



Cambridge International AS & A Level

CHEMISTRY

9701/41

Paper 4 A Level Structured Questions

May/June 2022

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.

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This document consists of **15** 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 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).

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- 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.

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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 | <p><u>'List rule' guidance</u></p> <p>For questions that require <i>n</i> responses (e.g. State two reasons ...):</p> <ul style="list-style-type: none"> • 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. |

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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.

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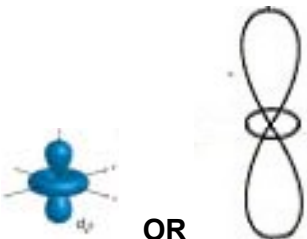
7 Guidance for chemical equations

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 ΔH_{latt} and ΔH_{hyd} decrease / both become less exothermic / less negative M2 ΔH_{latt} decreases / changes less/becomes less exothermic by a smaller extent OR ΔH_{hyd} decreases / changes more / dominant factor M3 ΔH_{sol} becomes less exothermic / less negative OR ΔH_{sol} becomes (more) endothermic / (more) positive OR $\Delta H_{\text{sol}} = \Delta H_{\text{hyd}} - \Delta H_{\text{latt}}$ expression AND reaction becomes less exothermic	3
1(b)	Mg: fizzing Ba: (fizzing and) white solid/ppt forms	1
1(c)	M1 solubility of BaSO_4 $= \sqrt{1.08 \times 10^{-10}} = 1.04 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ M2 $= 1.04 \times 10^{-5} \times 233.4 / 10 = 2.43 \times 10^{-4} \text{ (g per 100 cm}^3\text{ of solution)}$ min 2sf	2
1(d)(i)	$-1473 = 180 + 503 + 965 + \Delta H_{\text{f}}^{\ominus} - 2469$ $\Delta H_{\text{f}}^{\ominus}$ of $\text{SO}_4^{2-}(\text{g}) = -652 \text{ kJ mol}^{-1}$ M1 correct five values used [1] M2 only correct five values used [1] M3 correct signs and evaluation [1]	3
1(d)(ii)	• BaSO_4 is more negative/bigger • as Ba^{2+} is smaller OR Ba^{2+} has a larger charge • stronger force of attraction between the ions One mark for two correct Two marks for all three correct	2

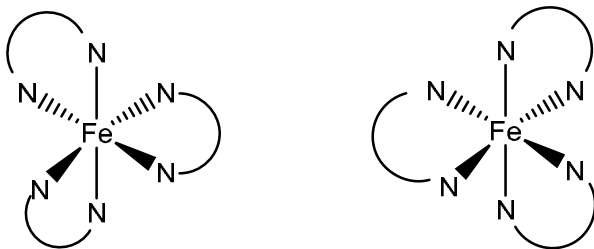
Question	Answer	Marks
1(e)(i)	M1 $\Delta G^\circ = 0$ so $T = \Delta H_r^\circ / \Delta S^\circ$ M2 $T = 132 / 0.616 = 214.3 \text{ K}$ $T = -58.7^\circ \text{C}$ min 2sf	2
1(e)(ii)	M1 $\Delta S^\circ = (203 + (70 \times 8) + (2 \times 192)) - (427 - (2 \times 95)) = +530 \text{ J K}^{-1} \text{ mol}^{-1}$ M2 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ M3 $\Delta G^\circ = 133 - (298 \times 0.530) = -24.9 \text{ kJ mol}^{-1}$ ecf 1dp min	3

Question	Answer	Marks
2(a)	forms one or more stable ions / compounds / oxidation states with incomplete / partially filled (3)d-orbital(s) / d-shell / d-subshell	1
2(b)		1
2(c)(i)	the catalyst and the reactants are in a different state / phase	1
2(c)(ii)	M1 adsorption of reactants to the surface of the catalyst M2 bonds in the reactants weaken (lowering the activation energy) M3 reaction occurs and the products are desorbed	3

Question	Answer	Marks
2(d)	M1 reaction 1: $2\text{KMnO}_4 + \text{H}_2\text{SO}_4 \rightarrow \text{Mn}_2\text{O}_7 + \text{H}_2\text{O} + \text{K}_2\text{SO}_4$ OR $2\text{KMnO}_4 + 2\text{H}_2\text{SO}_4 \rightarrow \text{Mn}_2\text{O}_7 + \text{H}_2\text{O} + 2\text{KHSO}_4$ M2 reaction 2: $\text{Mn}_2\text{O}_7 \rightarrow 2\text{MnO}_2 + 1.5\text{O}_2$	2
2(e)(i)	M1 $[\text{Mn}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Mn}(\text{OH})_2 + 6\text{H}_2\text{O}$ M2 precipitation / acid-base / deprotonation	2
2(e)(ii)	M1 $[\text{Mn}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{MnCl}_4]^{2-} + 6\text{H}_2\text{O}$ M2 ligand exchange / substitution / replacement / displacement	2
2(e)(iii)	MnO_2 AND redox	1

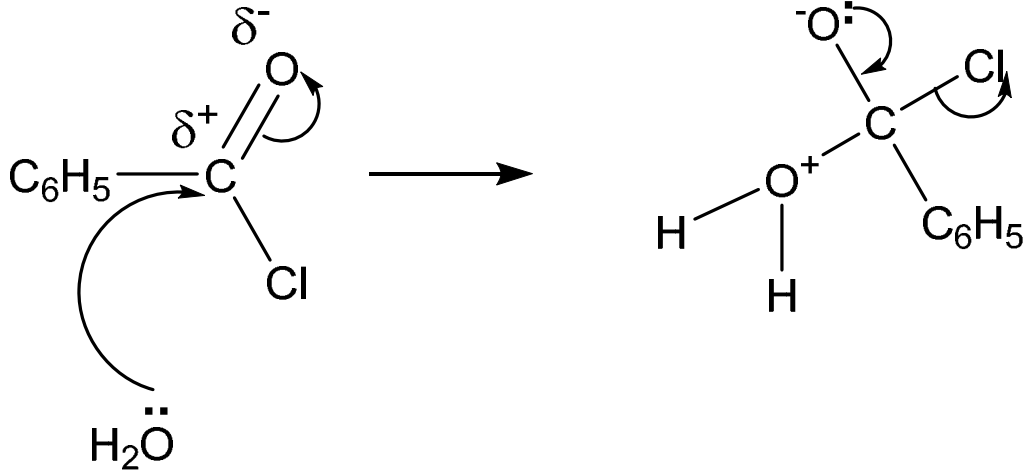
Question	Answer	Marks
3(a)(i)	evidence of tangent drawn at $t = 40$ s and calculation of gradient $= 0.000170 \text{ (mol dm}^{-3} \text{ s}^{-1}) \text{ min 2sf}$	1
3(a)(ii)	M1 evidence of construction lines and calculation of two $t_{1/2}$ OR evidence of construction lines and times for halving of concentration M2 deduction: constant half-life / constant time between halving of concentration $\rightarrow$ 1st order	2
3(b)	M1 two half-lives in 320 s so $t_{1/2} = 160$ s M2 $k = 0.693 / 160 = 0.00433 \text{ s}^{-1}$ ecf min 2sf	2
3(c)(i)	voltage / EMF / potential difference when a half-cell is connected to a (standard) hydrogen electrode under standard conditions	1
3(c)(ii)	ions move (from the salt bridge) to maintain charge balance / complete the circuit	1

