towards ***n***.
- Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response.
- Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

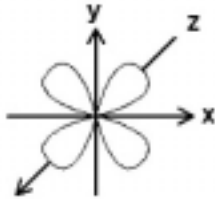
Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

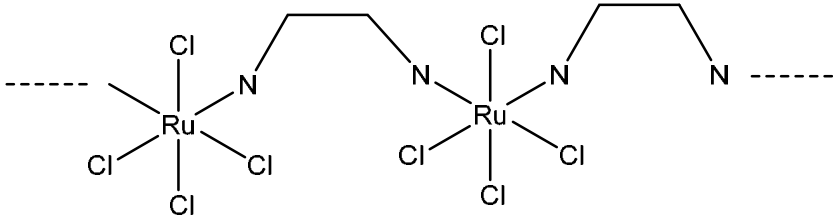
7 Guidance for chemical equations

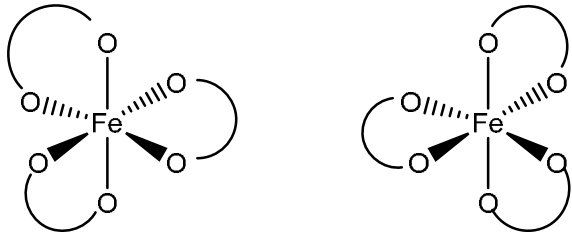
Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

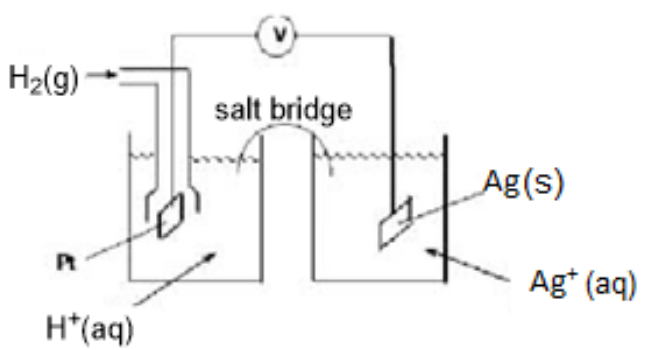
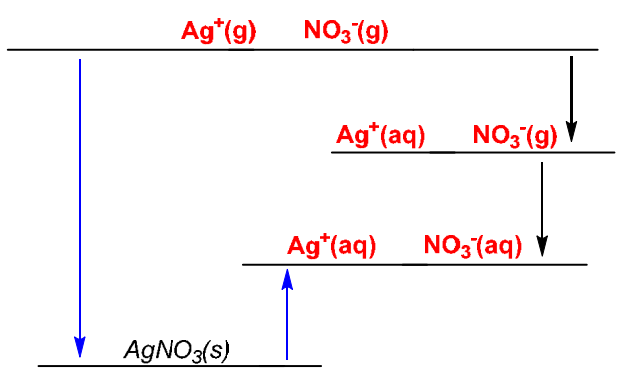
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Question	Answer	Marks
1(a)(i)	M1 strontium > calcium > magnesium M2 ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative M3 ΔH_{latt} changes more M4 ΔH_{sol} becomes more exothermic / more negative	4
1(a)(ii)	pH increases as the concentration of $[\text{OH}^-]$ ions increases	1
1(b)	M1 $[\text{H}^+] = 10^{-12.2}$ OR 6.31×10^{-13} M2 $[\text{OH}^-] = 0.0158 \text{ mol dm}^{-3}$ ecf M3 $[\text{Ba}(\text{OH})_2] = 0.01585 \div 2 = 7.92$ ecf M4 mol of $\text{Ba}(\text{OH})_2 = 0.00792 \div 4 = 1.98 \times 10^{-3}$ mass $\text{Ba}(\text{OH})_2 = 0.339 \text{ g}$ ecf	4
1(c)(i)	$K_{\text{sp}} = [\text{Fe}^{2+}][\text{OH}^-]^2$	1
1(c)(ii)	M1 $K_{\text{sp}} = 4 \times (5.85 \times 10^{-6})^3 = 8.01 \times 10^{-16}$ M2 $\text{mol}^3 \text{ dm}^{-9}$	2

Question	Answer	Marks
2(a)(i)	element which forms one or more stable ion with incomplete d orbitals	1
2(a)(ii)	they have vacant d orbitals that are energetically accessible	1
2(b)(i)	orbitals of the same energy	1
2(b)(ii)		1

