

Cambridge International AS & A Level

CHEMISTRY**9701/41**

Paper 4 A Level Structured Questions

October/November 2025**MARK SCHEME**Maximum Mark: 100

Published

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- 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.

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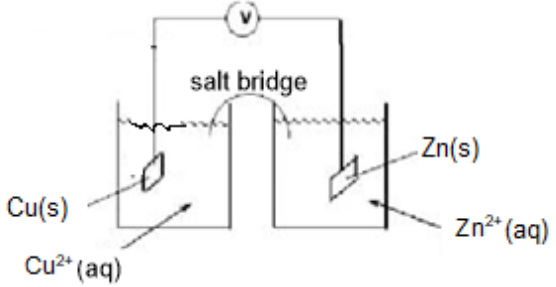
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TE	Transcription error

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1(a)(i)	$\text{Sr}(\text{HCO}_3)_2 \rightarrow \text{SrCO}_3 + \text{CO}_2 + \text{H}_2\text{O}$	1
1(a)(ii)	M1: radius of cation / M^{2+} increases OR charge density of cation / M^{2+} decreases M2: less polarisation / less distortion of the anion / carbonate ion	2
1(b)	M1: least soluble $\text{CaF}_2 < \text{SrF}_2 < \text{BaF}_2$ most soluble M2: ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative M3: ΔH_{hyd} changes less / becomes less exothermic by a smaller extent OR ΔH_{latt} changes more / becomes less exothermic by a larger extent M4: ΔH_{sol} becomes more exothermic / more negative	4
1(c)(i)	enthalpy change when one mole of gaseous ions dissolve in water to form a solution	1
1(c)(ii)	M1: ionic radii AND ionic charge M2: (ionic) radii increase / charge density decreases AND ΔH_{hyd} decreases/less exothermic AND less attraction between water molecules and (gaseous) ions OR as ionic charge increases / charge density increases AND ΔH_{hyd} increases/more exothermic AND more attraction between water molecules and (gaseous) ions	2
1(d)	M1: use of -2957 / -1926 / -505 AND $2 \times (-505)$ M2: correct signs and evaluation ΔH_{sol} of $\text{MgF}_2(\text{s}) = -1926 + (2 \times -505) - (-2957) = (+)21 \text{ kJ mol}^{-1}$	2
1(e)(i)	M1: $K_{\text{sp}} = [\text{Hg}_2^{2+}] [\text{F}^-]^2$ M2: units = $\text{mol}^3 \text{ dm}^{-9}$	2
1(e)(ii)	$K_{\text{sp}} = 2^2 \times (9.20 \times 10^{-3})^3 = 3.11 \times 10^{-6}$ min 2sf	1

Question	Answer	Marks
2(a)	the (3)d and (4)s sub-shells / orbitals / electrons are close / similar in energy	1
2(b)	species or ion formed by a central metal atom/ion AND surrounded by/bonded to (one or more) ligands	1
2(c)(i)	NaOH / OH ⁻ (aq) AND precipitation / ligand exchange / deprotonation / acid–base	1
2(c)(ii)	M1: Fe(H₂O)₄(OH)₂ is oxidised (from + 2 to + 3 on standing) M2: $E^\ominus$ of Fe(H₂O)₃(OH)₃ is more negative than $E^\ominus$ of O₂ OR $E^\ominus_{\text{cell}} = 0.40 - (-0.56) = (+)0.96 \text{ V}$ M3: $4\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2 + \text{O}_2 \rightarrow 4\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 2\text{H}_2\text{O}$	3
2(d)	$\Delta G^\ominus = -2 \times 1.67 \times 96\,500 = -322\,310 \text{ J mol}^{-1}$ M1: $\Delta G^\ominus = -nE^\ominus_{\text{cell}}F$ AND $n = 2$ OR $-2 \times 1.67 \times 96\,500$ M2: $\Delta G^\ominus = -322.3 \text{ kJ mol}^{-1}$	2

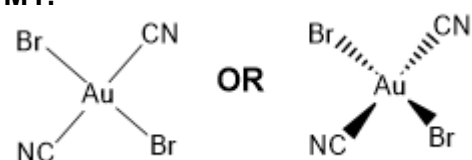
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3(a)	heterogeneous AND MnO ₂ is in a different state / phase to the reactants / H ₂ O ₂	1
3(b)(i)	M1: (expt 2 and 3) [I⁻] × 2 initial rate × 2 so 1st order wrt [I⁻] M2: (expt 1 and 2) [I⁻] × 2, [H₂O₂] × 0.5 initial rate × 1 so 1st order wrt [H₂O₂] OR (expt 1 and 4) [I⁻] × 4 initial rate × 4 AND [H⁺] × 4 so zero order wrt [H⁺] OR (expt 1 and 3) [I⁻] × 4, [H₂O₂] × 0.5 initial rate × 2 so 1st order wrt [H₂O₂] M3: (expt 1 and 4) [I⁻] × 4, [H⁺] × 4 initial rate × 4 so zero order wrt [H⁺] OR (expt 3 and 4) [H₂O₂] × 2 initial rate × 2 AND [H⁺] × 4 so zero order wrt [H⁺] OR (expt 3 and 4) [H₂O₂] × 2, [H⁺] × 4 initial rate × 2 so 1st order wrt [H₂O₂] M4: rate = k [H₂O₂] [I⁻] OR rate = k [H₂O₂] [I⁻] [H⁺]⁰	4
3(b)(ii)	M1: $k = 2.42 \times 10^{-3} \div (0.045 \times 0.030) = 1.79 \text{ min } 2\text{sf}$ M2: units = dm³ mol⁻¹ s⁻¹	2
3(c)(i)	M1: calculation of one $t_{1/2} = 60 \text{ s} \pm 5 \text{ s}$ M2: two $t_{1/2}$ calculated that are constant	2
3(c)(ii)	$k = \ln 2 \div 60 = 0.0116$ OR $k = 0.693 \div 60 = 0.0116 \text{ min } 2\text{sf}$	1
3(d)	increases k and increases the rate of reaction	1
4(a)	M1: potential difference / voltage / EMF AND between two half-cells / two electrodes (in a cell) M2: (at concentration of) 1 mol dm⁻³ AND (pressure of) 1 atm / 101 kPa AND (temperature of) 298 K / 25 °C	2

Question	Answer	Marks
4(b)(i)	 M1: salt bridge labelled AND voltmeter / V AND wire to electrode and liquid level shown [complete circuit] M2: Cu(s) AND Cu²⁺(aq) M3: Zn(s) AND Zn²⁺(aq)	3
4(b)(ii)	ions AND electrons	1
4(b)(iii)	M1: Nernst equation $E = E^\ominus + (0.059/z) \log(\text{Zn}^{2+}/\text{Zn})$ M2: $E = -0.76 + (0.059 / 2) \log(0.25) = -0.778 \text{ V}$ OR $E = -0.76 + (8.31 \times 298) / (96\,500 \times 2) \ln(0.25) = -0.778 \text{ V}$ min 2sf	2
4(c)(i)	(from) +4 (to) +3	1
4(c)(ii)	$\text{Zn} + 2\text{MnO}_2 \rightarrow \text{ZnO} + \text{Mn}_2\text{O}_3$	1
4(c)(iii)	$E^\ominus (\text{MnO}_2 / \text{Mn}_2\text{O}_3) = 1.47 - 1.28 = (+)0.19 \text{ V}$	1