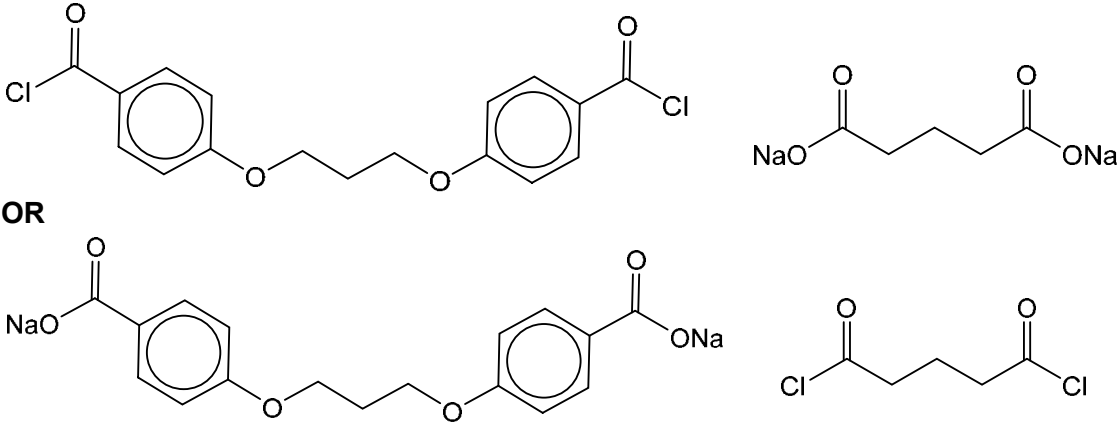
Question	Answer	Marks
3(c)(iii)	298K, 1 atm, 1 mol dm⁻³ Pt, H₂(g), good delivery system, 298 K, 1 atm Pt, Cr₂O₇²⁻(aq), H⁺(aq) / Cr³⁺(aq), 1 mol dm⁻³ seen once, voltmeter three for one mark, six for two marks, nine for three marks	3
3(c)(iv)	SHE labelled negative AND arrow in the external circuit moving away from this electrode	1
3(d)(i)	M1 $\text{Cr}_2\text{O}_7^{2-} + 3\text{CH}_3\text{CHO} + 8\text{H}^+ \rightleftharpoons 2\text{Cr}^{3+} + 3\text{CH}_3\text{COOH} + 4\text{H}_2\text{O}$ ALLOW $\text{Cr}_2\text{O}_7^{2-} + 3\text{CH}_3\text{CHO} + 5\text{H}^+ \rightleftharpoons 2\text{Cr}^{3+} + 3\text{CH}_3\text{COO}^- + 4\text{H}_2\text{O}$ M1 $E_{\text{cell}}^\ominus = +2.27 \text{ (V)}$	2
3(d)(ii)	M1 $\Delta G^\ominus = -nFE_{\text{cell}}^\ominus$ M2 $\Delta G^\ominus = -4 \times 96\,500 \times 2.01 = -775\,860 \text{ J mol}^{-1}$ $\Delta G^\ominus = -776 \text{ kJ mol}^{-1} \text{ min 3sf}$	2

Question	Answer	Marks
4(a)	• five 3d orbitals in the isolated Fe^{2+} ion of same energy • splitting two higher and three lower d orbitals • energy of non-degenerate d orbitals in the complex more than degenerate d orbitals in isolated ion two for one mark, three for two marks	2
4(b)(i)	M1 (a species) that donates / uses two lone pairs M2 to form dative / coordinate bonds to a metal atom / metal ion / TM / TE / metal	2
4(b)(ii)	 M1 one correct 3D diagram with three bipy ligands M2 both diagrams correct M3 optical isomerism	3
4(c)	$[\text{Fe}(\text{CN})_6]^{3-}$ AND equilibrium lies most to the left / lowest $E^\ominus$ value	1
4(d)	M1 N sp^2 AND C sp^2 M2 σ bonds are formed by end-on-end overlap orbitals between C-H / C-C / C-N M3 π bonds are formed by sideways overlap of p orbitals between C-N / C-C	3

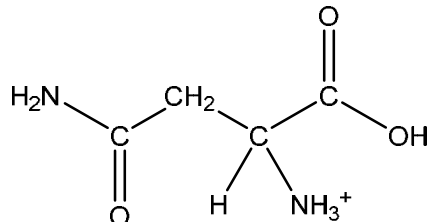
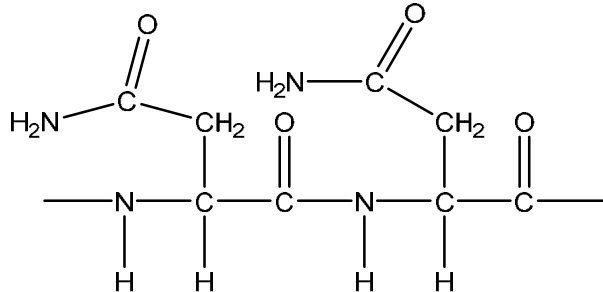
Question	Answer	Marks
4(e)	pyridine 3-chloropyridine + H⁺ M1 first curly arrow to Cl⁺ M2 correct intermediate M3 second curly arrow AND H⁺ formed / lost	3