Question	Answer	Marks
2(c)	M1 $2\text{AgNO}_3 + 2\text{NaOH} \rightarrow \text{Ag}_2\text{O} + 2\text{NaNO}_3 + \text{H}_2\text{O}$ OR $2\text{Ag}^+ + 2\text{OH}^- \rightarrow \text{Ag}_2\text{O} + \text{H}_2\text{O}$ M2 $\text{Ag}_2\text{O} + 4\text{NH}_3 + \text{H}_2\text{O} \rightarrow 2[\text{Ag}(\text{NH}_3)_2]\text{OH}$ OR $\text{Ag}^+ + 2\text{NH}_3 + \text{OH}^- \rightarrow [\text{Ag}(\text{NH}_3)_2]\text{OH}$	2
2(d)	M1 bond angle H–N–Ag is 109.5° M2 shape is linear AND bond angle for N–Ag–N is 180°	2
2(e)	M1 $\text{Ag}_2\text{O} + \text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{Ag} + 2\text{OH}^-$ M2 $\text{Zn} + 2\text{OH}^- \rightarrow \text{Zn}(\text{OH})_2 + 2\text{e}^-$	2
2(f)	For example:  M1 presence of <i>dps</i> ligand bonded to two Ru M2 the rest of the structure correct	2

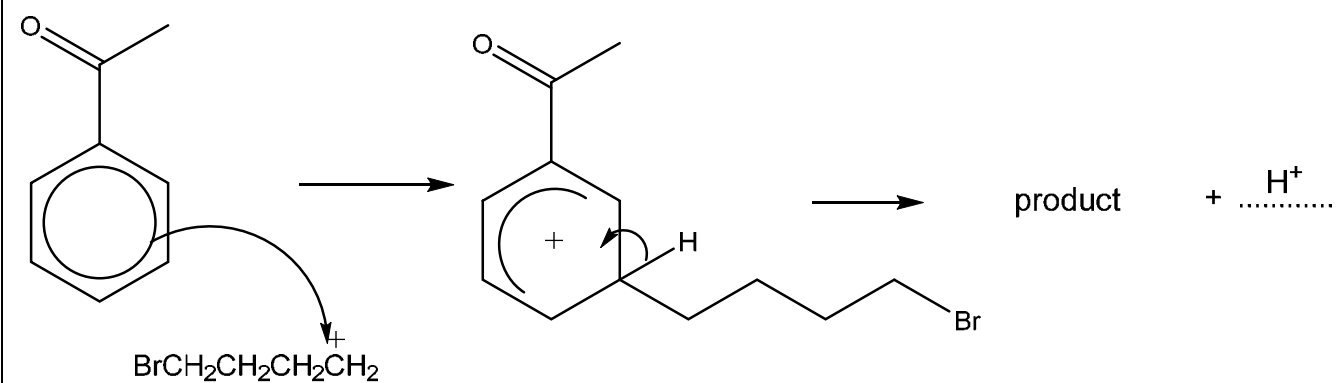
Question	Answer	Marks
3(a)	$\text{Li}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O} \rightarrow \text{Li}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}$	1
3(b)	M1 CaC_2O_4 AND Ca^{2+} has a smaller ionic radius / Ca^{2+} has a higher charge density M2 anion / $\text{C}_2\text{O}_4^{2-}$ becomes more polarised / distorted	2
3(c)	M1 d orbital(s) of different energy / d-d splitting occurs M2 electron(s) promoted / excited M3 light is absorbed AND colour seen is complementary	3
3(d)	$2\text{K}_3\text{Fe}(\text{C}_2\text{O}_4)_3 \rightarrow 2\text{K}_2\text{Fe}(\text{C}_2\text{O}_4)_2 + \text{K}_2\text{C}_2\text{O}_4 + 2\text{CO}_2$	1
3(e)		2
3(f)	M1 $\text{HC}_2\text{O}_4^- + \text{H}^+ \rightarrow \text{H}_2\text{C}_2\text{O}_4$ M2 $\text{HC}_2\text{O}_4^- + \text{OH}^- \rightarrow \text{C}_2\text{O}_4^{2-} + \text{H}_2\text{O}$	2
3(g)	M1 $2\text{C}_2\text{O}_4^{2-} + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{CO}_2(\text{g}) + 4\text{OH}^-(\text{aq})$ M2 $E_{\text{cell}} = 0.40 - (-0.59) = 0.99 \text{ V}$	2

