



Cambridge International AS & A Level

CHEMISTRY

9701/41

Paper 4 A Level Structured Questions

May/June 2020

MARK SCHEME

Maximum Mark: 100

Published

Students did not sit exam papers in the June 2020 series due to the Covid-19 global pandemic.

This mark scheme is published to support teachers and students and should be read together with the question paper. It shows the requirements of the exam. The answer column of the mark scheme shows the proposed basis on which Examiners would award marks for this exam. Where appropriate, this column also provides the most likely acceptable alternative responses expected from students. Examiners usually review the mark scheme after they have seen student responses and update the mark scheme if appropriate. In the June series, Examiners were unable to consider the acceptability of alternative responses, as there were no student responses to consider.

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This document consists of **15** printed pages.

Generic Marking Principles

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GENERIC MARKING PRINCIPLE 1:

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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'.

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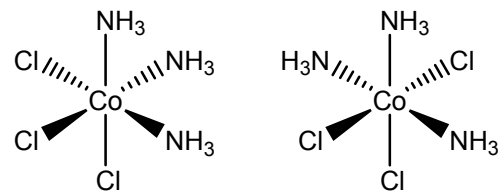
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Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

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

Question	Answer	Marks
1(a)(i)	(a molecule or ion) formed by a (central) metal atom / ion surrounded by / bonded to (one or more) ligands	1
1(a)(ii)	M1: blue ppt/solid M2: $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{OH})_2 + 6\text{H}_2\text{O}$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$ M3: precipitation/ acid-base M4: blue solution M5: $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Co}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ M6: ligand exchange/displacement/substitution/replacement	6
1(b)	• solution turns blue $\rightarrow$ pink • a white ppt. of AgCl forms • equilibrium shifts to the left / $[\text{Cl}^-]$ decreases Two correct responses = 1 mark Three correct responses = 2 marks	2
1(c)	 geometric ALLOW cis-trans Two correct responses = 1 mark Three correct responses = 2 marks	2
1(d)(i)	each nitrogen / the four nitrogen's has a lone pair of electrons (to the metal ion) Two correct responses = 1 mark	1

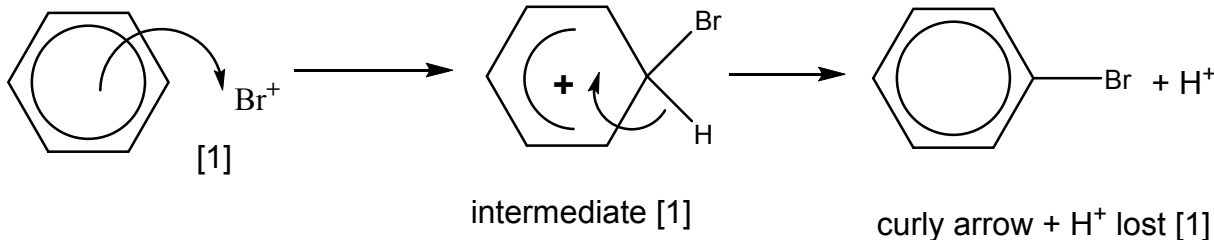
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1(d)(ii)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + \text{C}_6\text{H}_{18}\text{N}_4 \rightarrow [\text{Co}(\text{C}_6\text{H}_{18}\text{N}_4)]^{2+} + 6\text{H}_2\text{O}$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + \text{C}_6\text{H}_{18}\text{N}_4 \rightarrow [\text{Co}(\text{C}_6\text{H}_{18}\text{N}_4)(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$	1

