



Cambridge International AS & A Level

CHEMISTRY

9701/41

Paper 4 A Level Structured Questions

May/June 2023

MARK SCHEME

Maximum Mark: 100

Published

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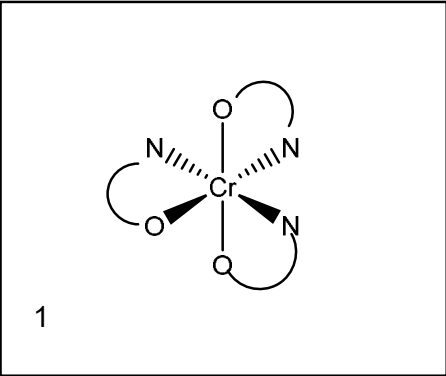
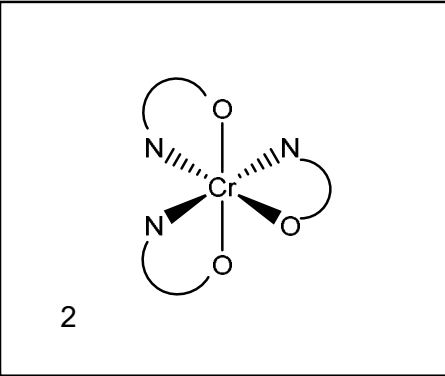
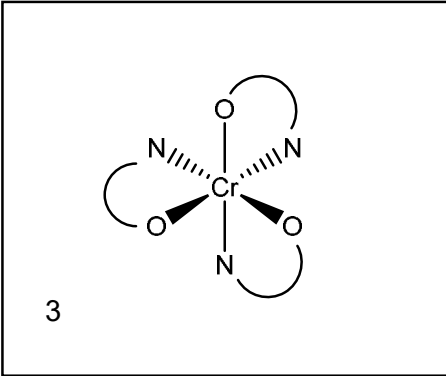
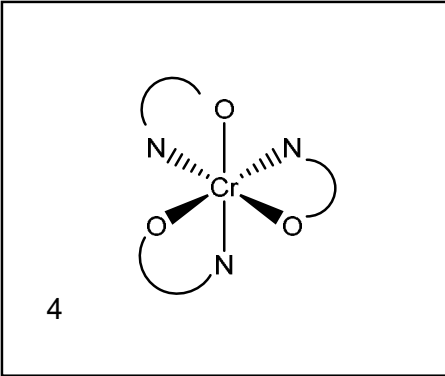
Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

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)	M1 increases (down the group) M2 radius / size of (cat)ion / M^{2+} increases M3 less polarisation / distortion of anion / nitrate ion / NO_3^- OR less weakening of N–O / N=O (bond)	3															
1(b)	$Cu(NO_3)_2 \rightarrow CuO + 2NO_2 + \frac{1}{2}O_2$	1															
1(c)	<table border="1"> <thead> <tr> <th>copper-containing species</th><th>formula of copper-containing species formed</th><th>colour copper-containing formed</th></tr> </thead> <tbody> <tr> <td>A</td><td>$[Cu(H_2O)_6]^{2+}$</td><td>(pale) blue</td></tr> <tr> <td>B</td><td>$Cu(H_2O)_4(OH)_2$ or $Cu(OH)_2$</td><td>(pale) blue</td></tr> <tr> <td>C</td><td>$[Cu(NH_3)_4(H_2O)_2]^{2+}$</td><td>dark blue</td></tr> <tr> <td>D</td><td>$CuCl_4^{2-}$</td><td>yellow</td></tr> </tbody> </table> Two correct for one mark, four correct for two marks, six correct for three marks, eight correct for four marks.	copper-containing species	formula of copper-containing species formed	colour copper-containing formed	A	$[Cu(H_2O)_6]^{2+}$	(pale) blue	B	$Cu(H_2O)_4(OH)_2$ or $Cu(OH)_2$	(pale) blue	C	$[Cu(NH_3)_4(H_2O)_2]^{2+}$	dark blue	D	$CuCl_4^{2-}$	yellow	4
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1(d)(i)	M1 (a species) that donates more than two lone pairs M2 to form dative / coordinate bonds to a metal atom or ion	2															
1(d)(ii)	six atoms circled, 2N and 4O from different CO_2^-	1															
1(d)(iii)	the number of co-ordinate bonds being formed by the metal ion	1															
1(d)(iv)	ligand exchange	1															
1(d)(v)	$[FeEDTA]^- > [CrEDTA]^- > [PbEDTA]^{2-}$ highest conc ⁿ lowest conc ⁿ AND K_{stab} of $[FeEDTA]^-$ is highest	1															

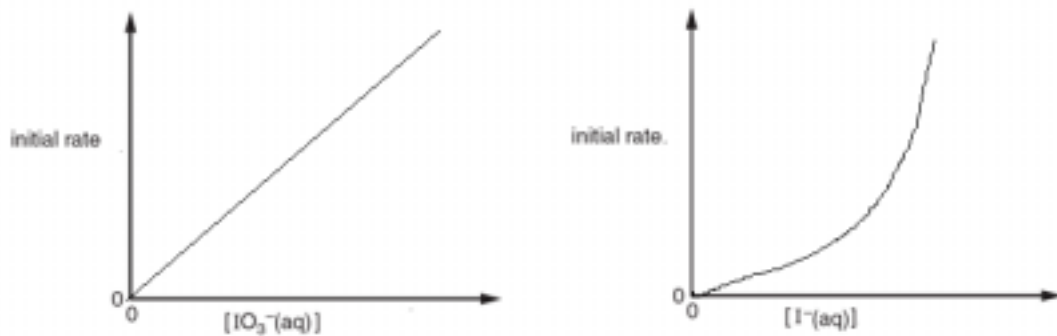
Question	Answer	Marks
1(e)	M1 moles of $\text{Cr}^{3+} = 2.096 \times 10^{-4}$ in 25.0 cm^3 M2 moles of $\text{Cr}^{3+} = 8.384 \times 10^{-4}$ (in 100.0 cm^3) moles of $\text{Cr}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O} = 8.384 \times 10^{-4} / 2 = 4.192 \times 10^{-4}$ M3 M_r of $\text{Cr}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O} = 0.2550 / 4.192 \times 10^{-4} = 608.3$ $n = (608.3 - 392.3) / 18 = 12$	3
1(f)	M1 ΔE is different M2 different frequency (of light) is absorbed	2

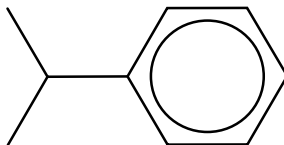
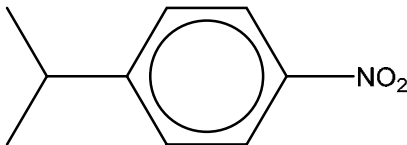
Question	Answer	Marks
2(a)	geometrical / cis-trans AND optical	1
2(b)	square planar	1

Question	Answer	Marks
2(c)	 1  2  3  4 Two correct for one mark, three correct for two marks, four correct for three marks.	3

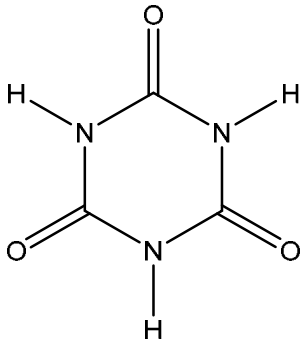
Question	Answer	Marks
2(d)(i)	M1 two correct curly arrows M2 correct dipole M3 correct structure of intermediate	3
2(d)(ii)	use an excess of ammonia OR limiting amount of oxirane	1
2(d)(iii)	M1 M2 elimination / dehydration / condensation	2

Question	Answer	Marks
3(a)(i)	the power to which the concentration of a reactant is raised in the rate equation	1