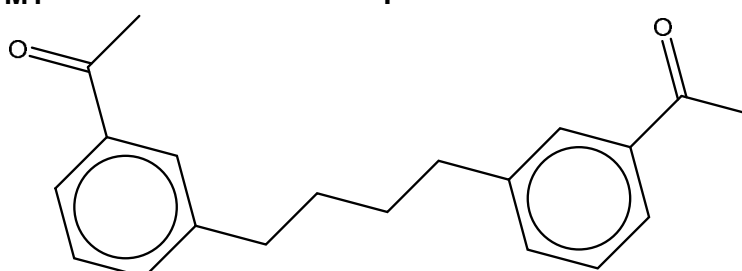
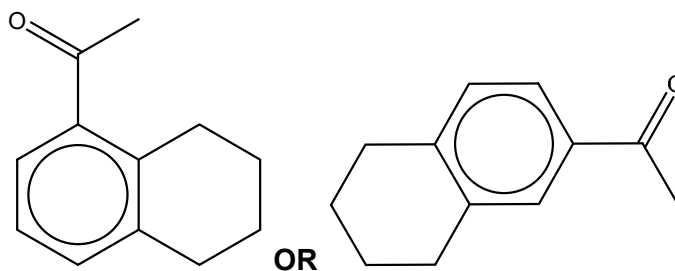
Question	Answer	Marks
4(a)	M1 voltage of a half-cell compared to SHE M2 1 mol dm ⁻³ AND 101 kPa AND 298 K	2
4(b)(i)	 M1 Pt Ag Ag⁺ M2 gas delivery system H₂ H⁺ M3 voltmeter salt bridge wiring Pt to V to Ag	3
4b(ii)	<i>E</i> value would be more negative AND shifts Ag ⁺ (+ e ⁻) ⇌ Ag to the left	1
4(c)	enthalpy change when one mole of a solute dissolves in water	1
4(d)(i)	 M1 two arrows in blue M2 correct species in red with all state symbols	2

Question	Answer	Marks
4(d)(ii)	$\Delta H_{\text{latt}} = -811.6 \text{ (kJ mol}^{-1}\text{)}$	1
4(e)	M1 $\text{Mg(NO}_3)_2(\text{s})$, $\text{NaNO}_3(\text{s})$, $\text{RbNO}_3(\text{s})$ M2 Mg^{2+} has a higher charge than Na^+ OR Rb^+ AND Na^+ has a smaller radius than Rb^+ M3 correct statement relating magnitude of LE to attraction between ions OR strength of ionic bonds	3

Question	Answer	Marks
5(a)(i)	tangent drawn at $t = 0$ AND gradient of tangent calculated at $t = 0$ answer between 0.016 to 0.040	1
5(a)(ii)	$[\text{I}^-]$ stays constant / $[\text{I}^-]$ does not change OR the overall order is one under these conditions	1
5(b)	M1 equation 1: $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$ M2 equation 2: $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$	2
5(c)	the rate constant and rate of reaction 1 will both increase	1
5(d)	$k = 0.693 \div t_{1/2}$ $t_{1/2} = 0.693 \div 0.0158 = 43.9 \text{ s}$	1
5(e)	$\text{NO} + \text{Br}_2 \rightarrow \text{NOBr}_2$ OR $\text{NO} + \text{Br}_2 \rightarrow \text{NOBr} + \text{Br}$ $\text{NOBr}_2 + \text{NO} \rightarrow 2\text{NOBr}$ OR $\text{Br} + \text{NO} \rightarrow \text{NOBr}$ M1 two equations adding up to the overall equation M2 step 1 has one NO and one Br_2 only and is identified as slow step	2