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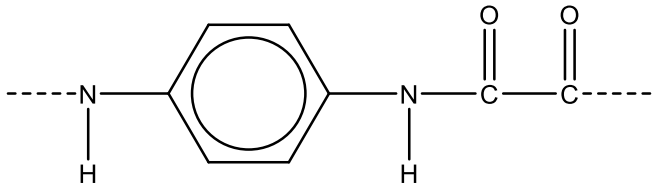
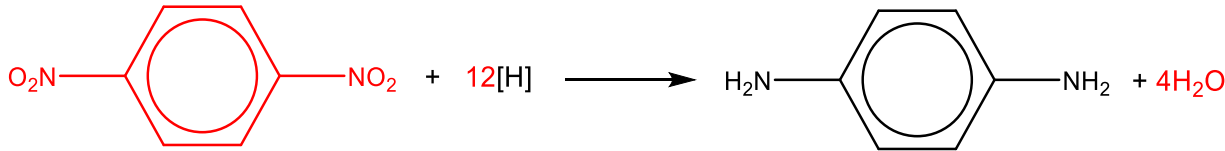
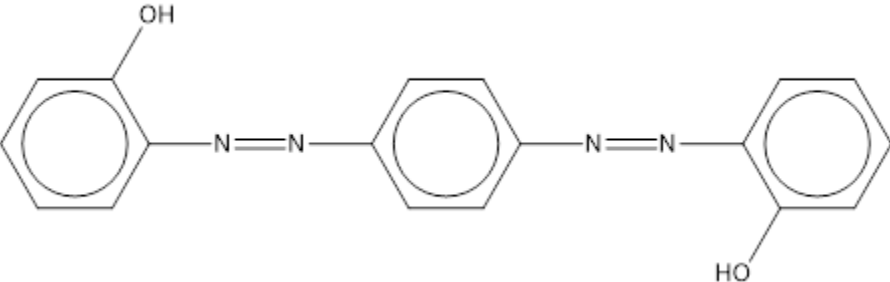
Question	Answer	Marks												
5(a)	<table><tr><th rowspan="2">species</th><th colspan="2">number of unpaired electrons</th></tr><tr><th>3d</th><th>4s</th></tr><tr><td>Cu</td><td>0</td><td>1</td></tr><tr><td>Cu²⁺</td><td>1</td><td>0</td></tr></table>	species	number of unpaired electrons		3d	4s	Cu	0	1	Cu ²⁺	1	0	1	
species	number of unpaired electrons													
	3d	4s												
Cu	0	1												
Cu ²⁺	1	0												
5(b)	• five 3d orbitals (lines, boxes) in the isolated Cu²⁺ ion of the same energy • splitting: three higher and two lower d orbitals • energy of all five d orbitals in complex higher than all d orbitals in isolated ion any two [1], all three [2]	2												
5(c)	M1: more than one (stable) oxidation state / exist in variable oxidation states M2: vacant / empty (d) orbitals are energetically accessible OR vacant / empty (d) orbitals can form dative bonds with ligands	2												
5(d)	<table><tr><th>metal ion</th><th>coordination number</th><th>formula of complex ion</th><th>charge of complex ion</th></tr><tr><td>Ag⁺</td><td>2</td><td><u>Ag</u>(CN)₂</td><td>1–</td></tr><tr><td>Fe²⁺</td><td>6</td><td><u>Fe</u>(CN)₆</td><td>4–</td></tr></table> each row [1]	metal ion	coordination number	formula of complex ion	charge of complex ion	Ag ⁺	2	<u>Ag</u> (CN) ₂	1–	Fe ²⁺	6	<u>Fe</u> (CN) ₆	4–	2
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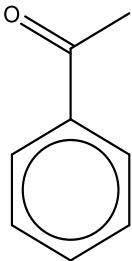
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5(e)	M1:  M2: (shape) square planar AND (bond angle) 180°	2
5(f)(i)	M1: moles $\text{MnO}_4^- = 0.075 \times 0.0225 = 1.6875 \times 10^{-3}$ M2: moles $\text{V}^{2+} = 5 / 3 \times 1.6875 \times 10^{-3} = 2.8125 \times 10^{-3}$ M3: mass V = $50.9 \times 2.8125 \times 10^{-3} = 0.143 \text{ g}$ % of V = $0.143 / 0.250 \times 100 = 57.3 \text{ min 2sf}$	3
5(f)(ii)	$2\text{VO}_3^- + 3\text{Zn} + 12\text{H}^+ \rightarrow 2\text{V}^{2+} + 3\text{Zn}^{2+} + 6\text{H}_2\text{O}$ M1: 2 : 3 ratio on both sides M2: rest of the equation correct	2

Question	Answer	Marks
6(a)(i)	M1: (R_f value) is distance moved by a component / spot / solute AND divided by distance moved by solvent OR (R_f value) is the ratio of distance moved by a component / spot / solute AND by distance moved by solvent M2: (retention time) is (the time) between injection and detection (of a component)	2

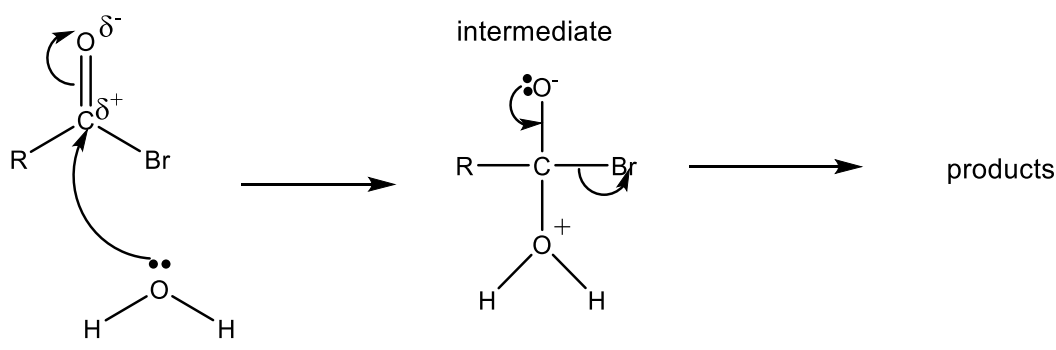
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6(a)(ii)	thin-layer chromatography: polar solvent OR non-polar solvent OR named solvent gas-liquid chromatography: non-volatile liquid OR high boiling point liquid	1						
6(b)	A is more soluble in the mobile phase OR A has less adsorption to the stationary phase	1						
6(c)(i)	<table><tr><td>compound</td><td>number of peaks observed</td></tr><tr><td>Y</td><td>2</td></tr><tr><td>Z</td><td>2</td></tr></table>	compound	number of peaks observed	Y	2	Z	2	1
compound	number of peaks observed							
Y	2							
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6(c)(ii)	M1: Y (two) singlet(s) M2: Z triplet AND quartet	2						

Question	Answer	Marks
7(c)(i)	 M1: correct displayed amide bond with C=O, (C₆H₅)–N and (C–)C=O M2: rest of the structure correct with continuation bonds	2
7(c)(ii)		1
7(d)(i)	M1:  M2: 	2

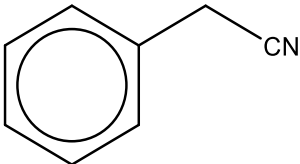
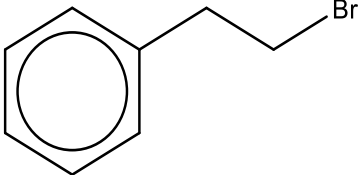
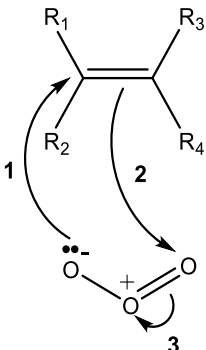
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7(d)(ii)	HNO ₂ (and HCl) AND ≤10 °C OR NaNO ₂ AND HCl AND ≤10 °C	1

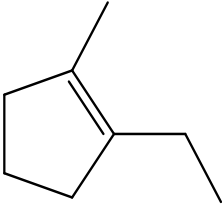
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8(a)(i)	NO ₂ group directs to 3 (and 5) / meta position AND due to being an electron-withdrawing / electronegative group	1
8(a)(ii)	HNO ₃ + H ₂ SO ₄ → NO ₂ ⁺ + HSO ₄ ⁻ + H ₂ O OR HNO ₃ + 2H ₂ SO ₄ → NO ₂ ⁺ + 2HSO ₄ ⁻ + H ₃ O ⁺	1
8(b)(i)		1
8(b)(ii)	M1: (reaction 1) ethanoyl chloride / CH ₃ COCl AND AlCl ₃ M2: (reaction 2) 2-bromopropane / (CH ₃) ₂ CHBr AND FeBr ₃	2
8(c)	M1: with C ₆ H ₅ Br no change / no precipitate AND with C ₆ H ₅ CH ₂ Br cream precipitate in C ₆ H ₅ Br M2: lone pair / p-orbital on Br delocalised / overlaps with ring / π system M3: C–Br bond stronger / has partially double bond character	3