Question	Answer	Marks																
5(a)	M1 benzoic acid > phenol > phenylmethanol M2 / M3 Any two of: - in benzoic acid negative inductive effect of C=O AND O-H bond is weakened OR due to delocalisation of minus charge by C=O / 2O carboxylate ion is stabilised - in phenol lone pair on oxygen is delocalised into the ring AND O-H bond is weakened - in phenyl methanol positive inductive effect of CH₂ group AND O-H bond is strengthened	3																
5(b)	<table><tr><td></td><td>benzoic acid</td><td>phenylmethanol</td><td>phenol</td></tr><tr><td>Na(s)</td><td>✓</td><td>✓</td><td>✓</td></tr><tr><td>NaOH(aq)</td><td>✓</td><td>✗</td><td>✓</td></tr><tr><td>Na₂CO₃(aq)</td><td>✓</td><td>✗</td><td>✗</td></tr></table> Three correct for one mark, six correct for two marks, nine correct for three marks		benzoic acid	phenylmethanol	phenol	Na(s)	✓	✓	✓	NaOH(aq)	✓	✗	✓	Na ₂ CO ₃ (aq)	✓	✗	✗	3
	benzoic acid	phenylmethanol	phenol															
Na(s)	✓	✓	✓															
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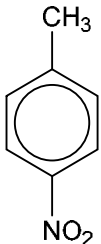
Question	Answer	Marks
5(c)(i)	POCl_3 and HCl AND SO_2 and HCl	1
5(c)(ii)	all the by-products / SO_2 and HCl are gaseous OR no liquid by-products formed	1
5(d)(i)	 On the left-hand side: • lone pair on O • correct arrow from O to C (of $\text{C}=\text{O}$) • dipole on $\text{C}=\text{O}$ • correct arrow on $\text{C}=\text{O}$ M1 / M2 Two correct for one mark, four correct for two marks On the right-hand side: M3 correct intermediate M4 arrow from lone pair on O^- to $\text{C}-\text{O}$ bond AND arrow from $\text{C}-\text{Cl}$ to Cl	4
5(d)(ii)	addition-elimination	1

Question	Answer	Marks
5(e)(i)	 OR	2
5(e)(ii)	hydrolysis OR heating in dilute acid / alkali	1

Question	Answer	Marks						
6(a)	a mixture containing equal amounts of each optical isomer	1						
6(b)	<table border="1"> <tr> <td></td><td>carbon-13 NMR</td><td>proton NMR</td></tr> <tr> <td>number of peaks in CDCl_3</td><td>4</td><td>5</td></tr> </table>		carbon-13 NMR	proton NMR	number of peaks in CDCl_3	4	5	1
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6(c)(i)	the pH at which an amino acid exists as a zwitterion OR the pH at which an amino acid has no overall charge	1						

Question	Answer	Marks								
6(c)(ii)		1								
6(d)	 M1 peptide bond displayed M2 rest of the structure correct + continuation bonds	2								
6(e)	<table border="1" data-bbox="878 912 1391 1176"><thead><tr><th>spot</th><th>identity</th></tr></thead><tbody><tr><td>E</td><td>Asn</td></tr><tr><td>F</td><td>Lys-Asn</td></tr><tr><td>G</td><td>Lys</td></tr></tbody></table> M1 table correctly completed M2 Lys and Lys-Asn are positively charged OR Asn is (nearly) uncharged M3 Lys-Asn has the highest M_r	spot	identity	E	Asn	F	Lys-Asn	G	Lys	3
spot	identity									
E	Asn									
F	Lys-Asn									
G	Lys									
6(f)(i)	aluminum oxide / silica (on solid support) AND inert gas / named inert gas e.g. N ₂	1								
6(f)(ii)	S AND R_f is the same as the unknown amino acid in both solvents	1								

Question	Answer	Marks
6(g)	mass of L = $58 / 44 \times 5.52 \times 10^{-2} = 7.28 \times 10^{-2} \text{ g}$ conc. of L = $7.28 \times 10^{-2} / 116 = 6.27 \times 10^{-4} \text{ (mol dm}^{-3}\text{) min 2sf}$	1

Question	Answer	Marks
7(a)(i)	phenylamine AND amine AND ester	1
7(a)(ii)	sp carbons = 0, sp ² carbons = 7, sp ³ carbons = 6	1
7(b)	6	1
7(c)	lone pair on the N can accept a proton	1
7(d)(i)		1
7(d)(ii)	step 1 M1 concentrated HNO ₃ and H ₂ SO ₄ step 2 M2 hot (alkaline) KMnO ₄ (followed by addition of H ⁺)	2
7(e)	step 4 M1 HOCH ₂ CH ₂ N(CH ₂ CH ₃) ₂ step 5 M2 Sn AND HCl M3 concentrated (HCl) AND heat / reflux	3
7(f)(i)	M1 ratio of the concentration of a solute in two solvents M2 at equilibrium	2

Question	Answer	Marks
7(f)(ii)	M1 $K_{pc} = [\text{procaine}]_{\text{oct}} / [\text{procaine}]_{\text{water}}$ $1.77 = (x / 50) / (0.5 - x / 75)$ M2 $1.77 = 1.5x / 0.5 - x$ $0.885 - 1.77x = 1.5x$ $x = 0.271 \text{ g min 2sf}$	2



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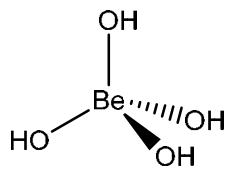
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1(b)(i)	M1 $K_{\text{sp}} = [\text{Be}^{2+}][\text{OH}^-]^2$ M2 $\text{mol}^3 \text{dm}^{-9}$ ecf	2
1(b)(ii)	M1 solubility of $\text{Be}(\text{OH})_2 = 2.40 \times 10^{-6} / 43 = 5.58 \times 10^{-8} (\text{mol dm}^{-3})$ ecf (b)(i) M2 $K_{\text{sp}} = 4 \times (5.58 \times 10^{-8})^3 = 6.95 \times 10^{-22}$ ecf min 2sf	2
1(c)(i)	as a molecule or ion formed by a central metal atom / metal ion dative bonded to / surrounded by one or more ligands	1
1(c)(ii)	 tetrahedral and correct 3D structure	1
1(d)(i)	d orbitals that are energetically accessible OR empty / vacant d orbitals AND form dative bonds / accept a lone pair from a ligand	1

Question	Answer				Marks
1(d)(ii)	complex ion	shape	coordination number	polarity	2
	cis-[Pt(en)Cl ₂]	square planar	4	polar	
	[Ag(NH ₃) ₂] ⁺	linear	2	non-polar	
	[Fe(C ₂ O ₄) ₃] ³⁻	octahedral	6	non-polar	
	three for one mark, six for two marks				
1(e)(i)	the equilibrium constant for the formation of the complex ion in a solvent (from its constituent ions or molecules)				1
1(e)(ii)	M1 $K_{\text{stab}} = [\text{Ni}(\text{en})_3^{2+}] / [\text{Ni}(\text{H}_2\text{O})_6^{2+}][\text{en}]^3$ M1 units = mol ⁻³ dm ⁹ ecf				2
1(e)(iii)	the equilibria lie to the right / product side OR equilibrium 1 lies more to the right AND <i>en</i> complex is more stable / [Ni(en) ₃] ²⁺ is more stable				1

Question	Answer	Marks
2(a)	the d and s sub-shells / orbitals are close / similar in energy	1
2(b)		1