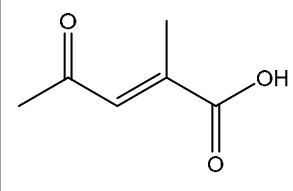
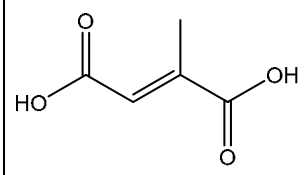
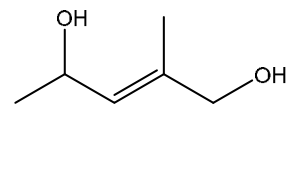
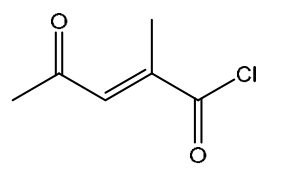
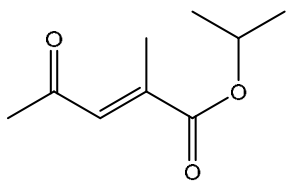
Question	Answer	Marks																
6(a)(i)	ratio of the concentrations of solute in two solvents	1																
6(a)(ii)	M1 $10.5 = (y \div 25) \div ((0.74 - y) \div 40)$ M2 $y = 0.642 \text{ g}$	2																
6(b)	<table border="1"><thead><tr><th></th><th>sp</th><th>sp²</th><th>sp³</th></tr></thead><tbody><tr><td>Kekulé benzene</td><td>0</td><td>6</td><td>0</td></tr><tr><td>Dewar benzene</td><td>0</td><td>4</td><td>2</td></tr><tr><td>Ladenburg benzene</td><td>0</td><td>0</td><td>6</td></tr></tbody></table> M1 row 1 and 2 correct M2 row 3 correct		sp	sp ²	sp ³	Kekulé benzene	0	6	0	Dewar benzene	0	4	2	Ladenburg benzene	0	0	6	2
	sp	sp ²	sp ³															
Kekulé benzene	0	6	0															
Dewar benzene	0	4	2															
Ladenburg benzene	0	0	6															
6(c)	M1 120° AND hexagonal/trigonal planar M2 C-C has π -bonds and σ -bonds AND C-H have σ -bonds only	2																
6(d)	bond strain OR ring strain	1																
6(e)	<table border="1"><thead><tr><th></th><th>peaks</th></tr></thead><tbody><tr><td>Dewar benzene</td><td>2</td></tr><tr><td>Ladenburg benzene</td><td>1</td></tr><tr><td>delocalised benzene</td><td>1</td></tr></tbody></table>		peaks	Dewar benzene	2	Ladenburg benzene	1	delocalised benzene	1	1								
	peaks																	
Dewar benzene	2																	
Ladenburg benzene	1																	
delocalised benzene	1																	
6(f)(i)	$\text{BrCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{FeBr}_3 \rightarrow \text{BrCH}_2\text{CH}_2\text{CH}_2\text{CH}_2^+ + \text{FeBr}_4^-$	1																

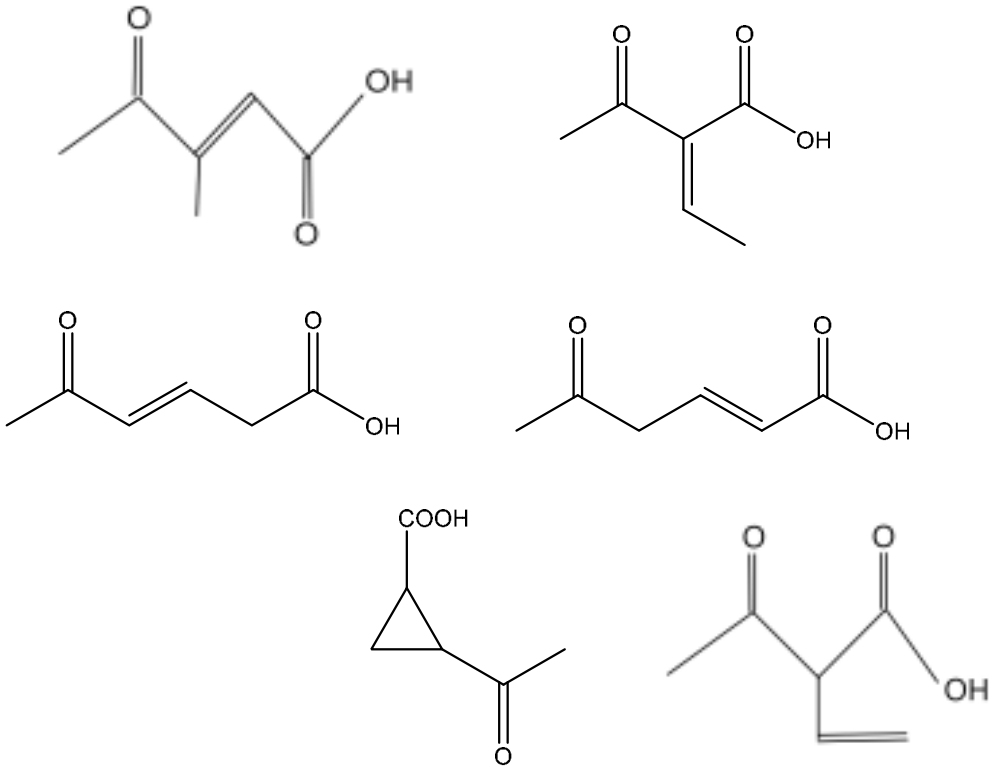
Question	Answer	Marks
6(f)(ii)	 M1 curly arrow from inside the hexagon towards C⁺ M2 structure of the intermediate M3 curly arrow from C–H bond into the ring AND H⁺	3