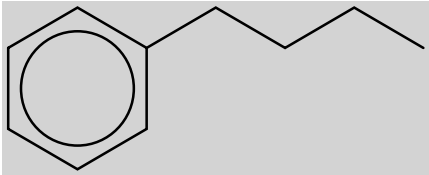
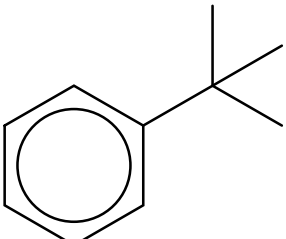
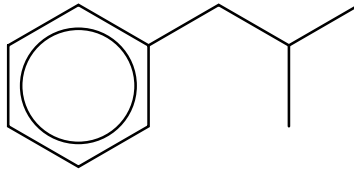
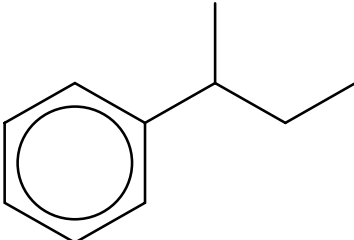
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2(a)(i)	M1 solubility increases down the group M2 ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative M3 ΔH_{latt} changes more (than ΔH_{hyd} as OH^- being smaller than M^{2+}) M4 ΔH_{sol} becomes more exothermic / more negative	4
2(a)(ii)	M1 $\text{Mg}(\text{OH})_2$ AND Mg^{2+} has a smaller ionic radii/ Mg^{2+} has a higher charge density M2 OH^- ion is polarised/distorted more	2

Question	Answer	Marks
3(a)(i)	$6\text{CO}_2 + 24\text{H}^+ + 24\text{e}^- \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O}$ ALLOW $6\text{CO}_2 + 12\text{H}^+ + 12\text{e}^- \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 3\text{O}_2$ for both marks ALLOW one mark for an unbalanced equation showing the correct species of either equation	2

Question	Answer	Marks
3(a)(ii)	salt bridge (indicated) voltmeter / V labelled O ₂ good delivery system H ₂ good delivery system Pt electrode H ⁺ / HCl / H ₂ SO ₄ solution labelled (at least once) 1 atm 1 mol dm ⁻³ quoted Every two correct responses = 1 mark	4
3(a)(iii)	$E^{\circ}_{\text{cell}} = (+) 1.23 \text{ V}$ AND positive electrode = O ₂ half-cell identified	1

Question	Answer	Marks
4(a)	M1 phenylmethanamine / U > phenylamine / T > benzamide / S [1] any two from: • alkyl group is electron donating so lone pair more able to accept a proton • lone pair on N overlaps with delocalised system so less able to accept a proton • presence of electron-withdrawing oxygen / carbonyl group means lone pair is not available to accept a proton OR amides are neutral	3
4(b)(i)	reaction 1 LiAlH ₄ reaction 2 heat NH ₃ under pressure/ heat NH ₃ in a sealed tube	2
4(b)(ii)	reaction 1 reduction reaction 2 nucleophilic substitution	2

Question	Answer	Marks
5(a)(i)	The substitution product is stabilised by delocalisation of (6) π -electrons OR The addition product is not stabilised by delocalisation of (6) π -electrons [1]	1
5(a)(ii)	 intermediate [1] curly arrow + H^+ lost [1] • first curly arrow • intermediate • 2nd curly arrow, product and H^+ formed / lost	3
5(a)(iii)	$\text{A/Br}_4^- + \text{H}^+ \rightarrow \text{A/Br}_3 + \text{HBr}$	1
5(b)	lone pair of oxygen is delocalised into the ring <u>any one from:</u> • phenol has a higher electron density in the ring • phenol can polarise/induce a dipole in Br_2	2
5(c)(i)	$\text{CH}_3\text{CH}_2\text{CH}^+\text{CH}_3$ $(\text{CH}_3)_2\text{CHCH}_2^+$ $(\text{CH}_3)_3\text{C}^+$ Each correct structure = 1 mark	3

Question	Answer	Marks
5(c)(ii)	 number of peaks in carbon-13 NMR = 8  number of peaks in carbon-13 NMR = 6  number of peaks in carbon-13 NMR = 7  number of peaks in carbon-13 NMR = 8 Two correct organic products = 1 mark three correct organic products = 2 marks all products linked correctly to NMR = 2 marks	4

Question	Answer	Marks
6(a)	M1 2-chloropropanoic acid > 3-chloropropanoic acid > propanoic acid [1] M2 CH₃CHClCO₂H / ClCH₂CH₂CO₂H (are more acidic) as they contain an electronegative Cl atom so weaken O-H bond / stabilise carboxylate anion [1] M3 CH₃CHClCO₂H (is more acidic than ClCH₂CH₂CO₂H) as the Cl atom is closer to CO₂H so weaken O-H bond more / stabilise carboxylate anion more [1]	3