Question	Answer	Marks
2(c)	M1 (in a complex / in the presence of ligands) the d-orbitals are split into two sets of orbitals M2 as an electron is excited / promoted M3 visible light is absorbed AND colour seen is complementary	3
2(d)(i)	$\text{Cu}(\text{OH})_2$: (pale / light) blue $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$: dark / deep blue	1
2(d)(ii)	(addition of OH^-) increases $[\text{OH}^-]$ AND shifts equilibrium to the right	1
2(e)	 M1 one correct 3D diagram with the six correct ligands M2 both 3D diagrams correct	2

Question	Answer	Marks
3(a)(i)	- enthalpy change / energy change - one mole of electrons (gained by) one mole of gaseous atoms two for one mark, three for two marks	2
3(a)(ii)	(energy required to overcome) the repulsion between the electron and anion / negative ion	1

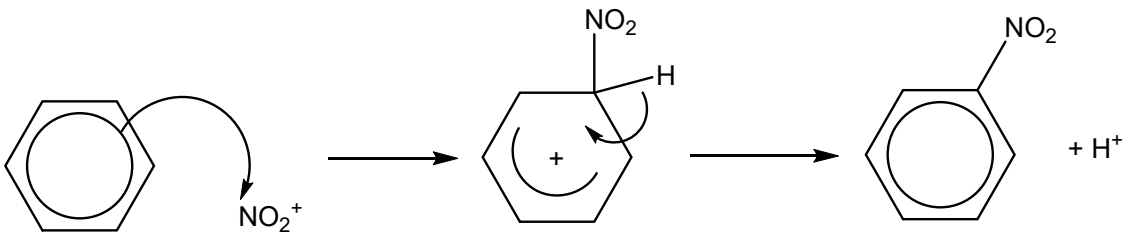
Question	Answer	Marks
3(a)(iii)	- less negative / less exothermic down the group - greater the distance between the nucleus and (the shells of the) electrons OR atomic radii increases OR more shielding by inner shells - the less attraction between nucleus and incoming electron (and the less energy released) two for one mark, three for two marks	2
3(b)	M1 use of correct seven numbers only in calculation / energy cycle M2 only 2 × used correctly M3 correct signs and evaluation ecf $\begin{aligned} -208 &= 131 + 906 + 1733 + 62 + 151 + 2x - 2605 \\ 2x &= -586 \\ x &= -293 \text{ kJ mol}^{-1} \end{aligned}$	3
3(c)	first box ticked AND Cd²⁺ larger / Cd²⁺ lower charge density AND less attraction between the ions / weaker ionic bonds	1

Question	Answer	Marks
4(a)(i)	M1 all five points plotted correctly M2 best-fit straight line (ruler) with negative gradient drawn	2
4(a)(ii)	M1 gradient correctly calculated OR gradient working seen M2 gradient = $-\Delta S^\circ$ ΔS° evaluated correctly ecf $\Delta S^\circ = (+)160 \pm 10 \text{ (J K}^{-1} \text{ mol}^{-1})$	2
4(b)(i)	$2\text{HCO}_3^- \rightarrow \text{CO}_3^{2-} + \text{CO}_2 + \text{H}_2\text{O}$	1

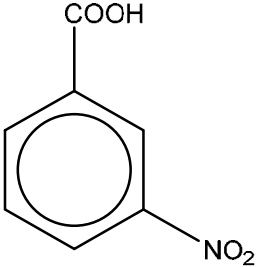
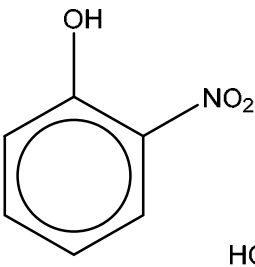
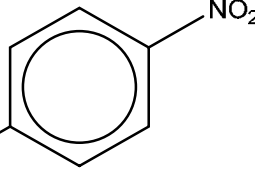
Question	Answer	Marks
4(b)(ii)	M1 ionic radius of M^+ / cationic radius increases OR charge density of ion / M^+ decreases down Group 1 M2 less distortion / polarisation of the anion / HCO_3^- OR CO bond / C-O / C=O less weakened	2
4(c)(i)	M1 solution which resists changes in pH when opposes / resists change in pH M2 when small amount of acid / H^+ or alkali / base / OH^- is added	2
4(c)(ii)	M1 (with acid) $HCO_3^- + H^+ \rightarrow H_2CO_3$ OR $HCO_3^- + H_3O^+ \rightarrow H_2CO_3 + H_2O$ M2 (with alkali) $H_2CO_3 + OH^- \rightarrow HCO_3^- + H_2O$	2
4(c)(iii)	M1 $K_a = 10^{-6.35} = 4.47 \times 10^{-7}$ M2 $[H^+] = 4.47 \times 10^{-7} / 14.1 = 3.17 \times 10^{-8}$ ecf M3 $pH = -\log [H^+] = 7.5$ ecf from a calculated $[H^+]$ min 2sf	3

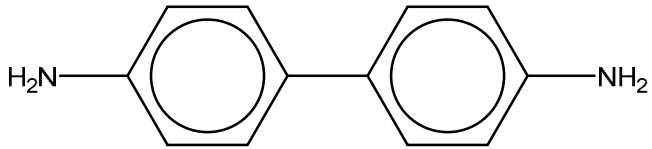
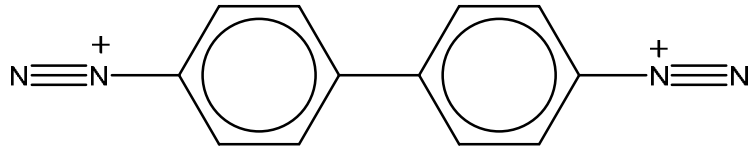
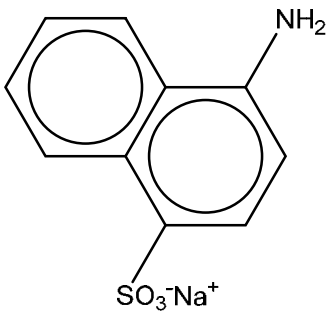
Question	Answer	Marks												
5(a)	<table border="1"> <thead> <tr> <th>electrolyte</th><th>substance liberated at the anode</th><th>substance liberated at the cathode</th></tr> </thead> <tbody> <tr> <td>$PbBr_2(l)$</td><td>Br_2 / bromine</td><td>Pb / lead</td></tr> <tr> <td>concentrated $NaCl(aq)$</td><td>Cl_2 / chlorine</td><td>H_2 / hydrogen</td></tr> <tr> <td>$Cu(NO_3)_2(aq)$</td><td>O_2 / oxygen (+ H_2O)</td><td>Cu / copper</td></tr> </tbody> </table> two for one mark, four for two marks, six for three marks	electrolyte	substance liberated at the anode	substance liberated at the cathode	$PbBr_2(l)$	Br_2 / bromine	Pb / lead	concentrated $NaCl(aq)$	Cl_2 / chlorine	H_2 / hydrogen	$Cu(NO_3)_2(aq)$	O_2 / oxygen (+ H_2O)	Cu / copper	3
electrolyte	substance liberated at the anode	substance liberated at the cathode												
$PbBr_2(l)$	Br_2 / bromine	Pb / lead												
concentrated $NaCl(aq)$	Cl_2 / chlorine	H_2 / hydrogen												
$Cu(NO_3)_2(aq)$	O_2 / oxygen (+ H_2O)	Cu / copper												