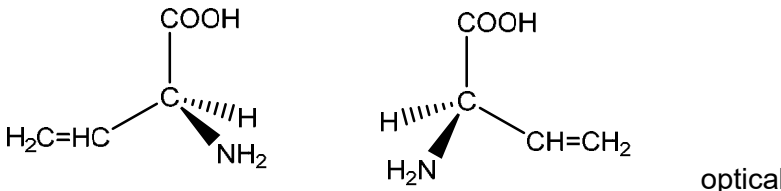
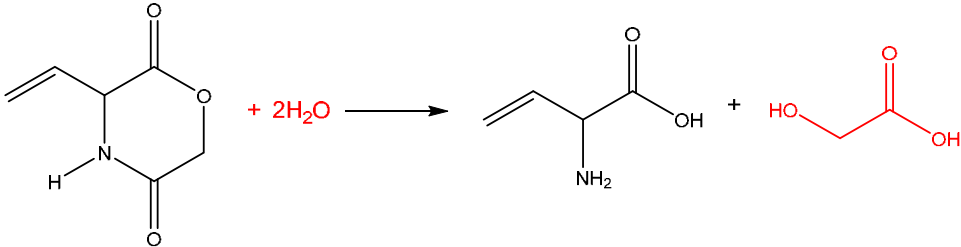
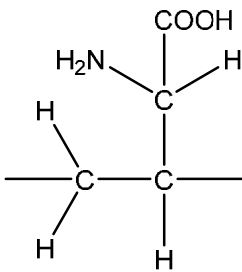
Question	Answer	Marks								
3(a)(ii)	<table><tr><td>the order of reaction with respect to $[\text{IO}_3^-]$</td><td>1</td></tr><tr><td>the order of reaction with respect to $[\text{H}^+]$</td><td>2</td></tr><tr><td>the order of reaction with respect to $[\text{I}^-]$</td><td>2</td></tr><tr><td>the overall order of reaction</td><td>5</td></tr></table> All correct for one mark	the order of reaction with respect to $[\text{IO}_3^-]$	1	the order of reaction with respect to $[\text{H}^+]$	2	the order of reaction with respect to $[\text{I}^-]$	2	the overall order of reaction	5	1
the order of reaction with respect to $[\text{IO}_3^-]$	1									
the order of reaction with respect to $[\text{H}^+]$	2									
the order of reaction with respect to $[\text{I}^-]$	2									
the overall order of reaction	5									
3(a)(iii)		1								
3(a)(iv)	M1 $k = \text{rate} / [\text{I}^-]^2 [\text{IO}_3^-] [\text{H}^+]^2 = (4.20 \times 10^{-2}) / (0.025^2 \times 0.04 \times 0.015^2) = 7.47 \times 10^6$ M2 units = $\text{mol}^{-4} \text{dm}^{12} \text{min}^{-1}$	2								
3(a)(v)	$0.0709 = k \times 0.12 \times [\text{H}^+]^2 \times 0.0125^2$ $[\text{H}^+] = 2.25 \times 10^{-2}$	1								
3(a)(vi)	$x = 10^2 / 1 = 100$	1								
3(b)	M1 step 1 $\text{Fe}^{3+} + \text{I}^- \rightarrow \text{FeI}^{2+}$ M2 step 2 $\text{FeI}^{2+} + \text{I}^- \rightarrow \text{Fe}^{2+} + \text{I}_2^-$ OR $\text{FeI}^{2+} + \text{I}^- \rightarrow \text{FeI}_2^+$ AND slowest step = step 2 M3 step 3 $\text{Fe}^{3+} + \text{I}_2^- \rightarrow \text{Fe}^{2+} + \text{I}_2$ OR $\text{FeI}_2^+ + \text{Fe}^{3+} \rightarrow 2\text{Fe}^{2+} + \text{I}_2$	3								

Question	Answer	Marks						
4(a)	M1 bond angle = 120° AND carbons are sp^2 M2 σ bonds are formed by end-on-end / head on / head to head / linear overlap of orbitals M3 π bonds are formed by sideways / lateral overlap of p orbitals	3						
4(b)(i)	X  [1] Y  [1]	2						
4(b)(ii)	M1 step 1 $(CH_3)_2CHBr$ and $FeBr_3 / AlBr_3$ M2 step 2 conc HNO_3 and conc H_2SO_4 M3 step 3 Sn and conc HCl	3						
4(c)	3,4,5-trimethylphenylamine	1						
4(d)	<table border="1" style="margin-left: auto; margin-right: auto;"><thead><tr><th>compound</th><th>number of peaks observed</th></tr></thead><tbody><tr><td style="text-align: center;">W</td><td style="text-align: center;">6</td></tr><tr><td style="text-align: center;">Z</td><td style="text-align: center;">6</td></tr></tbody></table> Both correct for one mark	compound	number of peaks observed	W	6	Z	6	1
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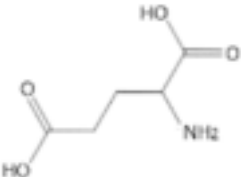
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5(a)(i)	palladium, platinum and rhodium / Pt, Pd, Rh	1
5(a)(ii)	a catalyst in a different state / phase to the reactants / substrate	1
5(b)(i)	measure / degree of disorder / randomness of a system OR the number of possible arrangements of the particles and the energy in a system	1

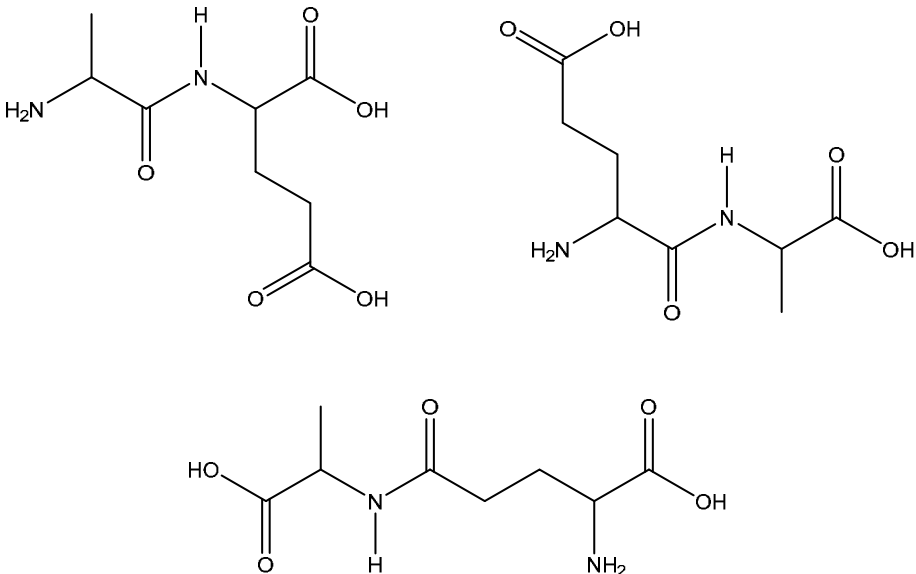
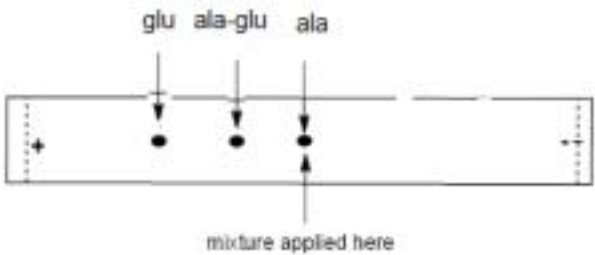
Question	Answer	Marks
5(b)(ii)	M1 $\Delta S^\circ = (192.8) + 213.8 - 238.2 - 188.8$ $\Delta S^\circ = -20.4 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ M2 $\Delta H^\circ = (-45.9) + (-393.5) - (-101.7) - (-241.8)$ $\Delta H^\circ = -95.9 \text{ (kJ mol}^{-1}\text{)}$ M3 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ M4 $\Delta G^\circ = -95.9 - (298 \times -0.0204) = -89.8 \text{ (kJ mol}^{-1}\text{)}$	4
5(c)	$4(\text{NH}_2)_2\text{CO} + 6\text{NO}_2 \rightarrow 7\text{N}_2 + 8\text{H}_2\text{O} + 4\text{CO}_2$	1
5(d)		1
5(e)(i)	$\text{p}K_a = -\log K_a$ AND $\text{pH} = -\log [\text{H}^+]$	1
5(e)(ii)	M1 $[\text{H}^+] = \sqrt{0.120 \times 2.00 \times 10^{-4}} = 4.89(317) \times 10^{-3}$ M2 $\text{pH} = 2.31$	2
5(e)(iii)	$\% \text{ ionisation} = 4.89 \times 10^{-3} / 0.12 \times 100 = 4.1\%$	1