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Question	Answer	Marks
8(d)(i)	(nucleophilic) addition–elimination	1
8(d)(ii)	 M1 M2: • lone pair on O • curly arrow from (lone pair) O (in H₂O) to C (of C=O) • correct dipole on C=O • curly arrow from the C=O bond to O atom any two [1], all four [2] M3: correct intermediate M4: curly arrow from (lone pair on) O⁽⁻⁾ to C–O bond AND curly arrow from C–Br to Br	4

Question	Answer	Marks
9(a)	M1: (basicity linked to) ability of lone pair / p-orbital to AND accept / coordinate with a proton / H⁺ M2: (lone pair of) electrons on N is delocalised into C=O group (and make amides neutral)	2

Question	Answer	Marks
9(b)(i)	M1: M  M2: N 	2
9(b)(ii)	LiAlH ₄	1
9(c)	ketone / carbonyl AND secondary / 2°	1
9(d)(i)	 curly arrow 1: from O lone pair to C atom (in C=C) curly arrow 2: from C=C bond to the right-hand O atom in O=O curly arrow 3: from O=O bond to O⁺	2

Question	Answer	Marks
9(d)(ii)		1

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Question	Answer	Marks
1(a)	$\text{Mg}(\text{NO}_3)_2 \rightarrow \text{MgO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$ OR $2\text{Mg}(\text{NO}_3)_2 \rightarrow 2\text{MgO} + 4\text{NO}_2 + \text{O}_2$	1
1(b)	M1: $\text{Mg}(\text{NO}_3)_2$ / magnesium nitrate AND magnesium ion / Mg^{2+} AND is smaller / has higher charge density M2: nitrate ion / anion is more distorted / polarised	2
1(c)(i)	magnesium sulfate and water / MgSO_4 and H_2O	1
1(c)(ii)	M1: magnesium sulfate / A has a more exothermic ΔH_{latt} and ΔH_{hyd} M2: difference in ΔH_{hyd} is greater M3: magnesium sulfate / A has a more exothermic ΔH_{sol}	3

Question	Answer	Marks
2(a)(i)	homolytic fission	1
2(a)(ii)	$\text{:}\ddot{\text{O}}\text{:}\ddot{\text{N}}\text{:}\ddot{\text{O}}\quad \text{H}\text{:}\ddot{\text{O}}\text{:}\ddot{\text{N}}\text{:}\ddot{\text{O}}$	1
2(a)(iii)	115–120°	1
2(b)	M1: $3.825 \times 10^{-3} / 0.003825 / 0.00383 / 0.0038 / 3.8 \times 10^{-3}$ M2: units = $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$	2
2(c)	not constant half-life because overall second order	1

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Question	Answer	Marks
2(d)	8.17 / 8.2	1
2(e)	- reactants are adsorbed onto the catalyst surface - bonds within reactant molecules are weakened - products are desorbed from catalyst surface Any two [1], all three [2]	2

Question	Answer	Marks
3(a)(i)	two species that differ by one proton / H^+	1
3(a)(ii)	H_2PO_4^- AND PO_4^{3-}	1
3(b)(i)	M1: $[\text{H}^+] = 2.51 \times 10^{-4}$ M2: $[\text{CH}_3\text{CH}_2\text{COOH}] = 4.67 \times 10^{-3}$	2
3(b)(ii)	3.98×10^{-11}	1
3(b)(iii)	$[\text{HCl}] = 2.51 \times 10^{-4}$	1
3(b)(iv)	M1: top box ticked AND weaker acid M2: alkyl group is electron donating M3: O–H bond strengthened / anion is destabilised	3
3(c)(i)	NaOH AND $\text{CH}_3\text{CH}_2\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{COO}^- + \text{H}_2\text{O}$	1
3(c)(ii)	H_2SO_4 AND conjugate base of $\text{CH}_3\text{CH}_2\text{COOH}$ is not present	1
3(d)(i)	3.69×10^{-5}	1

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Question	Answer	Marks
3(d)(ii)	M1: $K_{sp} = [\text{Mn}^{2+}][\text{OH}^-]^2$ M2: units = $\text{mol}^3 \text{dm}^{-9}$	2
3(d)(iii)	2.0×10^{-13}	1

Question	Answer	Marks
4(a)	energy required when one mole of gaseous atoms is formed from the element	1
4(b)	energy released when one mole of gaseous atoms gains one mole of electrons and becomes one mole of gaseous 1^- ions	1
4(c)	M1: iodine atom has greater radius M2: less attraction between nucleus and incoming electron in iodine	2
4(d)	M1: $\frac{1}{2} (-486 + (2 \times 364))$ M2: +121	2

Question	Answer	Marks
5(a)(i)	$\text{Co}^{2+} = [\text{Ar}] 3d^7$ AND $\text{Co}^{3+} = [\text{Ar}] 3d^6$	1
5(a)(ii)	has vacant d orbitals that are energetically accessible	1
5(a)(iii)	- pink - blue - aqueous Any two [1], all three [2]	2
5(a)(iv)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O} + 4\text{H}^+$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O}$	1

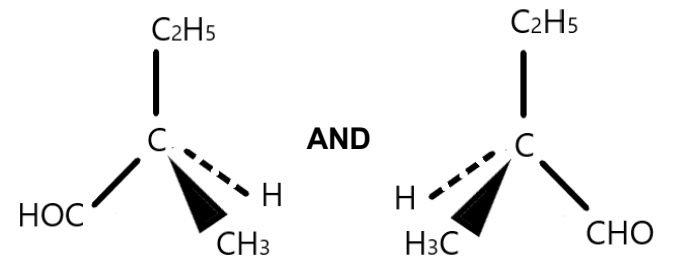
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Question	Answer	Marks
5(a)(v)	ligand exchange	1
5(a)(vi)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{OH})_2 + 6\text{H}_2\text{O}$	1
5(b)(i)	M1: Nernst equation $E = E^\ominus + (0.059 / z) \times \log\left(\frac{[\text{oxidised}]}{[\text{reduced}]}\right)$ M2: $E = -0.28 + (0.059 / 2) \times \log(0.02)$	2
5(b)(ii)	1.66 V	1
5(b)(iii)	$3\text{Co} + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ \rightarrow 3\text{Co}^{2+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	1
5(b)(iv)	$\text{Co}^{2+} / \text{Co}$, $\text{Co}^{2+} / \text{Co}$, $\text{Cr}_2\text{O}_7^{2-} / \text{Cr}^{3+}$	1
5(c)	M1: moles of cobalt = $0.547 / 58.9 = 0.00929$ M2: coulombs required = $0.00929 \times 96500 \times 2 = 1792$ M3: time required = $1792 / 0.50 = 3584.8 \text{ s} = 59.7 \text{ minutes}$ 3sf	3

Question	Answer	Marks
6(a)(i)	$\text{Ni}(\text{CO})_4$	1
6(a)(ii)	- ethanedioate given as C_2O_4 - formula shows one Ni and three ligands - charge = 4^- any two [1], all three [2] $\text{Ni}(\text{C}_2\text{O}_4)_3^{4-}$ scores [2]	2

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Question	Answer	Marks
6(a)(iii)	F AND optical	1
6(b)(i)	N atom can donate one lone pair of electrons	1
6(b)(ii)	$[\text{Cd}(\text{en})_2]^{2+}$ AND has a larger K_{stab} / is more stable	1
6(b)(iii)	$\frac{[\text{Cd}(\text{CH}_3\text{NH}_2)_4]^{2+}}{[\text{Cd}^{2+}][\text{CH}_3\text{NH}_2]^4}$	1

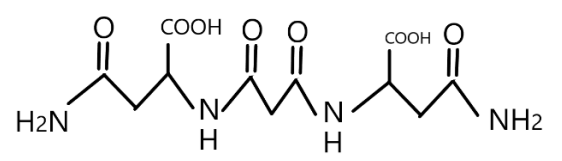
Question	Answer	Marks
7(a)	M1: Q $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CHO}$ M2: 	2
7(b)(i)	T $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCH}_3$ AND V $(\text{CH}_3)_2\text{CHCOCH}_3$	1
7(b)(ii)	- yellow solid $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ OR $(\text{CH}_3)_2\text{CHCOOH}$ CHI_3 Any two [1], all three [2]	2
7(c)(i)	S $(\text{CH}_3)_3\text{CCHO}$	1