Question	Answer	Marks
5(b)(i)	$F = Le$ OR F is directly proportional to L	1
5(b)(ii)	number of Cu^{2+} formed = $0.35 / 63.5 = 5.51 \times 10^{-3}$ $Q = I \times t = 0.60 \times 30 \times 60 = 1080 \text{ C}$ number of electrons = $1080 / 1.6 \times 10^{-19} = 6.75 \times 10^{21}$ ecf number of Cu^{2+} ions = $6.75 \times 10^{21} / 2 = 3.375 \times 10^{21}$ ecf number of Cu^{2+} ions per mole (L) = $3.375 \times 10^{21} / 5.51 \times 10^{-3} = 6.12 \times 10^{23}$ ecf min 2sf all five points for four marks ALLOW valid alternate calculations of L	4

Question	Answer	Marks
6(a)(i)	 M1 first curly arrow from within hexagon to N of the NO_2^+ M2 correct intermediate M3 second curly arrow from C-H bond into the ring AND H^+ formed / lost	3
6(a)(ii)	$\text{HSO}_4^- + \text{H}^+ \rightarrow \text{H}_2\text{SO}_4$	1

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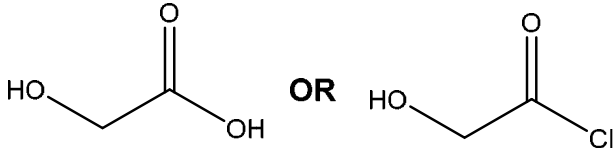
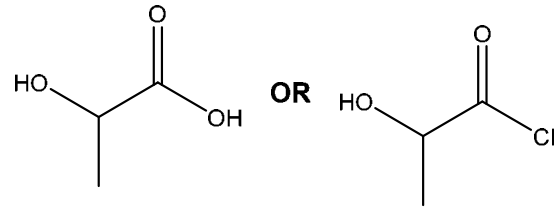
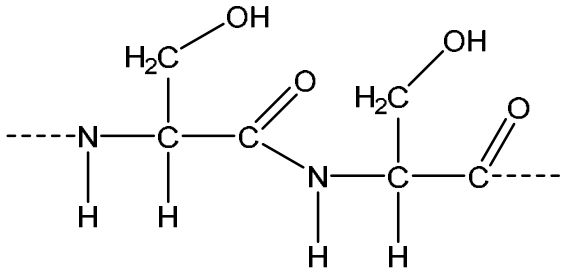
Question	Answer	Marks
6(b)	M1 benzoic acid M2 phenol    OR	2
6(c)	M1 phenol > benzene > benzoic acid M2 / M3 <u>phenol:</u> • lone pair / p-orbital on oxygen delocalises into the ring / overlaps with π-delocalised ring • accepts / attracts / polarises NO_2^+ / electrophiles better <u>benzoic acid:</u> • COOH / C=O is an electron-withdrawing / positive inductive effect two for one mark, three for two marks M4 (phenol-oxygen) increases electron density in the ring (<i>as compared to benzene as a result of the OH group</i>) OR (benzoic acid-COOH) decreases electron density in the ring (<i>as compared to benzene as a result of the COOH group</i>)	4

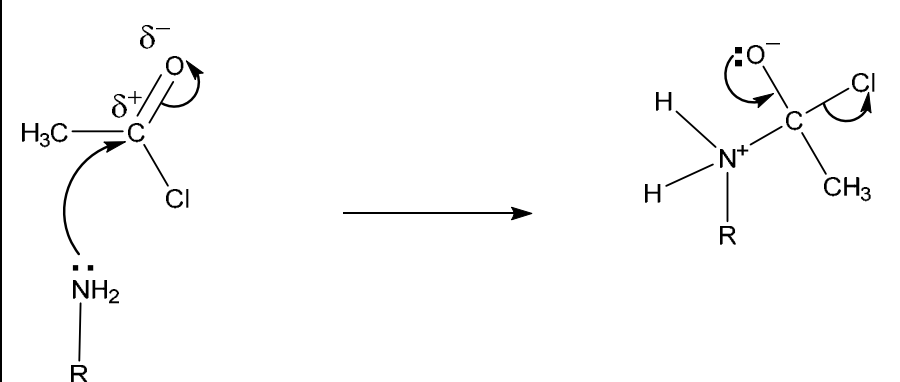
Question	Answer	Marks
6(d)(i)	X  Z  Y 	3
6(d)(ii)	step 1 M1 Sn and hydrochloric acid / HCl M2 concentrated (HCl) + heat / reflux (followed by NaOH) step 2 M3 HNO₂ and (HCl) ≤ 10°C OR NaNO₂, HCl and ≤ 10°C	3

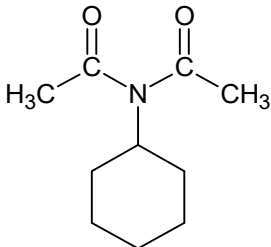
Question	Answer	Marks
7(a)	TMS reference OR standard OR to define d = 0 D₂O solvent OR identification of O-H / N-H protons / group	1

Question	Answer			Marks
7(b)(i)	ketone	number of peaks observed in proton NMR spectrum	number of peaks observed in carbon-13 NMR spectrum	2
	pentan-2-one	4	5	
	pentan-3-one	2	3	
	3-methylbutanone	3	4	
	three for one mark, six for two marks			
7(b)(ii)	M1 3-methylbutanone M2 3-methylbutanone AND pentan-2-one			2
7(c)(i)	six / 6			1
7(c)(ii)	C ₂₁ H ₃₄ O ₅			1
7(c)(iii)	a substance that is able to <u>rotate</u> the plane of polarised light in opposite directions			1

Question	Answer	Marks
8(a)	M1 chloroethanoic acid > ethanoic acid > phenol > ethanol M2 correct link of acidity once can be implied from M1 weakens O—H / carboxylate anion stabilised M3 / M4 explanation linked to structure • ($ClCH_2CO_2H$ > ethanoic acid) due to electronegative / electron withdrawing / negative inductive effect of Cl • (ethanoic acid > phenol) due to electronegative / electron withdrawing / negative inductive effect of $COOH$ / $C=O$ • (phenol > ethanol) due to lone pair of oxygen overlapping / delocalised into the ring • (ethanol weakest) alkyl group is electron donating / positive inductive effect two for one mark, four for two marks	4