Question	Answer	Marks
6(a)(i)	carboxylic acid, amine, alkene Two correct for one mark, three correct for two marks	2

Question	Answer	Marks
6(a)(ii)	 optical Two correct for one mark, three correct for two marks.	2
6(b)(i)		1
6(b)(ii)	hydrolysis	1
6(c)(i)		1

Question	Answer	Marks
6(c)(ii)	M1 amide linkage displayed correctly M2 rest of the structure correct	2
6(c)(iii)	condensation polymers can be hydrolysed	1

Question	Answer	Marks
7(a)	M1 diethylamine > ethylamine > ethanamide <u>explanation</u> M2 basicity linked to ability of lone pair on N to accept a proton / H ⁺ M3 electron donating ethyl group increases electron density on N / makes lone pair more available for donation M4 lone pair of electrons on N is delocalised into C=O group	4
7(b)(i)	M1 resists change in pH M2 when a small amount of acid or alkali is added	2
7(b)(ii)	M1 $\text{H}_2\text{NCH}(\text{CH}_3)\text{COOH} + \text{H}^+ \rightarrow \text{H}_3\text{N}^+\text{CH}(\text{CH}_3)\text{COOH}$ M2 $\text{H}_2\text{NCH}(\text{CH}_3)\text{COOH} + \text{OH}^- \rightarrow \text{H}_2\text{NCH}(\text{CH}_3)\text{COO}^- + \text{H}_2\text{O}$	2
7(c)(i)		1

Question	Answer	Marks
7(c)(ii)	 M1 displayed peptide bond (between two amino acids) M2 rest of the structure correct	2
7(d)	 M1 relative positions of the spots drawn M2 Ala is a zwitterion / neutral / at its isoelectric point (at pH 6) OR ala-glu AND glu are negatively charged M3 glu has lower M_r OR ala-glu has higher M_r	3

Question	Answer				Marks
7(e)(i)					3
	chemical shift (δ)	splitting pattern	number of ^1H atoms responsible for the peak	number of protons on the adjacent carbon(s)	
	1.4	doublet	3	1	
	3.5	singlet	3	0	
	4.0	quartet	1	3	
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7(e)(ii)	one extra peak for NH_2 group seen in CDCl_3 , AND H exchanged for D in D_2O				1

Question	Answer				Marks																
8(a)	<table><tr><td>energy change</td><td>always positive</td><td>always negative</td><td>either negative or positive</td></tr><tr><td>lattice energy</td><td></td><td>✓</td><td></td></tr><tr><td>enthalpy of hydration</td><td></td><td>✓</td><td></td></tr><tr><td>enthalpy of solution</td><td></td><td></td><td>✓</td></tr></table> All correct for one mark				energy change	always positive	always negative	either negative or positive	lattice energy		✓		enthalpy of hydration		✓		enthalpy of solution			✓	1
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8(b)	The energy / enthalpy change when 1 mole of gaseous ions is dissolved in water				1																
8(c)(i)	M1 use of correct six numbers only 682.8 178.2 590 1145 111.9 324.6 M2 2× used correctly with Br (2 × 111.9 and 2 × 324.6) M3 correct signs and evaluation to give −2170.6 kJ mol^{−1}				3																

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8(c)(ii)	M1 use of correct three numbers only 2170.6 103.1 and 1579 M2 correct signs & evaluation -347 kJ mol^{-1}	2
8(c)(iii)	M1 Br^- has a smaller ionic radius M2 Br^- has stronger attractive forces with water molecules	2



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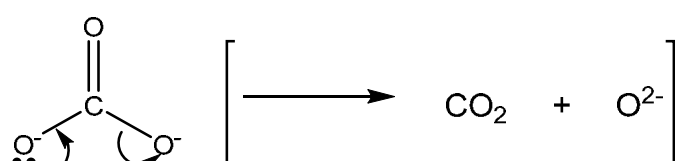
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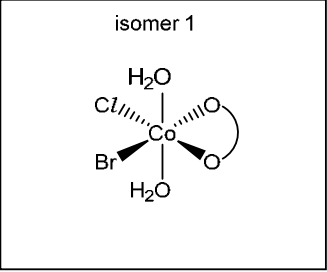
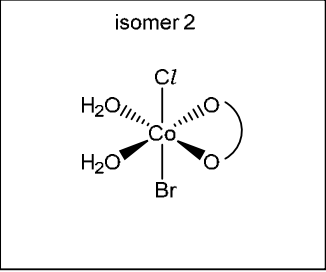
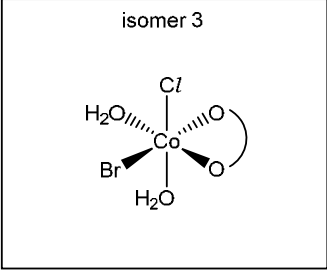
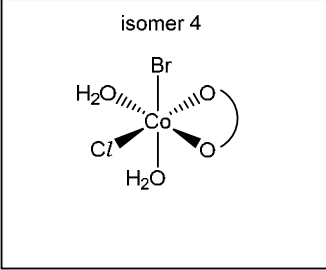
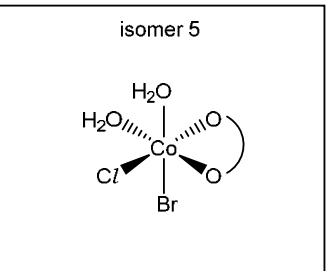
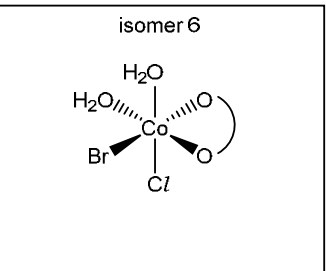
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Question	Answer	Marks
1(a)(i)	 ARROW 1 starts from O⁻ to the C–O bond AND ARROW 2 starts at the C–O bond to other O⁻ ion	1
1(a)(ii)	M1 increases (down the group) M2 (cat)ionic radius / ion size increases (down the group) OR charge density of M²⁺ decreases M3 less polarisation / distortion of anion / carbonate ion / CO₃⁽²⁾⁻	3
1(b)(i)	M1 energy released when one mole of a ionic solid / compound is formed M2 from gas (phase) ion(s) / gaseous ion(s) (under standard conditions)	2
1(b)(ii)	(ΔH_{decomp} / it) becomes more positive/less negative (down the group) - size /(ionic) radii of oxide ion is smaller (than carbonate ion) ORA - so ΔH_{latt} of oxides becomes ORA less exothermic faster OR less negative faster OR changes more OR changes faster Any two [1], all three [2]	2
1(c)(i)	$2\text{MnO}_4^- + 6\text{H}^+ + 5\text{SO}_3^{2-} \rightarrow 2\text{Mn}^{2+} + 3\text{H}_2\text{O} + 5\text{SO}_4^{2-}$	1