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Question	Answer	Marks
7(c)(ii)	U $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$	1
7(c)(iii)	triplet AND two hydrogen atoms on neighbouring carbon atoms	1
7(c)(iv)	TMS / tetramethylsilane / $\text{Si}(\text{CH}_3)_4$	1
7(d)	4 3 5 3 Any two [1], all four [2]	2

Question	Answer	Marks
8(a)	the pH at which an amino acid exists as a zwitterion	1
8(b)	M1: $[\text{HOOCCH}(\text{NH}_3)\text{CH}_2\text{CONH}_2]^+$ M2: $[\text{HOOCCH}(\text{NH}_3)\text{CH}_2\text{COOH}]^+$ $\begin{array}{c} \text{O} \quad \text{H} \quad \quad \text{O} \\ \parallel \quad \quad \quad \parallel \\ \text{HO}-\text{C}-\text{C}-\text{CH}_2-\text{C}-\text{NH}_2 \\ \\ \text{NH}_3^+ \end{array}$ $\begin{array}{c} \text{O} \quad \text{H} \quad \quad \text{O} \\ \parallel \quad \quad \quad \parallel \\ \text{HO}-\text{C}-\text{C}-\text{CH}_2-\text{C}-\text{OH} \\ \\ \text{NH}_3^+ \end{array}$	2

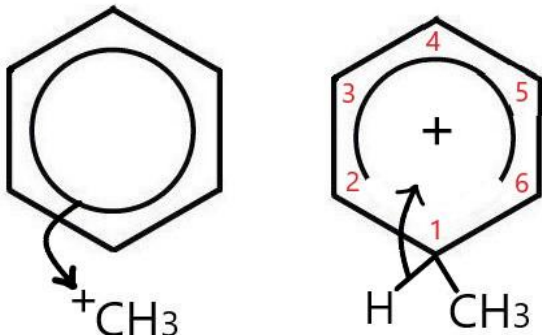
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Question	Answer	Marks
8(c)	M1: $\text{HOCH}_2\text{CH}(\text{NH}_2)\text{CH}_2\text{CH}_2\text{NH}_2$ M2: $\text{HOCH}_2\text{CH}(\text{NH}_2)\text{CH}_2\text{CH}_2\text{OH}$ $\begin{array}{c} \text{H} \\ \\ \text{HOCH}_2 - \text{C} - \text{CH}_2 - \text{CH}_2\text{NH}_2 \\ \\ \text{NH}_2 \end{array}$ $\begin{array}{c} \text{H} \\ \\ \text{HOCH}_2 - \text{C} - \text{CH}_2 - \text{CH}_2\text{OH} \\ \\ \text{NH}_2 \end{array}$	2
8(d)(i)	$\text{HOOCCH}_2\text{COOH} + 2\text{SOCl}_2 \rightarrow \text{ClOOCCH}_2\text{COCl} + 2\text{SO}_2 + 2\text{HCl}$	[1] 1
8(d)(ii)	$\text{HOOCCH}(\text{CH}_2\text{CONH}_2)\text{NHCOCH}_2\text{CONHCH}(\text{CH}_2\text{CONH}_2)\text{COOH}$ M1: three molecules joined, with four correct amide groups only M2: whole structure correct as above, displayed formula accepted, skeletal formula as below accepted 	2
8(e)	M1: hydrolysis of amide to carboxylate ion M2: hydrolysis of $-\text{COOH}$ to carboxylate ion and rest of molecule $-\text{OOCCH}(\text{NH}_2)\text{CH}_2\text{COO}^-$	2

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Question	Answer	Marks
8(f)	- three monomer residues - all linkages correct - correct trailing bonds - repeat unit marked contains correct atoms Any two [1], any three [2], all four [3] $ \begin{array}{c} \text{CH}_2\text{CONH}_2 \qquad \qquad \text{CH}_2\text{CONH}_2 \\ \qquad \qquad \qquad \\ -\text{COCHNH}-[\text{COCHNH}]_n-\text{COCHNH}- \\ \\ \text{CH}_2\text{CONH}_2 \end{array} $	3
8(g)(i)	- rotate the plane of the plane polarised light - by the same angle - in opposite directions Any two [1], all three [2]	2
8(g)(ii)	racemic mixture	1

Question	Answer	Marks
9(a)	- all C atoms are sp^2 hybridised - bonds between C atoms are σ and π - C–C σ bonds are formed by overlap of sp^2 hybrid orbitals - C–C π bonds are formed by overlap of p orbitals - bonds between C and H atoms are σ - C–H bonds are formed by overlap of sp^2 hybrid orbitals and s orbitals Any two [1], any four [2], all six [3]	3

Question	Answer	Marks
9(b)	CH_3Cl and AlCl_3	1
9(c)	 M1: curly arrow from within hexagon towards ^+C M2: intermediate, usual rules for horseshoe and $+$ charge M3: curly arrow from C-H bond into ring AND H^+ product	3
9(d)	M1: HNO_3 AND H_2SO_4 M2: concentrated AND $25\text{ }^\circ\text{C} \leq T \leq 60\text{ }^\circ\text{C}$	2
9(e)	alkaline KMnO_4	1
9(f)	4-nitrobenzoic acid	1
9(g)	(hot) concentrated HCl and Sn	1
9(h)	M1: perform step 3 before step 2 OR perform step 2 before step 1 M2: COOH is 3-directing OR NO_2 is 3-directing	2

Cambridge International AS & A Level

CHEMISTRY**9701/43**

Paper 4 A Level Structured Questions

October/November 2025**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 October/November 2025 series for most Cambridge IGCSE, Cambridge International A and AS Level 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 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.

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	Correct point or mark awarded
	Incorrect point or mark not awarded
	Unclear
	Information missing or insufficient for credit
	Benefit of the doubt given
	Contradiction in response otherwise markworthy, mark not given
	Part of the correct answer has been seen. Full credit has not been awarded.
	Error carried forward applied
	Incorrect or insufficient point ignored while marking the rest of the response
	Rounding error
	Repetition

Annotation	Meaning
SEEN	Blank page or part of script seen
SF	Error in number of significant figures
TE	Transcription error

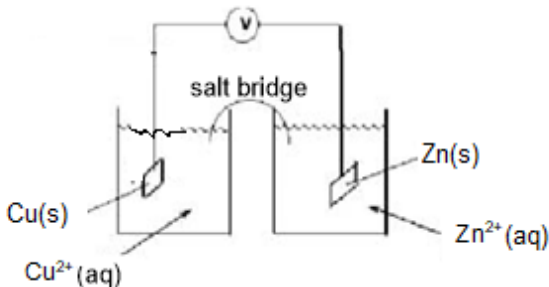
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Question	Answer	Marks
1(a)(i)	$\text{Sr}(\text{HCO}_3)_2 \rightarrow \text{SrCO}_3 + \text{CO}_2 + \text{H}_2\text{O}$	1
1(a)(ii)	M1: radius of cation / M^{2+} increases OR charge density of cation / M^{2+} decreases M2: less polarisation / less distortion of the anion / carbonate ion	2
1(b)	M1: least soluble $\text{CaF}_2 < \text{SrF}_2 < \text{BaF}_2$ most soluble M2: ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative M3: ΔH_{hyd} changes less / becomes less exothermic by a smaller extent OR ΔH_{latt} changes more / becomes less exothermic by a larger extent M4: ΔH_{sol} becomes more exothermic / more negative	4
1(c)(i)	enthalpy change when one mole of gaseous ions dissolve in water to form a solution	1
1(c)(ii)	M1: ionic radii AND ionic charge M2: (ionic) radii increase / charge density decreases AND ΔH_{hyd} decreases/less exothermic AND less attraction between water molecules and (gaseous) ions OR as ionic charge increases / charge density increases AND ΔH_{hyd} increases/more exothermic AND more attraction between water molecules and (gaseous) ions	2
1(d)	M1: use of -2957 / -1926 / -505 AND $2 \times (-505)$ M2: correct signs and evaluation ΔH_{sol} of $\text{MgF}_2(\text{s}) = -1926 + (2 \times -505) - (-2957) = (+)21 \text{ kJ mol}^{-1}$	2
1(e)(i)	M1: $K_{\text{sp}} = [\text{Hg}_2^{2+}] [\text{F}^-]^2$ M2: units = $\text{mol}^3 \text{ dm}^{-9}$	2
1(e)(ii)	$K_{\text{sp}} = 2^2 \times (9.20 \times 10^{-3})^3 = 3.11 \times 10^{-6}$ min 2sf	1