Question	Answer	Marks
8(b)	• oxidation • (solution) decolourises OR purple → colourless / pale pink OR bubbles • $\text{HOCCOOH} + [\text{O}] \rightarrow 2\text{CO}_2 + \text{H}_2\text{O}$ OR $5\text{HOCCOOH} + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 10\text{CO}_2 + 8\text{H}_2\text{O} + 2\text{Mn}^{2+}$ two for one mark, three for two marks	2
8(c)	M1  M2 	2
8(d)	 M1 peptide linkage shown displayed with saturated C each side M2 rest of structure correct AND continuation bonds	2

Question	Answer	Marks
8(e)	addition polymers do not hydrolyse OR condensation polymers can hydrolyse	1
9(a)	cyclohexylamine > ammonia > phenylamine (order of basicity) linked to ability of N to accept a proton / donate its lone pair (to a proton) - alkyl / cyclo / hexyl group is electron donating group / positive inductive group (and increases electron density on N) - lone pair / p-orbital from N in phenylamine delocalised / overlaps with ring (and decreases electron density on N) two for one mark, three for two marks	3
9(b)(i)	(nucleophilic) addition-elimination	1
9(b)(ii)	 M1 / M2 - lone pair on N - correct arrow from (lone pair) N to C (of C=O) - dipole on C=O - correct arrow on C=O two for one mark, four for two marks M3 correct intermediate M4 arrow from lone pair on O⁻ to C-O bond AND arrow from C-Cl to Cl	4

Question	Answer	Marks
9(b)(iii)		1



Cambridge International AS & A Level

CHEMISTRY

9701/43

Paper 4 A Level Structured Questions

May/June 2022

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 2022 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

This document consists of **15** 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 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.

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 | <p><u>'List rule' guidance</u></p> <p>For questions that require <i>n</i> responses (e.g. State two reasons ...):</p> <ul style="list-style-type: none"> • 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.

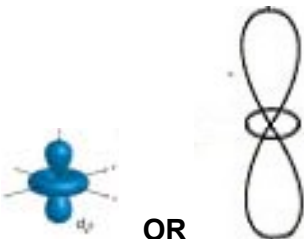
7 Guidance for chemical equations

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 ΔH_{latt} and ΔH_{hyd} decrease / both become less exothermic / less negative M2 ΔH_{latt} decreases / changes less/becomes less exothermic by a smaller extent OR ΔH_{hyd} decreases / changes more / dominant factor M3 ΔH_{sol} becomes less exothermic / less negative OR ΔH_{sol} becomes (more) endothermic / (more) positive OR $\Delta H_{\text{sol}} = \Delta H_{\text{hyd}} - \Delta H_{\text{latt}}$ expression AND reaction becomes less exothermic	3
1(b)	Mg: fizzing Ba: (fizzing and) white solid/ppt forms	1
1(c)	M1 solubility of BaSO_4 $= \sqrt{1.08 \times 10^{-10}} = 1.04 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ M2 $= 1.04 \times 10^{-5} \times 233.4 / 10 = 2.43 \times 10^{-4} \text{ (g per 100 cm}^3\text{ of solution)}$ min 2sf	2
1(d)(i)	$-1473 = 180 + 503 + 965 + \Delta H_{\text{f}}^{\ominus} - 2469$ $\Delta H_{\text{f}}^{\ominus}$ of $\text{SO}_4^{2-}(\text{g}) = -652 \text{ kJ mol}^{-1}$ M1 correct five values used [1] M2 only correct five values used [1] M3 correct signs and evaluation [1]	3
1(d)(ii)	• BaSO_4 is more negative/bigger • as Ba^{2+} is smaller OR Ba^{2+} has a larger charge • stronger force of attraction between the ions One mark for two correct Two marks for all three correct	2

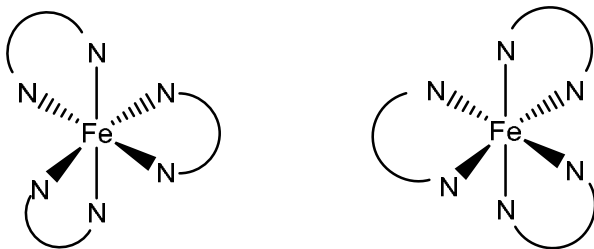
Question	Answer	Marks
1(e)(i)	M1 $\Delta G^\circ = 0$ so $T = \Delta H_r^\circ / \Delta S^\circ$ M2 $T = 132 / 0.616 = 214.3 \text{ K}$ $T = -58.7^\circ \text{C}$ min 2sf	2
1(e)(ii)	M1 $\Delta S^\circ = (203 + (70 \times 8) + (2 \times 192)) - (427 - (2 \times 95)) = +530 \text{ J K}^{-1} \text{ mol}^{-1}$ M2 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ M3 $\Delta G^\circ = 133 - (298 \times 0.530) = -24.9 \text{ kJ mol}^{-1}$ ecf 1dp min	3

Question	Answer	Marks
2(a)	forms one or more stable ions / compounds / oxidation states with incomplete / partially filled (3)d-orbital(s) / d-shell / d-subshell	1
2(b)		1
2(c)(i)	the catalyst and the reactants are in a different state / phase	1
2(c)(ii)	M1 adsorption of reactants to the surface of the catalyst M2 bonds in the reactants weaken (lowering the activation energy) M3 reaction occurs and the products are desorbed	3

Question	Answer	Marks
2(d)	M1 reaction 1: $2\text{KMnO}_4 + \text{H}_2\text{SO}_4 \rightarrow \text{Mn}_2\text{O}_7 + \text{H}_2\text{O} + \text{K}_2\text{SO}_4$ OR $2\text{KMnO}_4 + 2\text{H}_2\text{SO}_4 \rightarrow \text{Mn}_2\text{O}_7 + \text{H}_2\text{O} + 2\text{KHSO}_4$ M2 reaction 2: $\text{Mn}_2\text{O}_7 \rightarrow 2\text{MnO}_2 + 1.5\text{O}_2$	2
2(e)(i)	M1 $[\text{Mn}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Mn}(\text{OH})_2 + 6\text{H}_2\text{O}$ M2 precipitation / acid-base / deprotonation	2
2(e)(ii)	M1 $[\text{Mn}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{MnCl}_4]^{2-} + 6\text{H}_2\text{O}$ M2 ligand exchange / substitution / replacement / displacement	2
2(e)(iii)	MnO_2 AND redox	1

