



Cambridge International AS & A Level

CHEMISTRY**9701/42**

Paper 4 A Level Structured Questions

May/June 2023

MARK SCHEME

Maximum Mark: 100

Published

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

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

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

This document consists of **19** 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.

PUBLISHED**GENERIC MARKING PRINCIPLE 5:**

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

GENERIC MARKING PRINCIPLE 6:

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

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	<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.

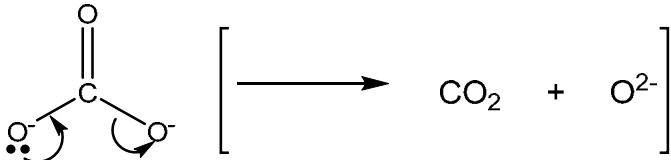
For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

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)(i)	 <p>ARROW 1 starts from O⁻ to the C–O bond AND ARROW 2 starts at the C–O bond to other O⁻ ion</p>	1
1(a)(ii)	<p>M1 increases (down the group)</p> <p>M2 (cat)ionic radius / ion size increases (down the group) OR charge density of M²⁺ decreases</p> <p>M3 less polarisation / distortion of anion / carbonate ion / CO₃⁽²⁾⁻</p>	3
1(b)(i)	<p>M1 energy released when one mole of a ionic solid / compound is formed M2 from gas (phase) ion(s) / gaseous ion(s) (under standard conditions)</p>	2
1(b)(ii)	<ul style="list-style-type: none"> • (ΔH_{decomp} / it) becomes more positive/less negative (down the group) • size /(ionic) radii of oxide ion is smaller (than carbonate ion) ORA • so ΔH_{latt} of oxides becomes ORA less exothermic faster OR less negative faster OR changes more OR changes faster <p>Any two [1], all three [2]</p>	2
1(c)(i)	$2\text{MnO}_4^- + 6\text{H}^+ + 5\text{SO}_3^{2-} \rightarrow 2\text{Mn}^{2+} + 3\text{H}_2\text{O} + 5\text{SO}_4^{2-}$	1

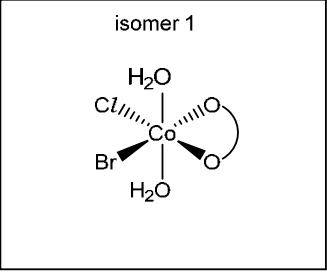
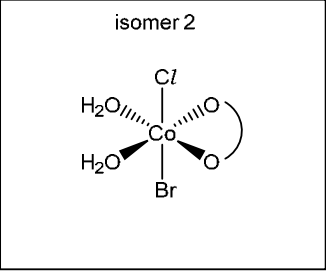
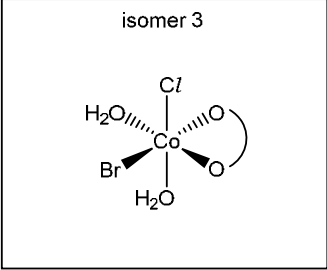
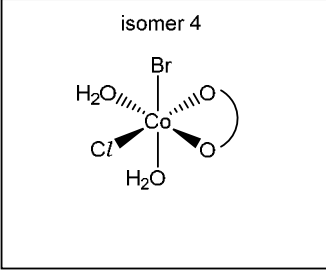
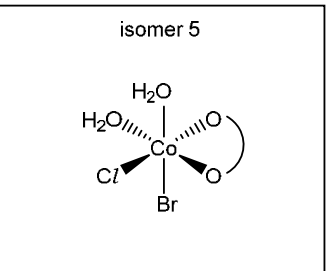
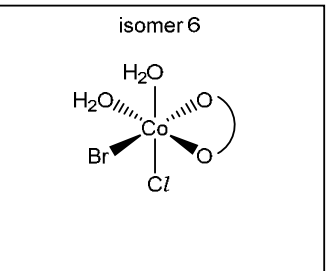
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Question	Answer	Marks
1(c)(ii)	<p>M1 M2 any two bullets [1] or all four [2]</p> <ul style="list-style-type: none"> moles $\text{MnO}_4^- = 0.025 \times 22.40 / 1000 = 5.6 \times 10^{-4}$ moles $\text{SO}_3^{2-} = 5.6 \times 10^{-4} \times 5 / 2 = 1.4 \times 10^{-3}$ (in 25 cm³) ecf from (c)(i) and bullet 1 moles $\text{SO}_3^{2-} = 1.4 \times 10^{-2}$ (in 250 cm³) ecf bullet 2 mass $\text{K}_2\text{SO}_3 = 1.4 \times 10^{-2} \times 158.3 = 2.2162$ g ecf bullet 3 <p>OR moles K_2SO_3 (if 100% pure) = $3.40 \div 158.3 = 0.02148$</p> <p>M3 % purity = $100 \times 2.2162 / 3.40 = 65.2 / 65.3$ % ecf min 2sf</p> <p>OR % purity = $100 \times 0.014 / 0.02148 = 65.2 / 65.3$ %</p>	3
1(d)	S(α) tetrahedral	1