Question	Answer	Marks
2(a)	the (3)d and (4)s sub-shells / orbitals / electrons are close / similar in energy	1
2(b)	species or ion formed by a central metal atom/ion AND surrounded by/bonded to (one or more) ligands	1
2(c)(i)	NaOH / OH ⁻ (aq) AND precipitation / ligand exchange / deprotonation / acid–base	1
2(c)(ii)	M1: Fe(H₂O)₄(OH)₂ is oxidised (from + 2 to + 3 on standing) M2: $E^\ominus$ of Fe(H₂O)₃(OH)₃ is more negative than $E^\ominus$ of O₂ OR $E^\ominus_{\text{cell}} = 0.40 - (-0.56) = (+)0.96 \text{ V}$ M3: $4\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2 + \text{O}_2 \rightarrow 4\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 2\text{H}_2\text{O}$	3
2(d)	$\Delta G^\ominus = -2 \times 1.67 \times 96\,500 = -322\,310 \text{ J mol}^{-1}$ M1: $\Delta G^\ominus = -nE^\ominus_{\text{cell}}F$ AND $n = 2$ OR $-2 \times 1.67 \times 96\,500$ M2: $\Delta G^\ominus = -322.3 \text{ kJ mol}^{-1}$	2

Question	Answer	Marks
3(a)	heterogeneous AND MnO ₂ is in a different state / phase to the reactants / H ₂ O ₂	1
3(b)(i)	M1: (expt 2 and 3) [I⁻] × 2 initial rate × 2 so 1st order wrt [I⁻] M2: (expt 1 and 2) [I⁻] × 2, [H₂O₂] × 0.5 initial rate × 1 so 1st order wrt [H₂O₂] OR (expt 1 and 4) [I⁻] × 4 initial rate × 4 AND [H⁺] × 4 so zero order wrt [H⁺] OR (expt 1 and 3) [I⁻] × 4, [H₂O₂] × 0.5 initial rate × 2 so 1st order wrt [H₂O₂] M3: (expt 1 and 4) [I⁻] × 4, [H⁺] × 4 initial rate × 4 so zero order wrt [H⁺] OR (expt 3 and 4) [H₂O₂] × 2 initial rate × 2 AND [H⁺] × 4 so zero order wrt [H⁺] OR (expt 3 and 4) [H₂O₂] × 2, [H⁺] × 4 initial rate × 2 so 1st order wrt [H₂O₂] M4: rate = k [H₂O₂] [I⁻] OR rate = k [H₂O₂] [I⁻] [H⁺]⁰	4
3(b)(ii)	M1: $k = 2.42 \times 10^{-3} \div (0.045 \times 0.030) = 1.79 \text{ min } 2\text{sf}$ M2: units = dm³ mol⁻¹ s⁻¹	2
3(c)(i)	M1: calculation of one $t_{1/2} = 60 \text{ s} \pm 5 \text{ s}$ M2: two $t_{1/2}$ calculated that are constant	2
3(c)(ii)	$k = \ln 2 \div 60 = 0.0116$ OR $k = 0.693 \div 60 = 0.0116 \text{ min } 2\text{sf}$	1
3(d)	increases k and increases the rate of reaction	1
4(a)	M1: potential difference / voltage / EMF AND between two half-cells / two electrodes (in a cell) M2: (at concentration of) 1 mol dm⁻³ AND (pressure of) 1 atm / 101 kPa AND (temperature of) 298 K / 25 °C	2

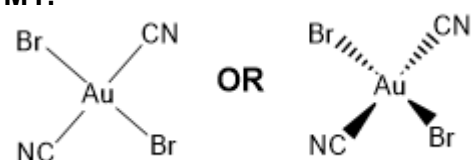
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Question	Answer	Marks
4(b)(i)	 M1: salt bridge labelled AND voltmeter / V AND wire to electrode and liquid level shown [complete circuit] M2: Cu(s) AND Cu²⁺(aq) M3: Zn(s) AND Zn²⁺(aq)	3
4(b)(ii)	ions AND electrons	1
4(b)(iii)	M1: Nernst equation $E = E^\ominus + (0.059/z) \log(\text{Zn}^{2+}/\text{Zn})$ M2: $E = -0.76 + (0.059 / 2) \log(0.25) = -0.778 \text{ V}$ OR $E = -0.76 + (8.31 \times 298) / (96\,500 \times 2) \ln(0.25) = -0.778 \text{ V min 2sf}$	2
4(c)(i)	(from) +4 (to) +3	1
4(c)(ii)	$\text{Zn} + 2\text{MnO}_2 \rightarrow \text{ZnO} + \text{Mn}_2\text{O}_3$	1
4(c)(iii)	$E^\ominus (\text{MnO}_2 / \text{Mn}_2\text{O}_3) = 1.47 - 1.28 = (+)0.19 \text{ V}$	1

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Question	Answer	Marks												
5(a)	<table><tr><th rowspan="2">species</th><th colspan="2">number of unpaired electrons</th></tr><tr><th>3d</th><th>4s</th></tr><tr><td>Cu</td><td>0</td><td>1</td></tr><tr><td>Cu²⁺</td><td>1</td><td>0</td></tr></table>	species	number of unpaired electrons		3d	4s	Cu	0	1	Cu ²⁺	1	0	1	
species	number of unpaired electrons													
	3d	4s												
Cu	0	1												
Cu ²⁺	1	0												
5(b)	• five 3d orbitals (lines, boxes) in the isolated Cu²⁺ ion of the same energy • splitting: three higher and two lower d orbitals • energy of all five d orbitals in complex higher than all d orbitals in isolated ion any two [1], all three [2]	2												
5(c)	M1: more than one (stable) oxidation state / exist in variable oxidation states M2: vacant / empty (d) orbitals are energetically accessible OR vacant / empty (d) orbitals can form dative bonds with ligands	2												
5(d)	<table><tr><th>metal ion</th><th>coordination number</th><th>formula of complex ion</th><th>charge of complex ion</th></tr><tr><td>Ag⁺</td><td>2</td><td><u>Ag</u>(CN)₂</td><td>1–</td></tr><tr><td>Fe²⁺</td><td>6</td><td><u>Fe</u>(CN)₆</td><td>4–</td></tr></table> each row [1]	metal ion	coordination number	formula of complex ion	charge of complex ion	Ag ⁺	2	<u>Ag</u> (CN) ₂	1–	Fe ²⁺	6	<u>Fe</u> (CN) ₆	4–	2
metal ion	coordination number	formula of complex ion	charge of complex ion											
Ag ⁺	2	<u>Ag</u> (CN) ₂	1–											
Fe ²⁺	6	<u>Fe</u> (CN) ₆	4–											