Question	Answer	Marks												
6(b)(i)	$K_{eq} = 4.07 \times 10^{-3} / 1.78 \times 10^{-4} = \mathbf{22.9}$	1												
6(b)(ii)	3 rd box ticked [to the right] AND as the K_{eq} is greater than one ecf on K_{eq}	1												
6(b)(iii)	pK_a 1.23 $\text{HO}_2\text{CCO}_2\text{H} + \text{H}_2\text{O} \rightleftharpoons \text{HO}_2\text{CCO}_2^- + \text{H}_3\text{O}^+$ OR $\text{HO}_2\text{CCO}_2\text{H} \rightleftharpoons \text{HO}_2\text{CCO}_2^- + \text{H}^+$ pK_a 4.19 $\text{HO}_2\text{CCO}_2^- + \text{H}_2\text{O} \rightleftharpoons ^-\text{O}_2\text{CCO}_2^- + \text{H}_3\text{O}^+$ OR $\text{HO}_2\text{CCO}_2^- \rightleftharpoons ^-\text{O}_2\text{CCO}_2^- + \text{H}^+$	2												
6(b)(iv)	$pK_a = -\log K_a$	1												
6(c)	<table border="1"> <thead> <tr> <th></th><th>reagents and conditions</th><th>observed change</th></tr> </thead> <tbody> <tr> <td>test 1</td><td>M1 Tollen's reagent, warm OR Fehling's solution, warm</td><td>silver mirror (brick)-red ppt.</td></tr> <tr> <td>test 2</td><td>M2 aqueous alkaline iodine OR 2,4-DNPH</td><td>yellow ppt. orange ppt.</td></tr> <tr> <td>test 3</td><td>M3 acidified MnO_4^-, warm</td><td>decolourises (and bubbles)</td></tr> </tbody> </table> Two correct observations = 1 mark Three correct observations = 2 marks		reagents and conditions	observed change	test 1	M1 Tollen's reagent, warm OR Fehling's solution, warm	silver mirror (brick)-red ppt.	test 2	M2 aqueous alkaline iodine OR 2,4-DNPH	yellow ppt. orange ppt.	test 3	M3 acidified MnO_4^- , warm	decolourises (and bubbles)	5
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Question	Answer				Marks
6(d)	chemical shift (δ)	environment of the carbon atom	hybridisation of the carbon atom		2
	27	CH ₃ circled	sp ³		
	163	COOH circled	sp ²		
	192	C=O(COOH) circled	sp ²		
	Award one mark for each correct column				
6(e)	chemical shift (δ)	group responsible for the peak	splitting pattern	number of ¹ H atoms responsible for the peak	3
	1.3	alkane / CH / CH ₃	triplet	3	
	2.2	CH ₃ CO or alkyl / CH next to C=O	singlet	3	
	4.0	CH ₂ O or alkyl / CH next to electronegative atom / C=O	quartet / quadruplet	2	
	Award one mark for every three correct responses.				
6(f)	CH AND CH ₃ circled these protons do not exchange with D ₂ O OR OH and NH protons exchange with D ₂ O				2
6(g)(i)	K _w = [D ⁺][DO ⁻]				1
6(g)(ii)	M1 [D ⁺] = √1.35 x 10 ⁻¹⁵ = 3.67 x10 ⁻⁸ M2 pH = -log [D ⁺] = 7.4(3) min 2sf				2