Question	Answer	Marks
2(a)	<p><i>Any two from:</i></p> <ul style="list-style-type: none"> they have variable / multiple oxidation states OWTTE they behave as catalysts they form complex ions / complexes they form coloured compounds/ions 	1
2(b)(i)	(is a molecule or ion formed by a central) metal atom / metal ion bonded / surrounded by (one or more) ligands	1

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Question	Answer				Marks																
2(b)(ii)	<table border="1" data-bbox="342 248 1402 715"> <thead> <tr> <th data-bbox="342 248 607 347">reagent added</th> <th data-bbox="607 248 853 347">formula of species formed</th> <th data-bbox="853 248 1155 347">colour / state of species formed</th> <th data-bbox="1155 248 1402 347">type of reaction</th> </tr> </thead> <tbody> <tr> <td data-bbox="342 347 607 483">an excess of $\text{NH}_3(\text{aq})$</td> <td data-bbox="607 347 853 483">$[\text{Co}(\text{NH}_3)_6]^{2+}$</td> <td data-bbox="853 347 1155 483">brown solution ALLOW <i>yellow-brown</i> solution</td> <td data-bbox="1155 347 1402 483">ligand exchange</td> </tr> <tr> <td data-bbox="342 483 607 582">an excess of concentrated HCl</td> <td data-bbox="607 483 853 582">$[\text{CoCl}_4]^{2-}$</td> <td data-bbox="853 483 1155 582">blue solution</td> <td data-bbox="1155 483 1402 582">ligand exchange</td> </tr> <tr> <td data-bbox="342 582 607 715">$\text{NaOH}(\text{aq})$</td> <td data-bbox="607 582 853 715">$\text{Co}(\text{OH})_2$ OR $\text{Co}(\text{OH})_2(\text{H}_2\text{O})_4$</td> <td data-bbox="853 582 1155 715">blue ppt. ALLOW pink ppt</td> <td data-bbox="1155 582 1402 715">precipitation</td> </tr> </tbody> </table> <p data-bbox="342 751 1122 818">formula and colour / state: any two [1], any four [2], all six [3] type of reaction: all three correct [1]</p>				reagent added	formula of species formed	colour / state of species formed	type of reaction	an excess of $\text{NH}_3(\text{aq})$	$[\text{Co}(\text{NH}_3)_6]^{2+}$	brown solution ALLOW <i>yellow-brown</i> solution	ligand exchange	an excess of concentrated HCl	$[\text{CoCl}_4]^{2-}$	blue solution	ligand exchange	$\text{NaOH}(\text{aq})$	$\text{Co}(\text{OH})_2$ OR $\text{Co}(\text{OH})_2(\text{H}_2\text{O})_4$	blue ppt. ALLOW pink ppt	precipitation	4
reagent added	formula of species formed	colour / state of species formed	type of reaction																		
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2(c)(i)	<p data-bbox="342 850 976 882">M1 (a species) that donates / uses two lone pairs</p> <p data-bbox="342 882 1223 914">M2 to form a two dative / coordinate bond to a metal atom / metal ion</p>				2																