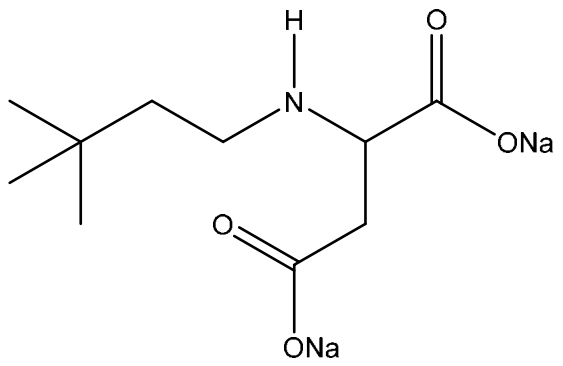
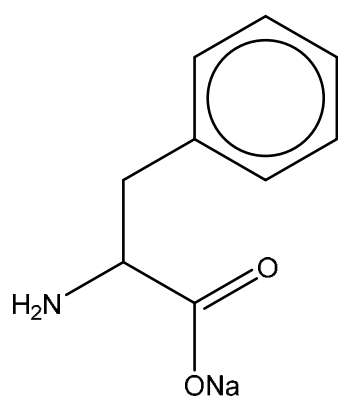
Question	Answer	Marks
6(f)(iii)	M1 Y  M2 Z  OR	2

Question	Answer	Marks
7(a)	methyl pentanoate	1
7(b)(i)	time between injection and detection	1
7(b)(ii)	29.5%	1

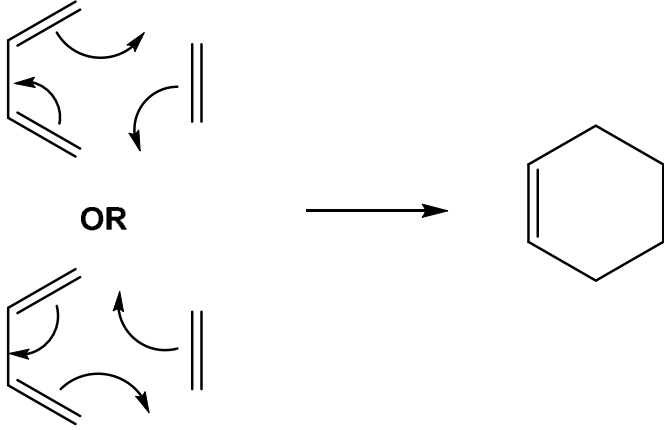
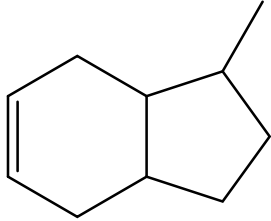
Question	Answer			Marks
7(c)(i)	ester	number of peaks seen in proton (¹ H) NMR	number of peaks seen in carbon-13 NMR	2
	B	5	6	
	C	4	5	
	M1 row 1 correct M2 row 2 correct			
7(c)(ii)	A and B			1

Question	Answer	Marks
7(d)	F, C₆H₈O₃  G CHI₃ H  alkaline I₂(aq) ↓ SOCl₂ ↘ LiAlH₄ ↓ J, C₆H₁₂O₂  K, C₆H₈O₂Cl  propan-2-ol ↓ L  one mark for each structure: F, G, H, J, K and L	6

Question	Answer	Marks
7(d)	six alternatives for F 	

Question	Answer	Marks
8(a)(i)	two	1
8(a)(ii)	amide amine ester carboxylic acid / carboxyl any two [1] all four [2]	2
8(b)(i)	M1 hydrolysis M2 acid–base	2
8(b)(ii)	  $\text{H}_3\text{C}-\text{OH}$ one mark for each structure	3

Question	Answer	Marks
9(a)(i)	$\text{C}_6\text{H}_5\text{OH} + \text{Na} \rightarrow \text{C}_6\text{H}_5\text{ONa} + \frac{1}{2}\text{H}_2$	1
9(a)(ii)	both structures for one mark	1
9(b)	M1 correct dipole AND curly arrow from inside the hexagon to the carbon atom M2 structure of the intermediate M3 curly arrow from C-H bond into the ring AND H^+	3

Question	Answer	Marks
9(c)(i)	 OR All three curly arrows for one mark	1
9(c)(ii)		1