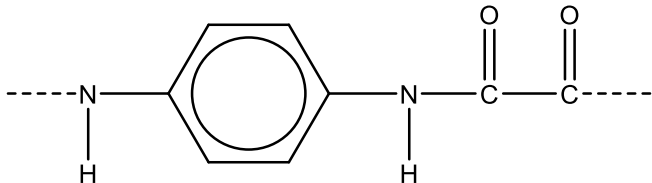
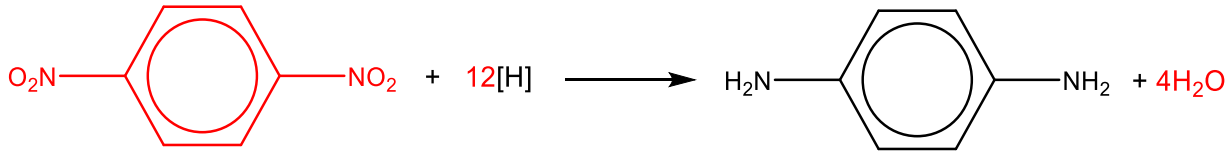
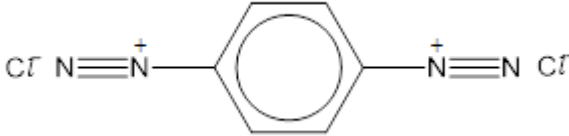
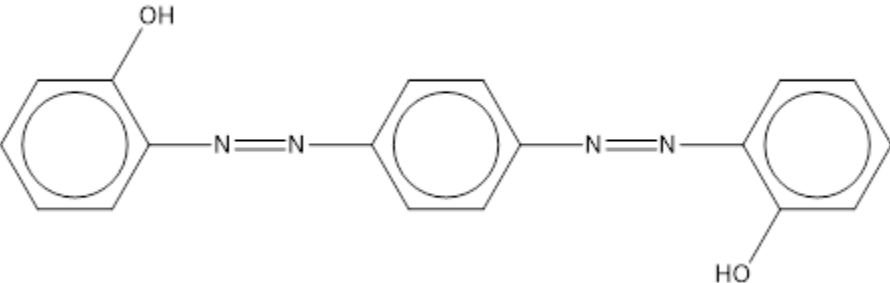
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Question	Answer	Marks
5(e)	M1:  M2: (shape) square planar AND (bond angle) 180°	2
5(f)(i)	M1: moles $\text{MnO}_4^- = 0.075 \times 0.0225 = 1.6875 \times 10^{-3}$ M2: moles $\text{V}^{2+} = 5 / 3 \times 1.6875 \times 10^{-3} = 2.8125 \times 10^{-3}$ M3: mass V = $50.9 \times 2.8125 \times 10^{-3} = 0.143 \text{ g}$ % of V = $0.143 / 0.250 \times 100 = 57.3 \text{ min } 2\text{sf}$	3
5(f)(ii)	$2\text{VO}_3^- + 3\text{Zn} + 12\text{H}^+ \rightarrow 2\text{V}^{2+} + 3\text{Zn}^{2+} + 6\text{H}_2\text{O}$ M1: 2 : 3 ratio on both sides M2: rest of the equation correct	2

Question	Answer	Marks
6(a)(i)	M1: (R_f value) is distance moved by a component / spot / solute AND divided by distance moved by solvent OR (R_f value) is the ratio of distance moved by a component / spot / solute AND by distance moved by solvent M2: (retention time) is (the time) between injection and detection (of a component)	2

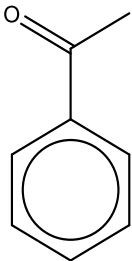
Question	Answer	Marks						
6(a)(ii)	thin-layer chromatography: polar solvent OR non-polar solvent OR named solvent gas-liquid chromatography: non-volatile liquid OR high boiling point liquid	1						
6(b)	A is more soluble in the mobile phase OR A has less adsorption to the stationary phase	1						
6(c)(i)	<table><tr><td>compound</td><td>number of peaks observed</td></tr><tr><td>Y</td><td>2</td></tr><tr><td>Z</td><td>2</td></tr></table>	compound	number of peaks observed	Y	2	Z	2	1
compound	number of peaks observed							
Y	2							
Z	2							
6(c)(ii)	M1: Y (two) singlet(s) M2: Z triplet AND quartet	2						

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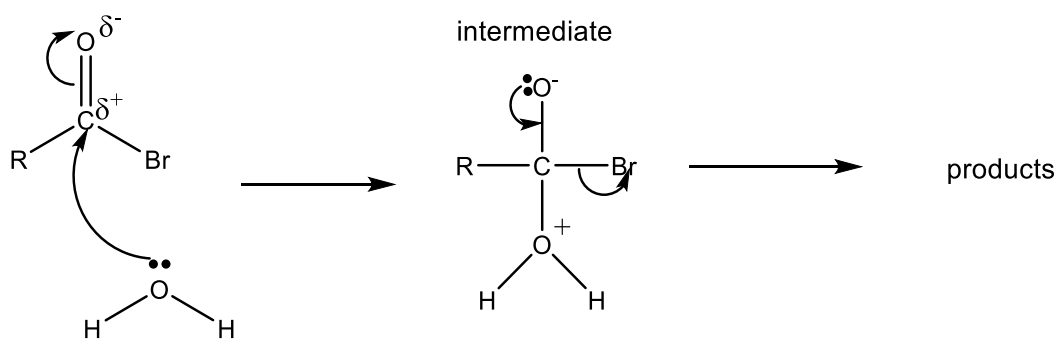
Question	Answer	Marks
7(c)(i)	 M1: correct displayed amide bond with C=O, (C₆H₅)–N and (C–)C=O M2: rest of the structure correct with continuation bonds	2
7(c)(ii)		1
7(d)(i)	M1:  M2: 	2

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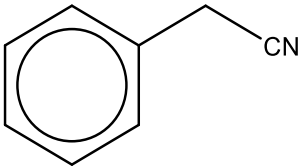
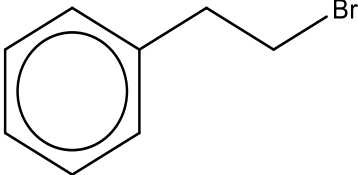
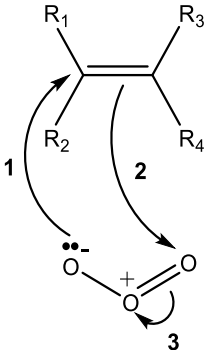
Question	Answer	Marks
7(d)(ii)	HNO ₂ (and HCl) AND ≤10 °C OR NaNO ₂ AND HCl AND ≤10 °C	1

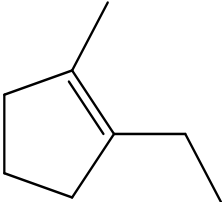
Question	Answer	Marks
8(a)(i)	NO ₂ group directs to 3 (and 5) / meta position AND due to being an electron-withdrawing / electronegative group	1
8(a)(ii)	HNO ₃ + H ₂ SO ₄ → NO ₂ ⁺ + HSO ₄ ⁻ + H ₂ O OR HNO ₃ + 2H ₂ SO ₄ → NO ₂ ⁺ + 2HSO ₄ ⁻ + H ₃ O ⁺	1
8(b)(i)		1
8(b)(ii)	M1: (reaction 1) ethanoyl chloride / CH ₃ COCl AND AlCl ₃ M2: (reaction 2) 2-bromopropane / (CH ₃) ₂ CHBr AND FeBr ₃	2
8(c)	M1: with C ₆ H ₅ Br no change / no precipitate AND with C ₆ H ₅ CH ₂ Br cream precipitate in C ₆ H ₅ Br M2: lone pair / p-orbital on Br delocalised / overlaps with ring / π system M3: C–Br bond stronger / has partially double bond character	3

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Question	Answer	Marks
8(d)(i)	(nucleophilic) addition–elimination	1
8(d)(ii)	 M1 M2: • lone pair on O • curly arrow from (lone pair) O (in H₂O) to C (of C=O) • correct dipole on C=O • curly arrow from the C=O bond to O atom any two [1], all four [2] M3: correct intermediate M4: curly arrow from (lone pair on) O⁽⁻⁾ to C–O bond AND curly arrow from C–Br to Br	4

Question	Answer	Marks
9(a)	M1: (basicity linked to) ability of lone pair / p-orbital to AND accept / coordinate with a proton / H⁺ M2: (lone pair of) electrons on N is delocalised into C=O group (and make amides neutral)	2

Question	Answer	Marks
9(b)(i)	M1: M  M2: N 	2
9(b)(ii)	LiAlH ₄	1
9(c)	ketone / carbonyl AND secondary / 2°	1
9(d)(i)	 curly arrow 1: from O lone pair to C atom (in C=C) curly arrow 2: from C=C bond to the right-hand O atom in O=O curly arrow 3: from O=O bond to O⁺	2

Question	Answer	Marks
9(d)(ii)		1

Cambridge International AS & A Level

CHEMISTRY**9701/44**

Paper 4 A Level Structured Questions

October/November 2025**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 October/November 2025 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

This document consists of **16** 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.