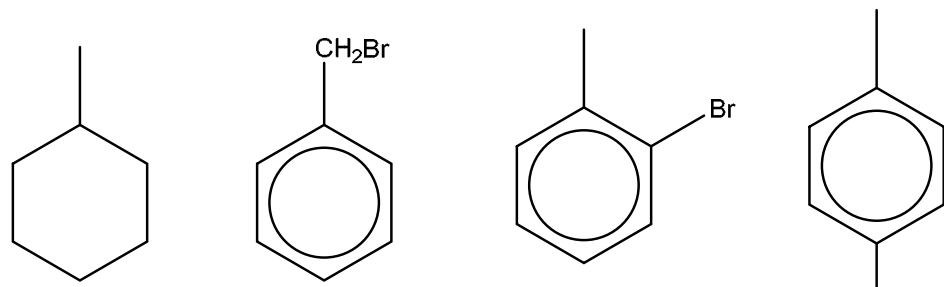
Question	Answer	Marks
2(c)(ii)	<p>Any four from:</p> <div style="display: flex; flex-wrap: wrap; justify-content: space-around;"> <div style="border: 1px solid black; padding: 5px; margin: 5px;"> <p style="text-align: center;">isomer 1</p>  </div> <div style="border: 1px solid black; padding: 5px; margin: 5px;"> <p style="text-align: center;">isomer 2</p>  </div> <div style="border: 1px solid black; padding: 5px; margin: 5px;"> <p style="text-align: center;">isomer 3</p>  </div> <div style="border: 1px solid black; padding: 5px; margin: 5px;"> <p style="text-align: center;">isomer 4</p>  </div> <div style="border: 1px solid black; padding: 5px; margin: 5px;"> <p style="text-align: center;">isomer 5</p>  </div> <div style="border: 1px solid black; padding: 5px; margin: 5px;"> <p style="text-align: center;">isomer 6</p>  </div> </div> <p>Any two [1], any three [2], all four [3]</p>	3
2(c)(iii)	<p>oxidation state of cobalt (+)3 AND type of stereoisomerism cis-trans OR geometric(al) OR optical</p>	1

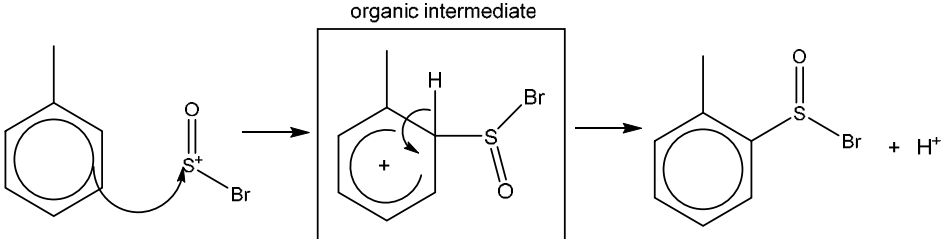
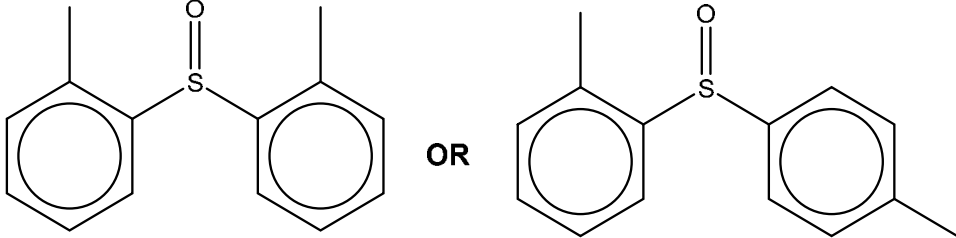
Question	Answer				Marks																
3(a)	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;">energy change</td> <td style="width: 16.5%;">always positive</td> <td style="width: 16.5%;">always negative</td> <td style="width: 34%;">can be either negative or positive</td> </tr> <tr> <td>bond energy</td> <td style="text-align: center;">✓</td> <td></td> <td></td> </tr> <tr> <td>enthalpy change of atomisation</td> <td style="text-align: center;">✓</td> <td></td> <td></td> </tr> <tr> <td>enthalpy change of formation</td> <td></td> <td></td> <td style="text-align: center;">✓</td> </tr> </table>				energy change	always positive	always negative	can be either negative or positive	bond energy	✓			enthalpy change of atomisation	✓			enthalpy change of formation			✓	1
energy change	always positive	always negative	can be either negative or positive																		
bond energy	✓																				
enthalpy change of atomisation	✓																				
enthalpy change of formation			✓																		
3(b)	M1 (enthalpy change) when one mole of gaseous atoms is produced IGNORE energy released M2 from its element(s) in its standard state / standard conditions / 298 K AND 1 atm				2																
3(c)	M1 use of correct six numbers only $-31 / 285 / 731 / -141 / 798 / 496$ M2 $2 \times$ used correctly with Ag (2×285 (570) and 2×731 (1462)) AND 0.5 with O=O (496 (248)) M3 correct signs and evaluation $-31 = (2 \times 285) + (2 \times 731) + (-141) + (798) + x + (0.5 \times 496)$ $x = -2968 \text{ kJ mol}^{-1}$				3																
3(d)	<table style="width: 100%; border: none;"> <tr> <td style="width: 33%; vertical-align: top;"> <ul style="list-style-type: none"> • Ag_2Se <i>least exothermic</i> </td> <td style="width: 33%; text-align: center; vertical-align: middle;">Ag_2S</td> <td style="width: 33%; text-align: right; vertical-align: top;"> <ul style="list-style-type: none"> • Ag_2O <i>most exothermic</i> </td> </tr> </table> <p style="text-align: right;">OWTTE</p> <ul style="list-style-type: none"> • charge density of anion decreases down the group ORA / radius/size of anion increases down the group / Se^{2-} largest radius / O^{2-} smallest radius / O has smallest ionic radius • less attraction between the ions / ionic bond gets weaker (with Ag_2Se) ORA <p>Any two [1], all three [2]</p>				<ul style="list-style-type: none"> • Ag_2Se <i>least exothermic</i> 	Ag_2S	<ul style="list-style-type: none"> • Ag_2O <i>most exothermic</i> 	2													
<ul style="list-style-type: none"> • Ag_2Se <i>least exothermic</i> 	Ag_2S	<ul style="list-style-type: none"> • Ag_2O <i>most exothermic</i> 																			
3(e)(i)	$(K_{\text{sp}} =) [\text{Ag}^+]^2[\text{SO}_3^{2-}]$				[1] 1																