Question	Answer	Marks
1(c)(ii)	M1 M2 any two bullets [1] or all four [2] - moles $\text{MnO}_4^- = 0.025 \times 22.40 / 1000 = 5.6 \times 10^{-4}$ - moles $\text{SO}_3^{2-} = 5.6 \times 10^{-4} \times 5 / 2 = 1.4 \times 10^{-3}$ (in 25 cm³) ecf from (c)(i) and bullet 1 - moles $\text{SO}_3^{2-} = 1.4 \times 10^{-2}$ (in 250 cm³) ecf bullet 2 - mass $\text{K}_2\text{SO}_3 = 1.4 \times 10^{-2} \times 158.3 = 2.2162 \text{ g}$ ecf bullet 3 OR moles K_2SO_3 (if 100% pure) = $3.40 \div 158.3 = 0.02148$ M3 % purity = $100 \times 2.2162 / 3.40 = 65.2 / 65.3 \%$ ecf min 2sf OR % purity = $100 \times 0.014 / 0.02148 = 65.2 / 65.3 \%$	3
1(d)	S(α) tetrahedral	1

Question	Answer	Marks
2(a)	<i>Any two from:</i> - they have variable / multiple oxidation states OWTTE - they behave as catalysts - they form complex ions / complexes - they form coloured compounds/ions	1
2(b)(i)	(is a molecule or ion formed by a central) metal atom / metal ion bonded / surrounded by (one or more) ligands	1

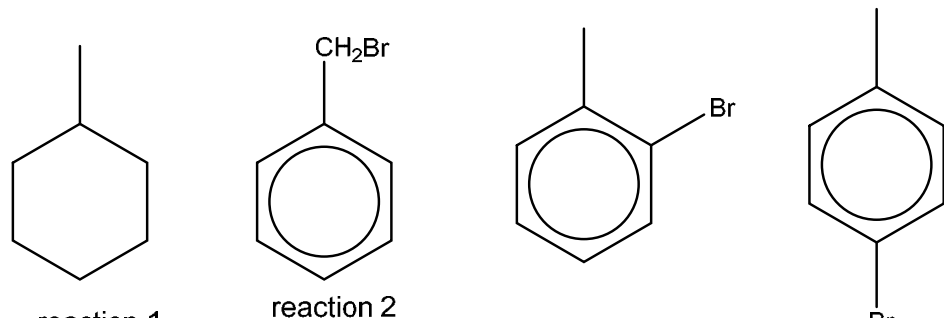
Question	Answer				Marks
2(b)(ii)					4
	reagent added	formula of species formed	colour / state of species formed	type of reaction	
	an excess of $\text{NH}_3(\text{aq})$	$[\text{Co}(\text{NH}_3)_6]^{2+}$	brown solution ALLOW <i>yellow-brown</i> solution	ligand exchange	
	an excess of concentrated HCl	$[\text{CoCl}_4]^{2-}$	blue solution	ligand exchange	
	$\text{NaOH}(\text{aq})$	$\text{Co}(\text{OH})_2$ OR $\text{Co}(\text{OH})_2(\text{H}_2\text{O})_4$	blue ppt. ALLOW pink ppt	precipitation	
	formula and colour / state: any two [1], any four [2], all six [3] type of reaction: all three correct [1]				
2(c)(i)	M1 (a species) that donates / uses two lone pairs M2 to form a two dative / coordinate bond to a metal atom / metal ion				2

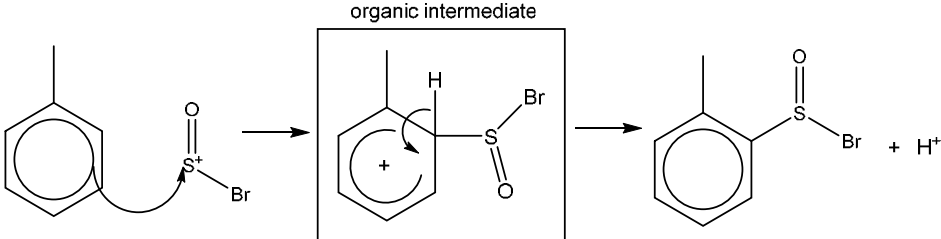
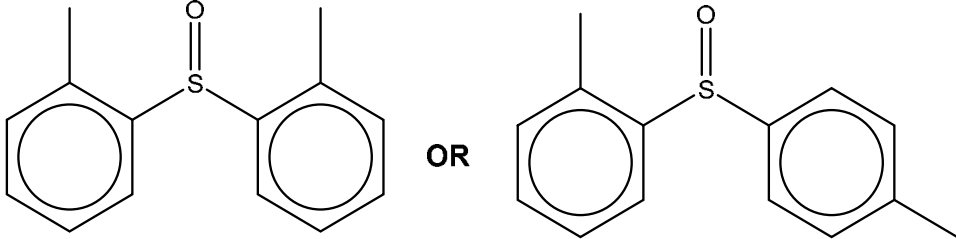
Question	Answer	Marks
2(c)(ii)	<i>Any four from:</i> isomer 1  isomer 2  isomer 3  isomer 4  isomer 5  isomer 6  Any two [1], any three [2], all four [3]	3
2(c)(iii)	oxidation state of cobalt (+)3 AND type of stereoisomerism cis-trans OR geometric(al) OR optical	1

Question	Answer	Marks
3(e)(ii)	$x = \sqrt[3]{1.5 \times 10^{-14} / 4} = 1.55 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ $[\text{Ag}^+] = 1.55 \times 10^{-5} \times 2 = 3.11 \times 10^{-5} \text{ (mol dm}^{-3}\text{) min 2sf ecf (e)(i)}$	1
3(f)	- feasibility / it increases as temperature increases ORA ΔS is positive / ΔS is >0 / entropy change is positive (and ΔH is positive) OR $-T\Delta S$ becomes more negative / $T\Delta S$ becomes more positive - as ΔG becomes / is negative / $\Delta G < 0$ Any two [1], all three [2]	2

Question	Answer	Marks
4(a)(i)	the sum/total of the power / exponent to which a concentration of a reactant is raised in the rate equation / law	1
4(a)(ii)	M1 (expt 1 and 2) when $[\text{Fe}^{3+}] \times 3$, rate $\times 3$ so first order w.r.t. Fe^{3+} M2 (expt 1 and 3) when $[\text{Fe}^{3+}] \times 2$, $[\text{I}^-] \times 2$, rate $\times 8$ so second order w.r.t. I^- OR (expt 2 and 3) when $[\text{Fe}^{3+}] \div 1.5$, $[\text{I}^-] \times 2$, rate $\times 2.7$ so second order w.r.t. I^-	2
4(a)(iii)	(rate =) $k[\text{Fe}^{3+}][\text{I}^-]^2$ [1] ecf (a)(ii)	1
4(a)(iv)	$k = \text{rate} / [\text{Fe}^{3+}][\text{I}^-]^2 = (2.64 \times 10^{-4}) / (0.04 \times 0.02^2)$ $k = 16.5 \text{ min 2sf ecf}$ units = $\text{mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$ ecf	2
4(a)(v)	(k and rate of reaction) both increase	1