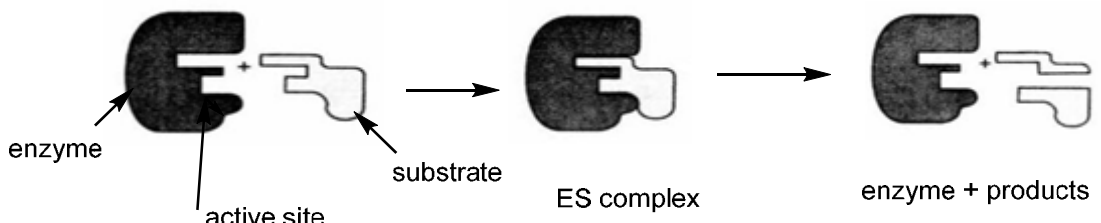
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7(a)(i)	M1 $K_{sp} = [Ag^+]^2[CO_3^{2-}]$ M2 units = $mol^3 dm^{-9}$	2
7(a)(ii)	$x = \sqrt[3]{6.3 \times 10^{-12}/4} = 1.16 \times 10^{-4} (mol dm^{-3})$ $[Ag^+] = 1.16 \times 10^{-4} \times 2 = \mathbf{2.33 \times 10^{-4}} (mol dm^{-3})$ min 2sf	1
7(a)(iii)	$6.3 \times 10^{-12} = [0.05]^2[CO_3^{2-}]$ $[CO_3^{2-}] = \mathbf{2.52 \times 10^{-9}} (mol dm^{-3})$ min 2sf	1
7(a)(iv)	M1 $E = E^\ominus + 0.059 \log[Ag^+]$ M2 $E = 0.80 + 0.059 \log(1.2 \times 10^{-4}) = \mathbf{0.57 V}$ ecf from (a)(ii) min 2sf	2
7(b)(i)	$\Delta S^\ominus = 72.7 + 56.5 - 96.2 = \mathbf{+33.0 J K^{-1} mol^{-1}}$	1
7(b)(ii)	M1 $\Delta G = \Delta H^\ominus - T\Delta S^\ominus$ M2 $\Delta G = (65.5) - (298 \times 0.033) = \mathbf{+55.7 kJ mol^{-1}}$ min 3sf M3 $\Delta G =$ positive so not feasible/spontaneous	3

Question	Answer	Marks
8(a)	M1 a solution that resists changes in pH M2 when small amounts of acid and alkali are added to it	2
8(b)(i)	$K_a = \frac{[NH_3][H^+]}{[NH_4^+]}$	1
8(b)(ii)	M1 $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ M2 $NH_3 + H_3O^+ \rightarrow NH_4^+ + H_2O$	2

Question	Answer	Marks
8(b)(iii)	M1 moles $\text{NH}_3(\text{initial}) = 0.25 \times 0.80 = 0.200$ AND moles $\text{HCl} = 0.20 \times 0.20 = 0.040$ (= moles $\text{NH}_4^+_{\text{eqm}}$) M2 moles $\text{NH}_3(\text{eqm}) = 0.20 - 0.04 = 0.160$ $[\text{H}^+] = (5.6 \times 10^{-10} \times 0.04)/(0.16) = 1.4 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ ecf on M1 M3 $\text{pH} = -\log(1.4 \times 10^{-10}) = 9.85$ ecf on M2 min 2sf	3

Question	Answer	Marks
9(a)	M1 data seen $\text{H}_2\text{O}_2/\text{H}_2\text{O} +1.77\text{V}$ and $\text{MnO}_2/\text{Mn}^{2+} +1.23 \text{ V}$ and $\text{O}_2/\text{H}_2\text{O}_2 +0.68 \text{ V}$ OR $E_{\text{cell}} = 0.55 \text{ V}$ (first step) and 0.54 V (second step) M2 $\text{MnO}_2 + \text{H}_2\text{O}_2 + 2\text{H}^+ \rightarrow \text{Mn}^{2+} + \text{O}_2 + 2\text{H}_2\text{O}$ M3 $\text{Mn}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{MnO}_2 + 2\text{H}^+$	3
9(b)	rate = $2.0 \times 10^{-6} \times 0.75 = 1.5 \times 10^{-6}$	1
9(c)(i)	slowest step in overall reaction	1
9(c)(ii)	$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{I}^- \rightarrow \text{I}_2 + 2\text{H}_2\text{O}$ OR $\text{H}_2\text{O}_2 + 2\text{HI} \rightarrow \text{I}_2 + 2\text{H}_2\text{O}$	1
9(c)(iii)	$\text{H}_2\text{O}_2 = 1$ AND $\text{I}^- = 1$ AND $\text{H}^+ = 0$	1

Question	Answer	Marks
10(a)	+4 and any of +1, +2, +3	1
10(b)	close similarity of energy of the 4s and 3d sub-shells	1