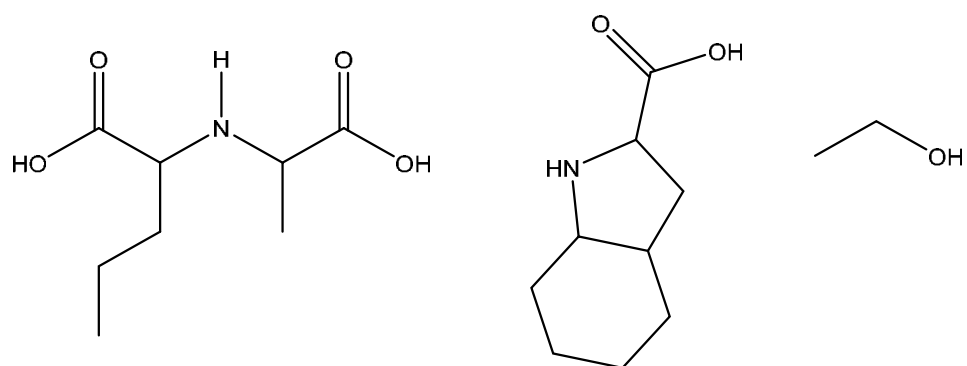
Question	Answer	Marks
3(e)(ii)	$x = \sqrt[3]{1.5 \times 10^{-14} / 4} = 1.55 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$ $[\text{Ag}^+] = 1.55 \times 10^{-5} \times 2 = 3.11 \times 10^{-5} \text{ (mol dm}^{-3}\text{) min 2sf ecf (e)(i)}$	1
3(f)	<ul style="list-style-type: none"> feasibility / it increases as temperature increases ORA ΔS is positive / ΔS is >0 / entropy change is positive (and ΔH is positive) OR $-T\Delta S$ becomes more negative / $T\Delta S$ becomes more positive as ΔG becomes / is negative / $\Delta G < 0$ <p>Any two [1], all three [2]</p>	2

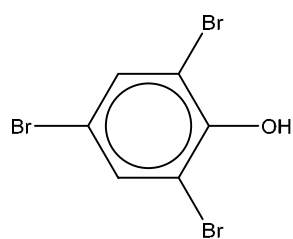
Question	Answer	Marks
4(a)(i)	the sum/total of the power / exponent to which a concentration of a reactant is raised in the rate equation / law	1
4(a)(ii)	<p>M1 (expt 1 and 2) when $[\text{Fe}^{3+}] \times 3$, rate $\times 3$ so first order w.r.t. Fe^{3+}</p> <p>M2 (expt 1 and 3) when $[\text{Fe}^{3+}]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