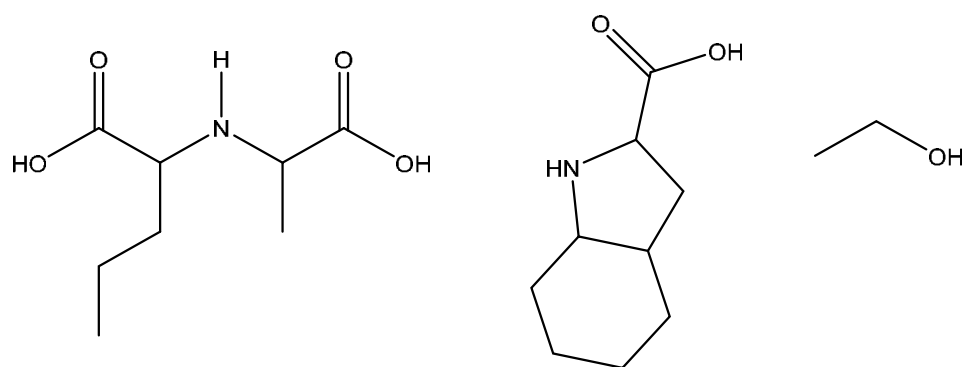
Question	Answer	Marks
4(b)(i)	step 1 as this has one mole of H_2O_2 and one mole of I^- OR step 1 as correct stoichiometry / coefficients of 1 H_2O_2 and 1 I^- OR step 1 as number of moles of each reactant are consistent with rate equation / their orders	1
4(b)(ii)	step 1 I oxid no $-1 \rightarrow +1$ AND O oxid no $-1 \rightarrow -2$ OR step 3 I oxid no $-1 \rightarrow 0$ AND I oxid no $+1 \rightarrow 0$	1
4(b)(iii)	intermediate AND formed (in step 2) and used up (in step 3) ALLOW oxidising agent (in step 3) AND oxidises I^- (to I_2)	1

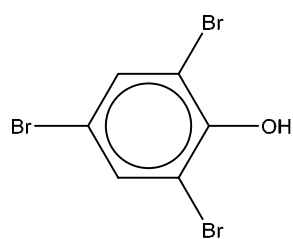
Question	Answer	Marks
5(a)(i)	 reaction 1 reaction 2 reaction 3 M1 M2 M3 BOTH	3
5(a)(ii)	M1 reaction 1: hydrogenation / reduction M2 mechanism 2: (free) radical substitution	2
5(b)	the substitution product is stabilised by delocalization of π -electrons / by π -electrons in the ring OR the addition product is not stabilised by delocalisation (of π -)electrons ALLOW addition product will remove π -electron delocalised system	1

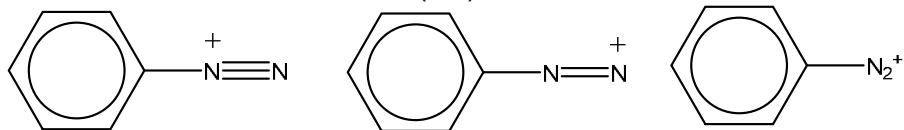
Question	Answer	Marks
5(c)(i)	 M1 curly arrow from inside the hexagon to S atom M2 structure of the intermediate M3 curly arrow from C-H bond into the ring AND formation/loss of H⁺	3
5(c)(ii)		1
5(d)(i)	$\text{CH}_3\text{COOH} + \text{SOBr}_2 \rightarrow \text{CH}_3\text{COBr} + \text{HBr} + \text{SO}_2$	1

Question	Answer	Marks
5(d)(ii)	M1 acyl bromides > acyl chlorides > alkyl chlorides easiest hardest M2 M3 Any two from: <i>Acyl bromides easiest</i> - in acyl bromides C–Br is much weaker ORA AND due to less orbital overlap / Br having a larger atomic radii <i>Acyl halides easier than alkyl chlorides</i> - carbon in C–Cl / C–Br / C–X bond is more δ^+/electron deficient OR C–Cl / C–Br bond is weaker (than C–Cl in alkyl chlorides) AND attached to an oxygen atom / two electronegative atoms / electron withdrawing C=O group ORA <i>alkyl chlorides hardest</i> - in alkyl chlorides C–Cl bond strengthened AND by positive inductive effect / electron donating effect of alkyl / R group	3

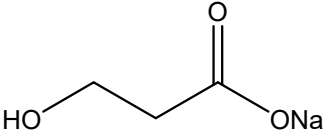
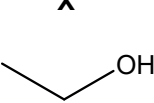
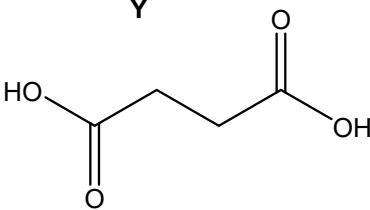
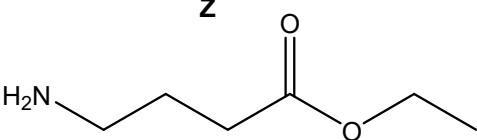
Question	Answer	Marks
6(a)(i)	5 / five	1
6(a)(ii)	M1 benefit: higher biological efficiency / activity (of the drug) OR less side effects OR smaller dose required (as drug more potent) M2 disadvantage: the need to separate (a racemic mixture into a single stereoisomer) OR lower yield (of biologically active molecule/product) OR need a chiral catalyst / enzyme (in the synthesis so expensive)	2
6(b)(i)	carboxylic acid/carboxyl, ester, amide, amine Any two [1], all four [2]	2

Question	Answer	Marks
6(b)(ii)	 3 × [1] for each structure	3

Question	Answer	Marks
7(a)	M1 p-orbital / lone pair from O atom is overlaps / delocalised into the ring M2 greater π electron density around the ring OR makes the ring more electron rich / positions 2,4,6 more electron rich M3 polarises electrophiles more easily	3
7(b)	iodobenzene AND as Br is more electronegative (than I / $I^{\delta+}/I^+$ in the electrophile)	1
7(c)(i)	$C_6H_6O / C_6H_5OH + Na \rightarrow C_6H_5O^-Na^+ + \frac{1}{2}H_2$	1
7(c)(ii)		1

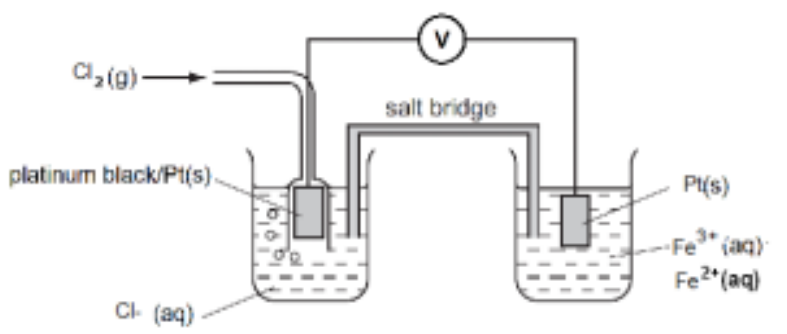
Question	Answer	Marks
7(c)(iii)	M1 reaction 1: aqueous HNO_3 / dilute HNO_3 M2 reaction 2: alkaline/ NaOH AND $\text{C}_6\text{H}_5\text{N}_2^+$ (Cl^-)  OR alkaline / NaOH AND benzene / phenyl diazonium ion / salt	2

Question	Answer	Marks
8(a)	- chlorobenzene is less reactive than chloroethane OWTTE - p-orbital / lone pair on Cl will overlap / delocalise into the ring - due to partial double C-Cl bond OWTTE OR C-Cl bond strengthened (more) Any two [1], all three [2]	2
8(b)(i)	ethyl 3-chloropropanoate	1

Question	Answer	Marks
8(b)(ii)	W  X  Y  Z  4 × [1] for each structure	4
8(b)(iii)	M1 step 1 NaCN / KCN in ethanol (heat) M2 step 2 H ₂ + Ni / H ₂ + Pt ALLOW LiAlH ₄	2
8(c)(i)	(because solvent / D / CDCl ₃) doesn't give a signal / peak / absorption ORA	1