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

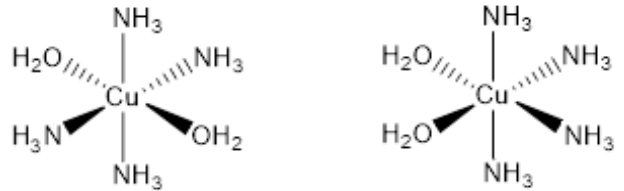
The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	Correct point or mark awarded
	Incorrect point or mark not awarded
	Unclear
	Information missing or insufficient for credit
	Benefit of the doubt given
	Contradiction in response otherwise markworthy, mark not given
	Part of the correct answer has been seen. Full credit has not been awarded.
	Error carried forward applied
	Incorrect or insufficient point ignored while marking the rest of the response
	Rounding error

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Annotation	Meaning
REP	Repetition
SEEN	Blank page or part of script seen
SF	Error in number of significant figures
TE	Transcription error

Question	Answer	Marks
1(a)	forms (one or more) stable ions / compounds / oxidation states with incomplete / partially filled (3)d orbital(s) / d shell / d sub-shell	1
1(b)(i)	(orbitals) are at the same energy	1
1(b)(ii)	$(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^9$	1
1(c)(i)	$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}(\text{aq})$ deep / dark / royal blue AND $[\text{CuCl}_4]^{2-}(\text{aq})$ yellow	1
1(c)(ii)	M1: d orbital(s) of different energy / d-d splitting occurs / d sub-shell splits M2: electron(s) promoted / excited M3: light / wavelength / frequency / photon absorbed AND complementary colour seen	3
1(d)(i)	M1: ligand exchange / replacement / substitution / displacement M2: $[\text{CuCl}_4]^{2-} + 4\text{NH}_3 + 2\text{H}_2\text{O} \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{Cl}^-$	2
1(d)(ii)	M1: one correct 3D structure of $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$ M2: correct 3D stereoisomer structure of isomer 1 	2
1(d)(iii)	cis isomer AND dipoles do not cancel	1
1(e)(i)	(two) oxygen and (one) nitrogen (can donate) three lone pair(s) of electrons (to the metal ion)	1

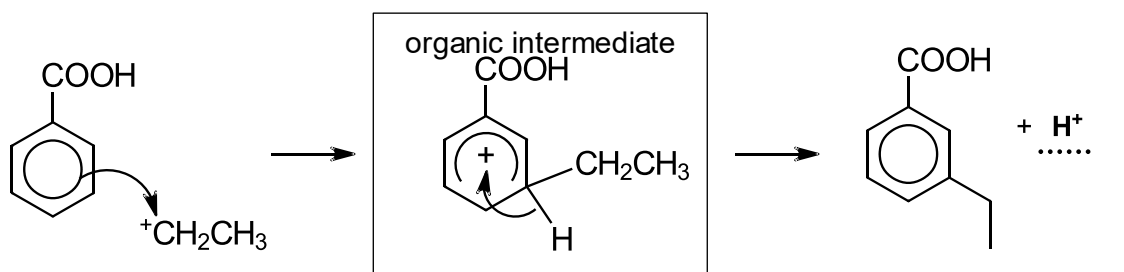
Question	Answer	Marks
1(e)(ii)	$[\text{Co}(\text{C}_4\text{H}_5\text{NO}_4)_2]^-$	1
1(f)(i)	equilibrium constant for the formation of the complex (ion) in a solvent / water / solution OR from its constituent ions or molecules	1
1(f)(ii)	$[\text{Ag}(\text{CN})_2]^-$ (aq) AND largest (value of) K_{stab}	1
1(g)	M1 M2: any two [1], all four [2] - moles $\text{MnO}_4^- = 0.015 \times 18.70 / 1000 = 2.805 \times 10^{-4}$ - moles $\text{SO}_3^{2-} = 2.805 \times 10^{-4} \times 5/2 = 7.0125 \times 10^{-4}$ (in 10 cm³) - moles $\text{SO}_3^{2-} = 1.753 \times 10^{-2}$ (in 250 cm³) - mass $\text{Na}_2\text{SO}_3 = 1.753 \times 10^{-2} \times 126.1 = 2.21$ g M3: % purity = $100 \times 2.21 / 3.75 = 58.9 - 59.0 \%$ min 2sf	3

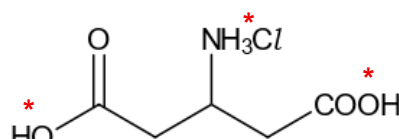
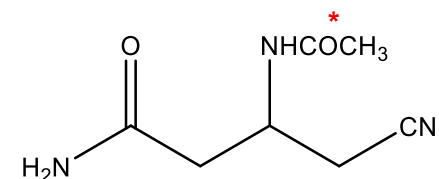
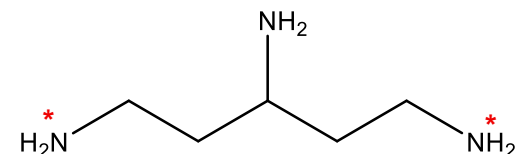
Question	Answer	Marks
2(a)	M1: (solubility) decreases down the group M2: ΔH_{latt} and ΔH_{hyd} decrease / become less exothermic / less negative M3: ΔH_{hyd} decreases / changes more / dominant factor / becomes less exothermic by a larger extent OR ΔH_{latt} decreases / changes less / changes slower M4: ΔH_{sol} becomes less exothermic / less negative OR ΔH_{sol} becomes (more) endothermic / (more) positive	4
2(b)(i)	$\text{Ag}_2\text{CrO}_4(\text{s}) \rightleftharpoons 2\text{Ag}^+(\text{aq}) + \text{CrO}_4^{2-}(\text{aq})$	1
2(b)(ii)	M1: $K_{\text{sp}} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$ M2: $\sqrt[3]{(1.12 \times 10^{-12} \div 4)} = 6.54 \times 10^{-5}$ M3: $[\text{Ag}^+] = 2 \times 6.54 \times 10^{-5} = 1.31 \times 10^{-4}$ (mol dm⁻³) min 2sf	3

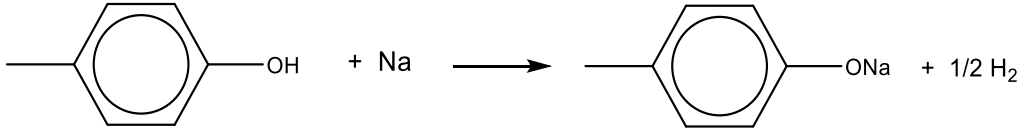
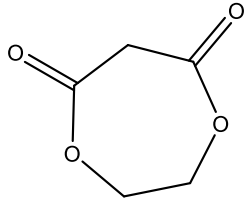
Question	Answer	Marks
2(c)(i)	$K_a = 10^{-6.49} = 3.236 \times 10^{-7}$ $[H^+]^2 = 8.08984 \times 10^{-9}$ M1: $[H^+] = 8.99 \times 10^{-5}$ M2: $pH = -\log(8.99 \times 10^{-5}) = 4.05$ min 2sf	2
2(c)(ii)	conjugate acid H_2CrO_4 AND conjugate base CrO_4^{2-}	1
2(d)(i)	(the energy change / released when) one mole of gaseous atoms become 1^- ions / gain one mole of electrons	1
2(d)(ii)	due to repulsion between negative ion and incoming / gained electron	1
2(d)(iii)	$2Ag^+(g) \ S^{2-}(g) \rightarrow Ag_2S(s)$	1
2(d)(iv)	M1: selection of correct six numbers only: $-33, 731, 279, -200, 532, -2677$ M2: use of $\times 2$ as only multiplier with Ag M3: correct signs and evaluation of data $-33 = 2\Delta H_{at} + (2 \times 731) + 279 + (-200) + 532 + (-2677)$ $2\Delta H_{at} = 571 \text{ (kJ mol}^{-1}\text{)}$ $\Delta H_{at} = +285.5 \text{ (kJ mol}^{-1}\text{)}$	3
2(e)	Ag_2S smaller / less negative / less exothermic lattice neergy AND larger ionic radius (of cation)	1