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

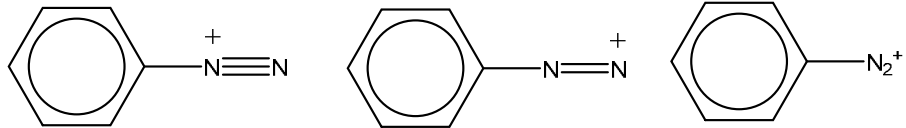
Question	Answer	Marks
5(a)(i)	 <p>reaction 1 reaction 2 reaction 3</p> <p>M1 M2 M3 BOTH</p>	3
5(a)(ii)	M1 reaction 1: hydrogenation / reduction M2 mechanism 2: (free) radical substitution	2
5(b)	the substitution product is stabilised by delocalization of π -electrons / by π -electrons in the ring OR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

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

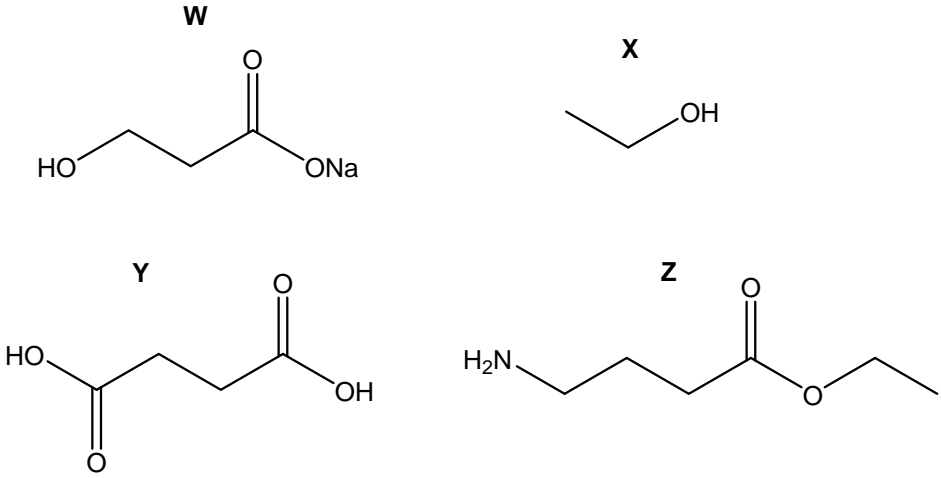
Question	Answer	Marks
6(b)(ii)	 <p>3 × [1] for each structure</p>	3

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

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Question	Answer	Marks
7(c)(iii)	<p>M1 reaction 1: aqueous HNO_3 / dilute HNO_3</p> <p>M2 reaction 2: alkaline/ NaOH AND $\text{C}_6\text{H}_5\text{N}_2^+$ (<i>Cl</i>⁻)</p> <div style="text-align: center;">  </div> <p>OR alkaline / NaOH AND benzene / phenyl diazonium ion / salt</p>	2

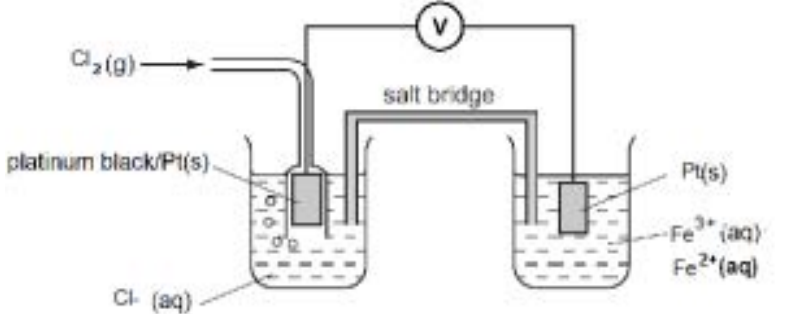
Question	Answer	Marks
8(a)	<ul style="list-style-type: none"> • chlorobenzene is less reactive than chloroethane OWTTE • p-orbital / lone pair on Cl will overlap / delocalise into the ring • due to partial double C-Cl bond OWTTE OR C-Cl bond strengthened (more) <p>Any two [1], all three [2]</p>	2
8(b)(i)	ethyl 3-chloropropanoate	1