Question	Answer				Marks
8(c)(ii)	chemical shift δ / ppm	environment of proton	splitting pattern	number of ^1H atoms responsible for the peak	4
	1.2	alkyl / alkane / (R-)CH ₍₃₎	triplet	3	
	2.8	alkyl next to C=O / CH ₍₂₎ C=O	triplet	2	
	3.7	alkyl next to electronegative atom / CH ₍₂₎ -Cl	triplet	2	
	3.9	alkyl next to electronegative atom / CH ₍₂₎ -O	quartet / quadruplet	2	
	Any three [1], any six [2], any nine [3], all twelve [4]				
8(c)(iii)	(δ = 3.9) three H on neighbouring / adjacent C / it's next to a CH ₃				1

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Question	Answer	Marks
9(a)	potential difference / voltage between the two half-cells / two electrodes (in a cell) under standard conditions	1
9(b)	 salt bridge voltmeter complete circuit [wires/salt bridge in/touching both solutions] Cl_2 Cl^- good delivery system (no arrow required) Pt Pt Fe^{2+} and Fe^{3+} Any three [1], any six [2], all nine [3]	3
9(c)	M1 $(\Delta G^\circ) = -nFE_{\text{cell}}^\circ$ OR $-2 \times 96500 \times 0.59$ M2 $\Delta G^\circ = -2 \times 96500 \times 0.59 = -113870 \text{ J mol}^{-1}$ $\Delta G^\circ = -114 \text{ kJ mol}^{-1}$ min 3sf ecf	2
9(d)(i)	$E = 0.77 + (0.059 / 1) \log (1/0.15)$ use of $z = 1$ $E = 0.82 \text{ V}$	1
9(d)(ii)	$E_{\text{cell}} = 0.59 + 0.77 - (\text{answer to (d)(i)}) = 0.54 \text{ V}$ ecf	1



Cambridge International AS & A Level

CHEMISTRY

9701/43

Paper 4 A Level Structured Questions

May/June 2023

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 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

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 descriptors 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.

PUBLISHED**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	<u>'List rule' guidance</u> For questions that require <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i>. • Incorrect responses should not be awarded credit but will still count towards <i>n</i>. • 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 <i>n</i> 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.

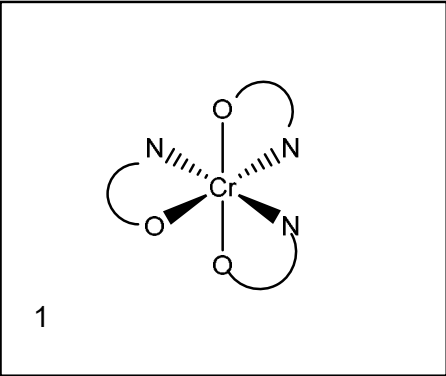
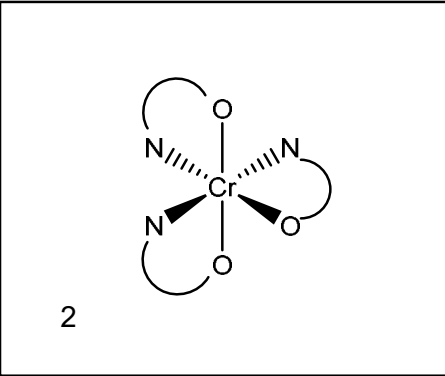
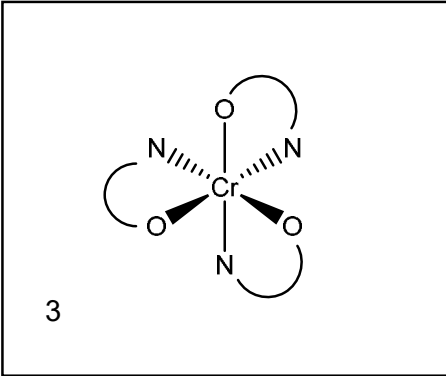
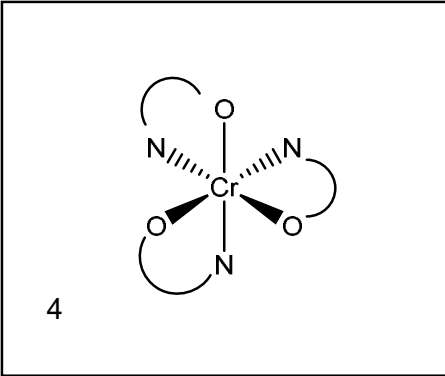
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

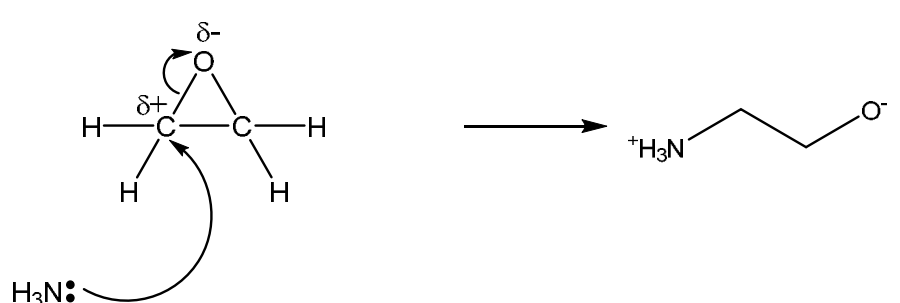
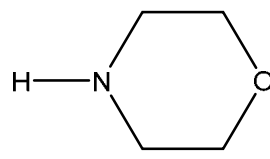
Question	Answer	Marks															
1(a)	M1 increases (down the group) M2 radius / size of (cat)ion / M^{2+} increases M3 less polarisation / distortion of anion / nitrate ion / NO_3^- OR less weakening of N–O / N=O (bond)	3															
1(b)	$\text{Cu}(\text{NO}_3)_2 \rightarrow \text{CuO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$	1															
1(c)	<table border="1"> <thead> <tr> <th>copper-containing species</th><th>formula of copper-containing species formed</th><th>colour copper-containing formed</th></tr> </thead> <tbody> <tr> <td>A</td><td>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$</td><td>(pale) blue</td></tr> <tr> <td>B</td><td>$\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$ or $\text{Cu}(\text{OH})_2$</td><td>(pale) blue</td></tr> <tr> <td>C</td><td>$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$</td><td>dark blue</td></tr> <tr> <td>D</td><td>CuCl_4^{2-}</td><td>yellow</td></tr> </tbody> </table> Two correct for one mark, four correct for two marks, six correct for three marks, eight correct for four marks.	copper-containing species	formula of copper-containing species formed	colour copper-containing formed	A	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	(pale) blue	B	$\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$ or $\text{Cu}(\text{OH})_2$	(pale) blue	C	$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$	dark blue	D	CuCl_4^{2-}	yellow	4
copper-containing species	formula of copper-containing species formed	colour copper-containing formed															
A	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	(pale) blue															
B	$\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$ or $\text{Cu}(\text{OH})_2$	(pale) blue															
C	$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$	dark blue															
D	CuCl_4^{2-}	yellow															
1(d)(i)	M1 (a species) that donates more than two lone pairs M2 to form dative / coordinate bonds to a metal atom or ion	2															
1(d)(ii)	six atoms circled, 2N and 4O from different CO_2^-	1															
1(d)(iii)	the number of co-ordinate bonds being formed by the metal ion	1															
1(d)(iv)	ligand exchange	1															
1(d)(v)	$[\text{FeEDTA}]^- > [\text{CrEDTA}]^- > [\text{PbEDTA}]^{2-}$ highest conc ⁿ lowest conc ⁿ AND K_{stab} of $[\text{FeEDTA}]^-$ is highest	1															