Question	Answer	Marks
10(c)	diagrams  The diagram illustrates the process of enzyme action in four stages connected by arrows. Stage 1: An enzyme (dark grey) with a specific shape and a labeled 'active site' (a notch) is shown next to a substrate (light grey) with a complementary shape. Labels 'enzyme' and 'substrate' point to their respective shapes. Stage 2: The substrate is bound within the enzyme's active site, forming the 'ES complex'. Stage 3: The substrate is broken down into two smaller products, which are released from the enzyme. Stage 4: The enzyme is shown again, ready to catalyze another reaction, labeled 'enzyme + products'. M1 (can be in words or diagram) substrate shape is complementary to active site M2 (can be in words or diagram) the substrate bind / bonds / fits into the active site M3 (can be in words or diagram) products are released M4 (words) lower E_A / bonds weakened (in substrate) Any three points	3



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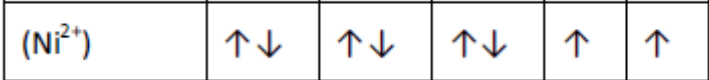
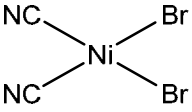
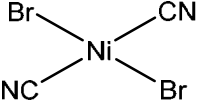
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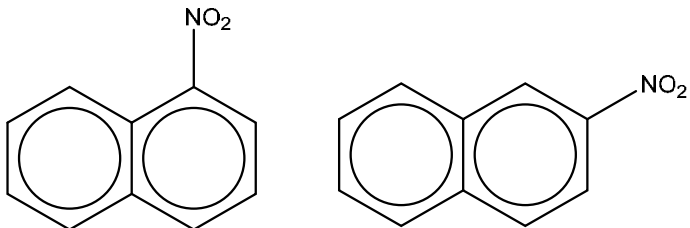
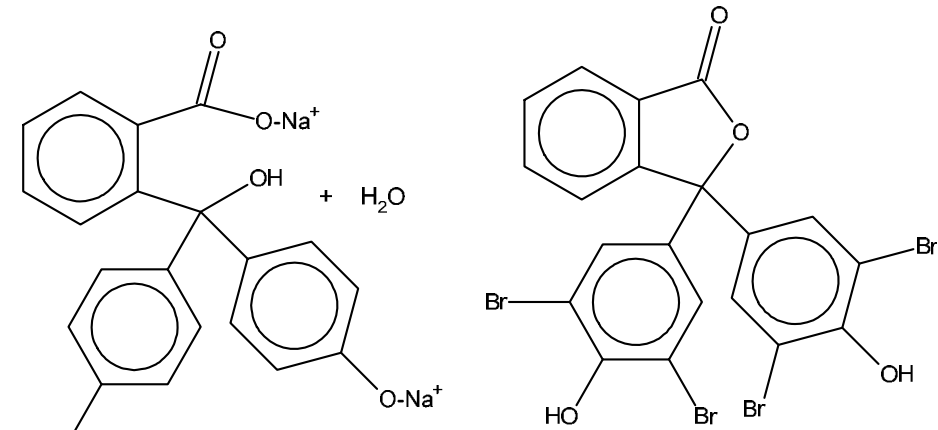
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1(a)(i)	M1 (a species) that donates/uses a many lone pairs/more than one lone pair M2 to form a dative/coordinate to a metal atom/metal ion/TM/TE/metal OR M1 (a species) that donates/uses lone pairs to form many/more than one M2 dative/coordinate bond to a metal atom/metal ion/TM/TE/metal	2
1(a)(ii)	structure of EDTA any six atoms circled of 2 N & 4 O	1
1(a)(iii)	M1 $K_{\text{stab1}} = \frac{[\text{CdEDTA}]^{2-}}{[\text{Cd}(\text{H}_2\text{O})_6]^{2+}[\text{EDTA}^{4-}]}$ M2 units = $\text{mol}^{-1} \text{dm}^3$	2
1(b)(i)	$K_{\text{eq4}} = K_{\text{stab3}}/K_{\text{stab2}}$	1
1(b)(ii)	M1 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G^\circ = 0.84 - (298 \times 0.0809)$ M2 $\Delta G^\circ = -23.3 \text{ (kJ mol}^{-1}\text{)}$ 3sf min	2
1(b)(iii)	more negative as $T\Delta S$ increases OR more negative as ΔS is positive	1