Question	Answer	Marks
8(b)(ii)	<p style="text-align: center;">  </p> <p style="text-align: center;">4 × [1] for each structure</p>	4
8(b)(iii)	<p>M1 step 1 NaCN / KCN in ethanol (heat) M2 step 2 H₂ + Ni / H₂ + Pt ALLOW LiAlH₄</p>	2
8(c)(i)	(because solvent / D / CDCl ₃) doesn't give a signal / peak / absorption ORA	1

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Question	Answer				Marks																				
8(c)(ii)	<table border="1" data-bbox="340 248 1476 783"> <thead> <tr> <th data-bbox="340 248 533 347">chemical shift δ / ppm</th> <th data-bbox="533 248 891 347">environment of proton</th> <th data-bbox="891 248 1099 347">splitting pattern</th> <th data-bbox="1099 248 1476 347">number of ^1H atoms responsible for the peak</th> </tr> </thead> <tbody> <tr> <td data-bbox="340 347 533 416">1.2</td> <td data-bbox="533 347 891 416">alkyl / alkane / (R-)CH₃</td> <td data-bbox="891 347 1099 416">triplet</td> <td data-bbox="1099 347 1476 416">3</td> </tr> <tr> <td data-bbox="340 416 533 515">2.8</td> <td data-bbox="533 416 891 515">alkyl next to C=O / CH₂C=O</td> <td data-bbox="891 416 1099 515">triplet</td> <td data-bbox="1099 416 1476 515">2</td> </tr> <tr> <td data-bbox="340 515 533 647">3.7</td> <td data-bbox="533 515 891 647">alkyl next to electronegative atom / CH₂-Cl</td> <td data-bbox="891 515 1099 647">triplet</td> <td data-bbox="1099 515 1476 647">2</td> </tr> <tr> <td data-bbox="340 647 533 783">3.9</td> <td data-bbox="533 647 891 783">alkyl next to electronegative atom / CH₂-O</td> <td data-bbox="891 647 1099 783">quartet / quadruplet</td> <td data-bbox="1099 647 1476 783">2</td> </tr> </tbody> </table> <p data-bbox="340 818 1003 852">Any three [1], any six [2], any nine [3], all twelve [4]</p>				chemical shift δ / ppm	environment of proton	splitting pattern	number of ^1H atoms responsible for the peak	1.2	alkyl / alkane / (R-)CH ₃	triplet	3	2.8	alkyl next to C=O / CH ₂ C=O	triplet	2	3.7	alkyl next to electronegative atom / CH ₂ -Cl	triplet	2	3.9	alkyl next to electronegative atom / CH ₂ -O	quartet / quadruplet	2	4
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8(c)(iii)	$(\delta = 3.9)$ three H on neighbouring / adjacent C / it's next to a CH ₃				1																				

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Question	Answer	Marks
9(a)	potential difference / voltage between the two half-cells / two electrodes (in a cell) under standard conditions	1
9(b)	 <p data-bbox="338 630 1579 726"> salt bridge voltmeter complete circuit [wires/salt bridge in/touching both solutions] Cl_2 Cl^- good delivery system (no arrow required) Pt Pt Fe^{2+} and Fe^{3+} </p> <p data-bbox="338 762 806 798">Any three [1], any six [2], all nine [3]</p>	3
9(c)	<p data-bbox="338 831 918 866">M1 $(\Delta G^\circ) = -nFE_{cell}^\circ$ OR $-2 \times 96500 \times 0.59$</p> <p data-bbox="338 903 963 938">M2 $\Delta G^\circ = -2 \times 96500 \times 0.59 = -113870 \text{ J mol}^{-1}$</p> <p data-bbox="338 943 761 978">$\Delta G^\circ = -114 \text{ kJ mol}^{-1}$ min 3sf ecf</p>	2
9(d)(i)	<p data-bbox="338 1007 929 1042">$E = 0.77 + (0.059 / 1) \log (1/0.15)$ use of $z = 1$</p> <p data-bbox="338 1046 481 1082">$E = 0.82 \text{ V}$</p>	1
9(d)(ii)	<p data-bbox="338 1102 985 1137">$E_{cell} = 0.59 + 0.77 - (\text{answer to (d)(i)}) = 0.54 \text{ V}$ ecf</p>	1