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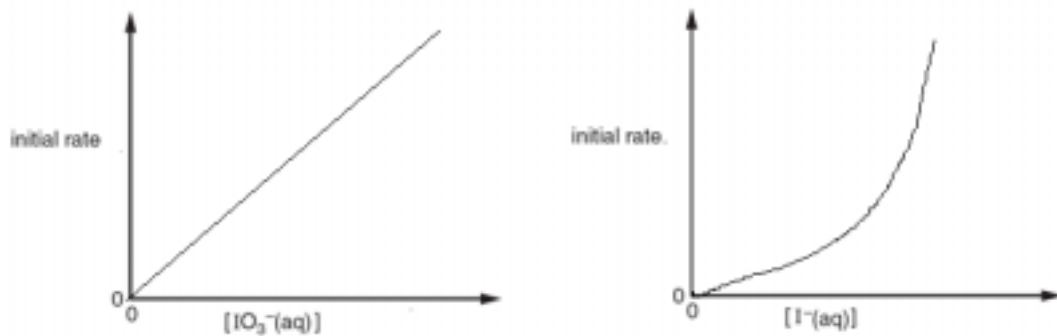
Question	Answer	Marks
1(e)	M1 moles of $\text{Cr}^{3+} = 2.096 \times 10^{-4}$ in 25.0 cm^3 M2 moles of $\text{Cr}^{3+} = 8.384 \times 10^{-4}$ (in 100.0 cm^3) moles of $\text{Cr}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O} = 8.384 \times 10^{-4} / 2 = 4.192 \times 10^{-4}$ M3 M_r of $\text{Cr}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O} = 0.2550 / 4.192 \times 10^{-4} = 608.3$ $n = (608.3 - 392.3) / 18 = 12$	3
1(f)	M1 ΔE is different M2 different frequency (of light) is absorbed	2

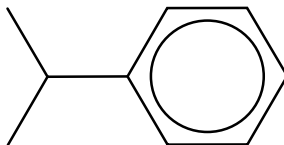
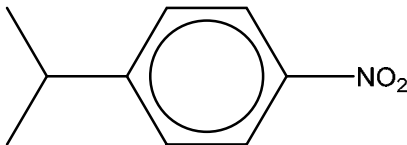
Question	Answer	Marks
2(a)	geometrical / cis-trans AND optical	1
2(b)	square planar	1

Question	Answer	Marks
2(c)	 1  2  3  4 Two correct for one mark, three correct for two marks, four correct for three marks.	3

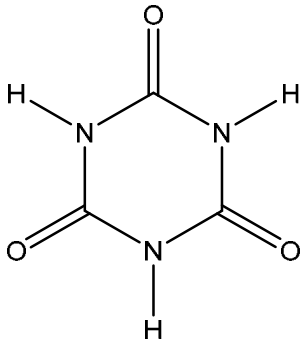
Question	Answer	Marks
2(d)(i)	 M1 two correct curly arrows M2 correct dipole M3 correct structure of intermediate	3
2(d)(ii)	use an excess of ammonia OR limiting amount of oxirane	1
2(d)(iii)	 M1 M2 elimination / dehydration / condensation	2

Question	Answer	Marks
3(a)(i)	the power to which the concentration of a reactant is raised in the rate equation	1

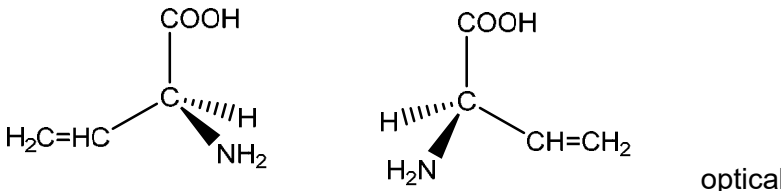
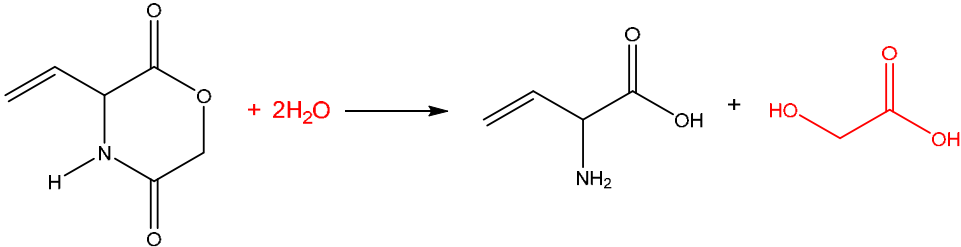
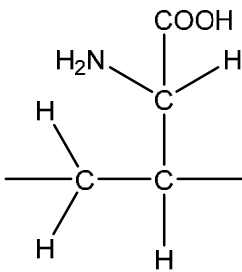
Question	Answer	Marks								
3(a)(ii)	<table><tr><td>the order of reaction with respect to $[\text{IO}_3^-]$</td><td>1</td></tr><tr><td>the order of reaction with respect to $[\text{H}^+]$</td><td>2</td></tr><tr><td>the order of reaction with respect to $[\text{I}^-]$</td><td>2</td></tr><tr><td>the overall order of reaction</td><td>5</td></tr></table> All correct for one mark	the order of reaction with respect to $[\text{IO}_3^-]$	1	the order of reaction with respect to $[\text{H}^+]$	2	the order of reaction with respect to $[\text{I}^-]$	2	the overall order of reaction	5	1
the order of reaction with respect to $[\text{IO}_3^-]$	1									
the order of reaction with respect to $[\text{H}^+]$	2									
the order of reaction with respect to $[\text{I}^-]$	2									
the overall order of reaction	5									
3(a)(iii)		1								
3(a)(iv)	M1 $k = \text{rate} / [\text{I}^-]^2 [\text{IO}_3^-] [\text{H}^+]^2 = (4.20 \times 10^{-2}) / (0.025^2 \times 0.04 \times 0.015^2) = 7.47 \times 10^6$ M2 units = $\text{mol}^{-4} \text{dm}^{12} \text{min}^{-1}$	2								
3(a)(v)	$0.0709 = k \times 0.12 \times [\text{H}^+]^2 \times 0.0125^2$ $[\text{H}^+] = 2.25 \times 10^{-2}$	1								
3(a)(vi)	$x = 10^2 / 1 = 100$	1								
3(b)	M1 step 1 $\text{Fe}^{3+} + \text{I}^- \rightarrow \text{FeI}^{2+}$ M2 step 2 $\text{FeI}^{2+} + \text{I}^- \rightarrow \text{Fe}^{2+} + \text{I}_2^-$ OR $\text{FeI}^{2+} + \text{I}^- \rightarrow \text{FeI}_2^+$ AND slowest step = step 2 M3 step 3 $\text{Fe}^{3+} + \text{I}_2^- \rightarrow \text{Fe}^{2+} + \text{I}_2$ OR $\text{FeI}_2^+ + \text{Fe}^{3+} \rightarrow 2\text{Fe}^{2+} + \text{I}_2$	3								

Question	Answer	Marks						
4(a)	M1 bond angle = 120° AND carbons are sp^2 M2 σ bonds are formed by end-on-end / head on / head to head / linear overlap of orbitals M3 π bonds are formed by sideways / lateral overlap of p orbitals	3						
4(b)(i)	X  [1] Y  [1]	2						
4(b)(ii)	M1 step 1 $(CH_3)_2CHBr$ and $FeBr_3 / AlBr_3$ M2 step 2 conc HNO_3 and conc H_2SO_4 M3 step 3 Sn and conc HCl	3						
4(c)	3,4,5-trimethylphenylamine	1						
4(d)	<table border="1" style="margin-left: auto; margin-right: auto;"><thead><tr><th>compound</th><th>number of peaks observed</th></tr></thead><tbody><tr><td style="text-align: center;">W</td><td style="text-align: center;">6</td></tr><tr><td style="text-align: center;">Z</td><td style="text-align: center;">6</td></tr></tbody></table> Both correct for one mark	compound	number of peaks observed	W	6	Z	6	1
compound	number of peaks observed							
W	6							
Z	6							