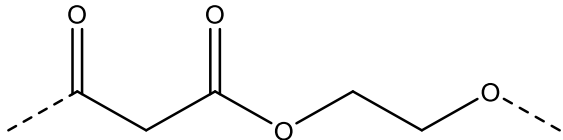
Question	Answer	Marks									
3(a)	number of possible arrangements of particles and energy in a system	1									
3(b)(i)	<table border="1"> <thead> <tr> <th>process</th><th>ΔS is negative</th><th>ΔS is positive</th></tr> </thead> <tbody> <tr> <td>steam condensing into water</td><td>✓</td><td></td></tr> <tr> <td>solid KCl dissolving into water</td><td></td><td>✓</td></tr> </tbody> </table>	process	ΔS is negative	ΔS is positive	steam condensing into water	✓		solid KCl dissolving into water		✓	1
process	ΔS is negative	ΔS is positive									
steam condensing into water	✓										
solid KCl dissolving into water		✓									
3(b)(ii)	M1: three numbers and correct multipliers used M2: correct signs and evaluation $\Delta S^\circ = (3 \times 203.0) + (223.1) - (2 \times 281.6) = (+)268.9 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$	2									
3(c)(i)	positive AND gas produced / on the right OR less / no gas on left	1									
3(c)(ii)	M1 and M2: calculation of gradient from the graph for ΔS gradient = $(-)/140 / 900 = (-)0.1556$ $\Delta S^\circ = (-)0.1556 \times 1000$ $= (+)155.6 \pm 5 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ M3: $T = 1120 \pm 5 \text{ (K)}$ M4: $\Delta H^\circ = (+)172 \pm 10 \text{ (kJ mol}^{-1}\text{)}$	4									

Question	Answer	Marks						
4(a)(i)	<table><tr><td>the order of reaction with respect to [H₂]</td><td>1</td></tr><tr><td>the order of reaction with respect to [NO]</td><td>2</td></tr><tr><td>overall order of the reaction</td><td>3</td></tr></table>	the order of reaction with respect to [H ₂]	1	the order of reaction with respect to [NO]	2	overall order of the reaction	3	1
the order of reaction with respect to [H ₂]	1							
the order of reaction with respect to [NO]	2							
overall order of the reaction	3							
4(a)(ii)	rate × $\frac{1}{4}$	1						
4(a)(iii)	rate × 27	1						
4(a)(iv)	a four-particle collision is unlikely	1						
4(a)(v)	step 1 2NO → N ₂ O ₂ step 2 N ₂ O ₂ + H ₂ → N ₂ O + H ₂ O step 3 N ₂ O + H ₂ → N ₂ + H ₂ O	2						
4(a)(vi)	intermediate formed (step 2) then used up later (step 3)	1						
4(b)	$k = 0.693 / 720 = 9.625 \times 10^{-4} \text{ min}^{-1}$ 2sf AND units: s ⁻¹	1						
4(c)(i)	homogeneous AND Co ³⁺ / catalyst / it is in the same phase / same state as the reactants	1						
4(c)(ii)	M1: (equation 1) 2Co ³⁺ + 2I ⁻ → 2Co ²⁺ + I ₂ M2: (equation 2) 2Co ²⁺ + S ₂ O ₈ ²⁻ → 2Co ³⁺ + 2SO ₄ ²⁻	2						
4(c)(iii)	repulsion of two negative / same charge ions slows the reaction / raises <i>E</i> _A	1						

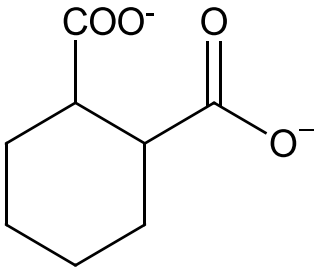
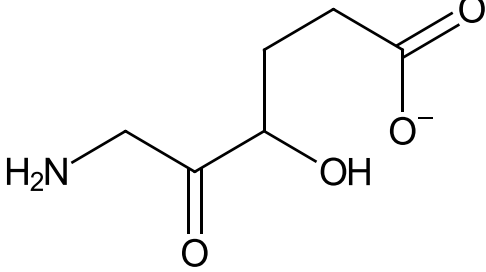
Question	Answer	Marks
5(a)	M1 and M2: any two [1], all three [2] • (hexagonal ring) planar / (trigonal) planar • 120° • sp² hybridised M3: p orbitals overlap sideways / laterally (with each other above and below the ring) forming π bonds M4: σ bonds form when sp² / hybridised orbitals overlap end-on-end / head on	4
5(b)(i)	M1: (reaction 5) Pt / Ni + H₂ (+ heat) M2: (reaction 6) (CH₃)₂CHCOCl + AlCl₃ (+ heat)	2
5(b)(ii)	reduction / hydrogenation	1
5(c)(i)	(CH ₂ CH ₃ group) directs to 2-, 4- (and 6-) positions AND due to being an electron donating group	1
5(c)(ii)	CH ₃ CH ₂ Br + FeBr ₃ → CH ₃ CH ₂ ⁺ + FeBr ₄ ⁻	1
5(c)(iii)	 M1: curly arrow from inside / touching the hexagon to (CH₂) group / C⁺ charge M2: structure of the intermediate M3: curly arrow from C-H bond into / onto the ring AND formation / loss of H⁺	3
5(c)(iv)	H ⁺ + FeBr ₄ ⁻ → HBr + FeBr ₃	1

Question	Answer	Marks												
6(a)	sp = 1 AND sp ² = 1 AND sp ³ = 3	1												
6(b)(i)	acid-base / neutralisation AND hydrolysis	1												
6(b)(ii)	reaction 7  reaction 8  reaction 9  any two * [1], any three * [2], any five * [3], all six * [4]	4												
6(c)(i)	five / 5	1												
6(c)(ii)	<table border="1"><thead><tr><th>proton environment</th><th>a</th><th>b</th><th>c</th></tr></thead><tbody><tr><td>name of splitting pattern</td><td>doublet</td><td>multiplet</td><td>doublet</td></tr><tr><td>chemical shift range, δ / ppm</td><td>2.2–3.0</td><td>3.2–4.0</td><td>2.0–3.0</td></tr></tbody></table> any three [1], all six [2]	proton environment	a	b	c	name of splitting pattern	doublet	multiplet	doublet	chemical shift range, δ / ppm	2.2–3.0	3.2–4.0	2.0–3.0	2
proton environment	a	b	c											
name of splitting pattern	doublet	multiplet	doublet											
chemical shift range, δ / ppm	2.2–3.0	3.2–4.0	2.0–3.0											

Question	Answer	Marks
7(a)	M1: (most acidic) benzoic acid 4-methylphenol water (least acidic) phenylmethanol M2: correct link of acidity to weakens O—H / H⁺ more easily lost / anion stabilised / conjugate base stabilised M3 and M4: any two [2] - for benzoic acid: negative inductive effect of C=O / electronegative C=O / two electronegative O / –ve charge delocalised (across two O) / resonance in –COO[–] - for 4-methylphenol: as lone pair on oxygen delocalised into the ring / π system / delocalised system OR p orbital on oxygen overlaps with ring / π system / delocalised system - for phenylmethanol: positive inductive effect of alkyl group / R / CH₂	4
7(b)		1
7(c)(i)		1
7(c)(ii)	(reaction 10) addition–elimination / condensation / esterification AND (reaction 11) addition–elimination / condensation (polymerisation) / esterification	1

Question	Answer	Marks
7(c)(iii)	 M1: ester linkage shown M2: rest of the structure correct with continuation bonds	2

Question	Answer	Marks
8(a)	- chlorobenzene is less reactive than ethanoyl chloride - p orbital / lone pair on Cl / –Cl will overlap / delocalise into the ring OR C of COCl has most electron deficient OR has an electronegative oxygen atom / two electronegative atoms / electron withdrawing C=O group - due to partial double C–Cl bond OR C–Cl bond strengthened (more) / stronger bond between Cl and benzene / ring OR C–Cl weakened in ROCl any two [1], all three [2]	2
8(b)(i)	- nitrile - amide - ketone / carbonyl - ester any two [1], all four [2]	2
8(b)(ii)	8 / eight	1
8(b)(iii)	no need to separate optical isomers	1

Question	Answer	Marks
8(c)	  M1: amide bond hydrolysed and COO⁻ and NH₂ formed M2: nitrile bond hydrolysed and COO⁻ formed M3: ester bond hydrolysed and COO⁻ and OH formed	3
8(d)(i)	percentage = $100 \times 28 / (28 + 58 + 13 + 42) = 19.9 (\%)$ min 2sf	1
8(d)(ii)	D is attracted more strongly to the stationary phase / forms stronger intermolecular forces with the stationary phase	1