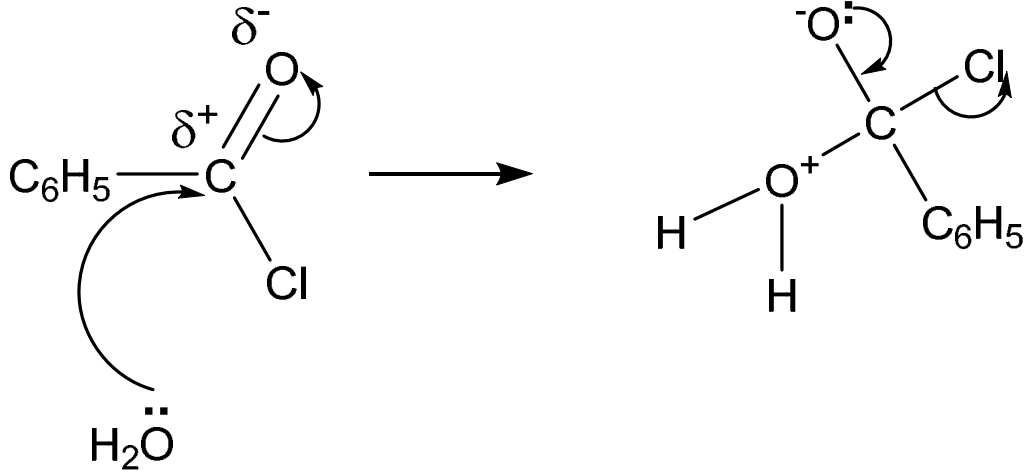
Question	Answer	Marks
3(a)(i)	evidence of tangent drawn at $t = 40$ s and calculation of gradient $= 0.000170 \text{ (mol dm}^{-3} \text{ s}^{-1}) \text{ min 2sf}$	1
3(a)(ii)	M1 evidence of construction lines and calculation of two $t_{1/2}$ OR evidence of construction lines and times for halving of concentration M2 deduction: constant half-life / constant time between halving of concentration $\rightarrow$ 1st order	2
3(b)	M1 two half-lives in 320 s so $t_{1/2} = 160$ s M2 $k = 0.693 / 160 = 0.00433 \text{ s}^{-1}$ ecf min 2sf	2
3(c)(i)	voltage / EMF / potential difference when a half-cell is connected to a (standard) hydrogen electrode under standard conditions	1
3(c)(ii)	ions move (from the salt bridge) to maintain charge balance / complete the circuit	1

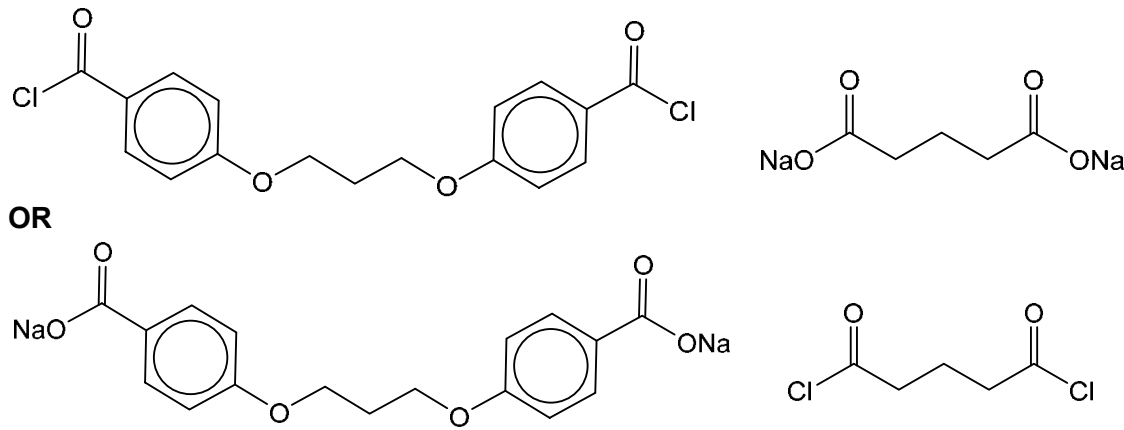
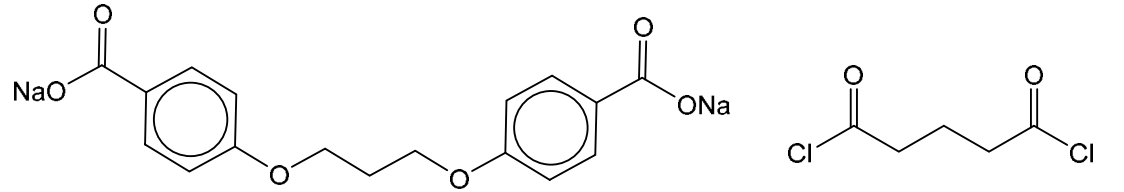
Question	Answer	Marks
3(c)(iii)	298K, 1 atm, 1 mol dm⁻³ Pt, H₂(g), good delivery system, 298 K, 1 atm Pt, Cr₂O₇²⁻(aq), H⁺(aq) / Cr³⁺(aq), 1 mol dm⁻³ seen once, voltmeter three for one mark, six for two marks, nine for three marks	3
3(c)(iv)	SHE labelled negative AND arrow in the external circuit moving away from this electrode	1
3(d)(i)	M1 $\text{Cr}_2\text{O}_7^{2-} + 3\text{CH}_3\text{CHO} + 8\text{H}^+ \rightleftharpoons 2\text{Cr}^{3+} + 3\text{CH}_3\text{COOH} + 4\text{H}_2\text{O}$ ALLOW $\text{Cr}_2\text{O}_7^{2-} + 3\text{CH}_3\text{CHO} + 5\text{H}^+ \rightleftharpoons 2\text{Cr}^{3+} + 3\text{CH}_3\text{COO}^- + 4\text{H}_2\text{O}$ M1 $E_{\text{cell}}^\ominus = +2.27 \text{ (V)}$	2
3(d)(ii)	M1 $\Delta G^\ominus = -nFE_{\text{cell}}^\ominus$ M2 $\Delta G^\ominus = -4 \times 96\,500 \times 2.01 = -775\,860 \text{ J mol}^{-1}$ $\Delta G^\ominus = -776 \text{ kJ mol}^{-1}$ min 3sf	2

Question	Answer	Marks
4(a)	• five 3d orbitals in the isolated Fe^{2+} ion of same energy • splitting two higher and three lower d orbitals • energy of non-degenerate d orbitals in the complex more than degenerate d orbitals in isolated ion two for one mark, three for two marks	2
4(b)(i)	M1 (a species) that donates / uses two lone pairs M2 to form dative / coordinate bonds to a metal atom / metal ion / TM / TE / metal	2
4(b)(ii)	 M1 one correct 3D diagram with three bipy ligands M2 both diagrams correct M3 optical isomerism	3
4(c)	$[\text{Fe}(\text{CN})_6]^{3-}$ AND equilibrium lies most to the left / lowest $E^\ominus$ value	1
4(d)	M1 N sp^2 AND C sp^2 M2 σ bonds are formed by end-on-end overlap orbitals between C-H / C-C / C-N M3 π bonds are formed by sideways overlap of p orbitals between C-N / C-C	3