Question	Answer	Marks
5(a)(i)	palladium, platinum and rhodium / Pt, Pd, Rh	1
5(a)(ii)	a catalyst in a different state / phase to the reactants / substrate	1
5(b)(i)	measure / degree of disorder / randomness of a system OR the number of possible arrangements of the particles and the energy in a system	1

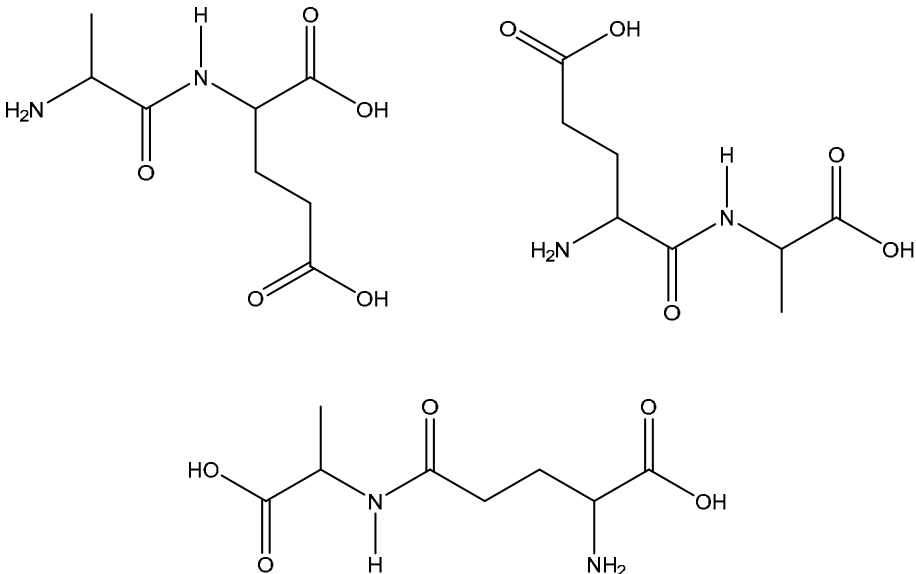
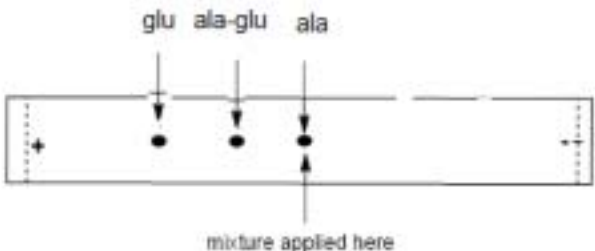
Question	Answer	Marks
5(b)(ii)	M1 $\Delta S^\circ = (192.8) + 213.8 - 238.2 - 188.8$ $\Delta S^\circ = -20.4 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ M2 $\Delta H^\circ = (-45.9) + (-393.5) - (-101.7) - (-241.8)$ $\Delta H^\circ = -95.9 \text{ (kJ mol}^{-1}\text{)}$ M3 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ M4 $\Delta G^\circ = -95.9 - (298 \times -0.0204) = -89.8 \text{ (kJ mol}^{-1}\text{)}$	4
5(c)	$4(\text{NH}_2)_2\text{CO} + 6\text{NO}_2 \rightarrow 7\text{N}_2 + 8\text{H}_2\text{O} + 4\text{CO}_2$	1
5(d)		1
5(e)(i)	$\text{p}K_a = -\log K_a$ AND $\text{pH} = -\log [\text{H}^+]$	1
5(e)(ii)	M1 $[\text{H}^+] = \sqrt{0.120 \times 2.00 \times 10^{-4}} = 4.89(317) \times 10^{-3}$ M2 $\text{pH} = 2.31$	2
5(e)(iii)	$\% \text{ ionisation} = 4.89 \times 10^{-3} / 0.12 \times 100 = 4.1\%$	1

Question	Answer	Marks
6(a)(i)	carboxylic acid, amine, alkene Two correct for one mark, three correct for two marks	2

Question	Answer	Marks
6(a)(ii)	 optical Two correct for one mark, three correct for two marks.	2
6(b)(i)		1
6(b)(ii)	hydrolysis	1
6(c)(i)		1

Question	Answer	Marks
6(c)(ii)	M1 amide linkage displayed correctly M2 rest of the structure correct	2
6(c)(iii)	condensation polymers can be hydrolysed	1

Question	Answer	Marks
7(a)	M1 diethylamine > ethylamine > ethanamide <u>explanation</u> M2 basicity linked to ability of lone pair on N to accept a proton / H ⁺ M3 electron donating ethyl group increases electron density on N / makes lone pair more available for donation M4 lone pair of electrons on N is delocalised into C=O group	4
7(b)(i)	M1 resists change in pH M2 when a small amount of acid or alkali is added	2
7(b)(ii)	M1 $\text{H}_2\text{NCH}(\text{CH}_3)\text{COOH} + \text{H}^+ \rightarrow \text{H}_3\text{N}^+\text{CH}(\text{CH}_3)\text{COOH}$ M2 $\text{H}_2\text{NCH}(\text{CH}_3)\text{COOH} + \text{OH}^- \rightarrow \text{H}_2\text{NCH}(\text{CH}_3)\text{COO}^- + \text{H}_2\text{O}$	2
7(c)(i)		1

Question	Answer	Marks
7(c)(ii)	 M1 displayed peptide bond (between two amino acids) M2 rest of the structure correct	2
7(d)	 M1 relative positions of the spots drawn M2 Ala is a zwitterion / neutral / at its isoelectric point (at pH 6) OR ala-glu AND glu are negatively charged M3 glu has lower M_r OR ala-glu has higher M_r	3

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Question	Answer				Marks
7(e)(i)					3
	chemical shift (δ)	splitting pattern	number of ^1H atoms responsible for the peak	number of protons on the adjacent carbon(s)	
	1.4	doublet	3	1	
	3.5	singlet	3	0	
	4.0	quartet	1	3	
Three correct for one mark, six correct for two marks, nine correct for three marks.					
7(e)(ii)	one extra peak for NH_2 group seen in CDCl_3 , AND H exchanged for D in D_2O				1

Question	Answer				Marks																
8(a)	<table><tr><td>energy change</td><td>always positive</td><td>always negative</td><td>either negative or positive</td></tr><tr><td>lattice energy</td><td></td><td>✓</td><td></td></tr><tr><td>enthalpy of hydration</td><td></td><td>✓</td><td></td></tr><tr><td>enthalpy of solution</td><td></td><td></td><td>✓</td></tr></table> All correct for one mark				energy change	always positive	always negative	either negative or positive	lattice energy		✓		enthalpy of hydration		✓		enthalpy of solution			✓	1
energy change	always positive	always negative	either negative or positive																		
lattice energy		✓																			
enthalpy of hydration		✓																			
enthalpy of solution			✓																		
8(b)	The energy / enthalpy change when 1 mole of gaseous ions is dissolved in water				1																
8(c)(i)	M1 use of correct six numbers only 682.8 178.2 590 1145 111.9 324.6 M2 2× used correctly with Br (2 × 111.9 and 2 × 324.6) M3 correct signs and evaluation to give −2170.6 kJ mol^{−1}				3																

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Question	Answer	Marks
8(c)(ii)	M1 use of correct three numbers only 2170.6 103.1 and 1579 M2 correct signs & evaluation -347 kJ mol^{-1}	2
8(c)(iii)	M1 Br^- has a smaller ionic radius M2 Br^- has stronger attractive forces with water molecules	2