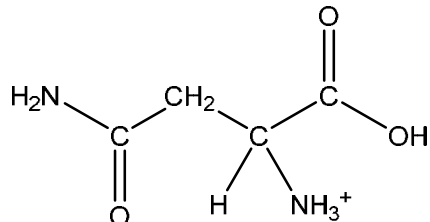
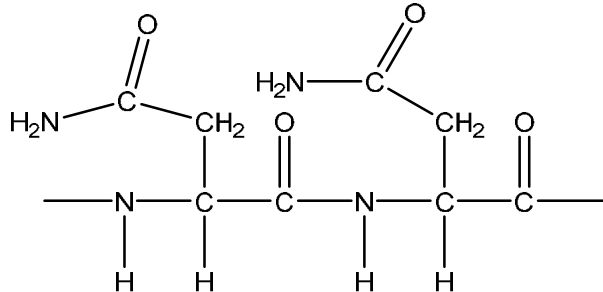
Question	Answer	Marks
4(e)	pyridine 3-chloropyridine + H⁺ M1 first curly arrow to Cl⁺ M2 correct intermediate M3 second curly arrow AND H⁺ formed / lost	3

Question	Answer	Marks																
5(a)	M1 benzoic acid > phenol > phenylmethanol M2 / M3 Any two of: - in benzoic acid negative inductive effect of C=O AND O-H bond is weakened OR due to delocalisation of minus charge by C=O / 2O carboxylate ion is stabilised - in phenol lone pair on oxygen is delocalised into the ring AND O-H bond is weakened - in phenyl methanol positive inductive effect of CH₂ group AND O-H bond is strengthened	3																
5(b)	<table><tr><td></td><td>benzoic acid</td><td>phenylmethanol</td><td>phenol</td></tr><tr><td>Na(s)</td><td>✓</td><td>✓</td><td>✓</td></tr><tr><td>NaOH(aq)</td><td>✓</td><td>✗</td><td>✓</td></tr><tr><td>Na₂CO₃(aq)</td><td>✓</td><td>✗</td><td>✗</td></tr></table> Three correct for one mark, six correct for two marks, nine correct for three marks		benzoic acid	phenylmethanol	phenol	Na(s)	✓	✓	✓	NaOH(aq)	✓	✗	✓	Na ₂ CO ₃ (aq)	✓	✗	✗	3
	benzoic acid	phenylmethanol	phenol															
Na(s)	✓	✓	✓															
NaOH(aq)	✓	✗	✓															
Na ₂ CO ₃ (aq)	✓	✗	✗															

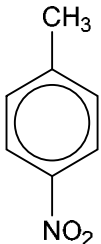
Question	Answer	Marks
5(c)(i)	POCl_3 and HCl AND SO_2 and HCl	1
5(c)(ii)	all the by-products / SO_2 and HCl are gaseous OR no liquid by-products formed	1
5(d)(i)	 On the left-hand side: • lone pair on O • correct arrow from O to C (of $\text{C}=\text{O}$) • dipole on $\text{C}=\text{O}$ • correct arrow on $\text{C}=\text{O}$ M1 / M2 Two correct for one mark, four correct for two marks On the right-hand side: M3 correct intermediate M4 arrow from lone pair on O^- to $\text{C}-\text{O}$ bond AND arrow from $\text{C}-\text{Cl}$ to Cl	4
5(d)(ii)	addition-elimination	1

Question	Answer	Marks
5(e)(i)	 OR 	2
5(e)(ii)	hydrolysis OR heating in dilute acid / alkali	1

Question	Answer	Marks						
6(a)	a mixture containing equal amounts of each optical isomer	1						
6(b)	<table border="1"> <tr> <td></td><td>carbon-13 NMR</td><td>proton NMR</td></tr> <tr> <td>number of peaks in CDCl_3</td><td>4</td><td>5</td></tr> </table>		carbon-13 NMR	proton NMR	number of peaks in CDCl_3	4	5	1
	carbon-13 NMR	proton NMR						
number of peaks in CDCl_3	4	5						
6(c)(i)	the pH at which an amino acid exists as a zwitterion OR the pH at which an amino acid has no overall charge	1						

Question	Answer	Marks								
6(c)(ii)		1								
6(d)	 M1 peptide bond displayed M2 rest of the structure correct + continuation bonds	2								
6(e)	<table border="1" data-bbox="878 912 1391 1176"><thead><tr><th>spot</th><th>identity</th></tr></thead><tbody><tr><td>E</td><td>Asn</td></tr><tr><td>F</td><td>Lys-Asn</td></tr><tr><td>G</td><td>Lys</td></tr></tbody></table> M1 table correctly completed M2 Lys and Lys-Asn are positively charged OR Asn is (nearly) uncharged M3 Lys-Asn has the highest M_r	spot	identity	E	Asn	F	Lys-Asn	G	Lys	3
spot	identity									
E	Asn									
F	Lys-Asn									
G	Lys									
6(f)(i)	aluminum oxide / silica (on solid support) AND inert gas / named inert gas e.g. N ₂	1								
6(f)(ii)	S AND R_f is the same as the unknown amino acid in both solvents	1								

Question	Answer	Marks
6(g)	mass of L = $58 / 44 \times 5.52 \times 10^{-2} = 7.28 \times 10^{-2} \text{ g}$ conc. of L = $7.28 \times 10^{-2} / 116 = 6.27 \times 10^{-4} \text{ (mol dm}^{-3}\text{) min 2sf}$	1

Question	Answer	Marks
7(a)(i)	phenylamine AND amine AND ester	1
7(a)(ii)	sp carbons = 0, sp ² carbons = 7, sp ³ carbons = 6	1
7(b)	6	1
7(c)	lone pair on the N can accept a proton	1
7(d)(i)		1
7(d)(ii)	step 1 M1 concentrated HNO ₃ and H ₂ SO ₄ step 2 M2 hot (alkaline) KMnO ₄ (followed by addition of H ⁺)	2
7(e)	step 4 M1 HOCH ₂ CH ₂ N(CH ₂ CH ₃) ₂ step 5 M2 Sn AND HCl M3 concentrated (HCl) AND heat / reflux	3
7(f)(i)	M1 ratio of the concentration of a solute in two solvents M2 at equilibrium	2

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Question	Answer	Marks
7(f)(ii)	M1 $K_{pc} = [\text{procaine}]_{\text{oct}} / [\text{procaine}]_{\text{water}}$ $1.77 = (x / 50) / (0.5 - x / 75)$ M2 $1.77 = 1.5x / 0.5 - x$ $0.885 - 1.77x = 1.5x$ $x = 0.271 \text{ g min 2sf}$	2