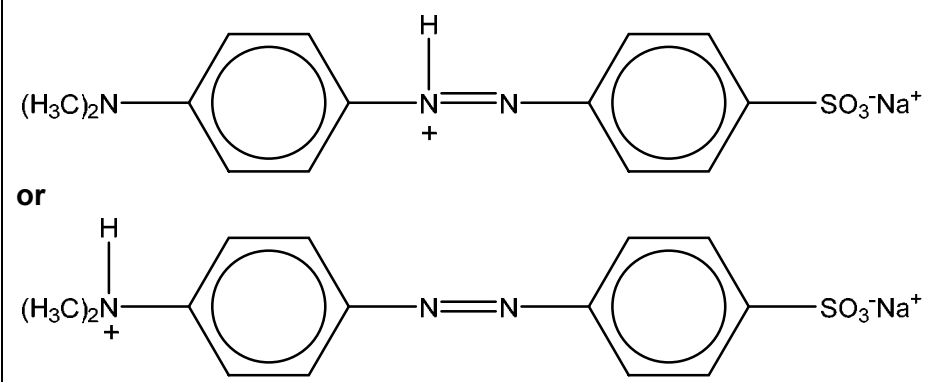
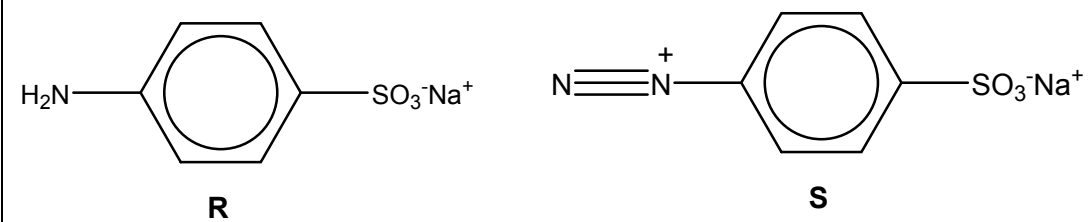
Question	Answer	Marks
2(a)	M1 solubility decreases down the group M2 ΔH_{latt} and ΔH_{hyd} both become less exothermic / more endothermic M3 ΔH_{latt} changes less (than ΔH_{hyd} as SO_4^{2-} being larger than M^{2+}) M4 ΔH_{sol} becomes less exothermic / less negative	4

Question	Answer	Marks
2(b)	M1 CaO_2 and Ca^{2+} has a smaller ionic radii/ Ca^{2+} has a higher charge density M2 anion/ O_2^{2-} becomes more polarised /distorted	2
2(c)	$\text{Mg}(\text{IO}_3)_2 \rightarrow \text{MgO} + 2.5\text{O}_2 + \text{I}_2$	1
2(d)(i)	M1 $K_{\text{sp}} = [\text{Ca}^{2+}][\text{IO}_3^-]^2$ M2 units = $\text{mol}^3 \text{dm}^{-9}$	2
2(d)(ii)	$K_{\text{sp}} = 4 \times (5.6 \times 10^{-3})^3$ $K_{\text{sp}} = 7.03 \times 10^{-7}$ 2sf min	1
2(d)(iii)	M1 $\text{Ca}(\text{IO}_3)_2$ AND as solubility of $\text{Ca}(\text{IO}_3)_2$ decreases M2 due to common ion effect	2
2(e)	M1 moles $\text{S}_2\text{O}_3^{2-} = 0.002 \times 12.4/1000$ $= 2.48 \times 10^{-5}$ moles of $\text{I}_2 = 1.24 \times 10^{-5}$ M2 moles of $\text{IO}_3^- = 4.13 \times 10^{-6}$ in 50 cm^3 moles of $\text{IO}_3^- = 2.07 \times 10^{-5}$ in 250 cm^3 mass of $\text{NaIO}_3 = 2.07 \times 10^{-5} \times 197.9$ M3 mass of $\text{NaIO}_3 = 0.0041$	3
2(f)	It is feasible as the E_{cell} will be positive/+0.12 V	1
2(g)(i)	M1 Rate = $k[\text{IO}_3^-][\text{SO}_3^{2-}][\text{H}^+]$ M2 units = $\text{mol}^{-2}\text{dm}^6\text{s}^{-1}$	2
2(g)(ii)	0.10	1

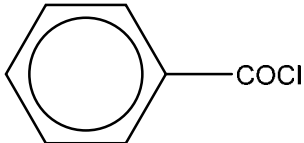
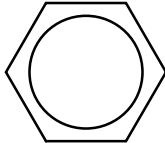
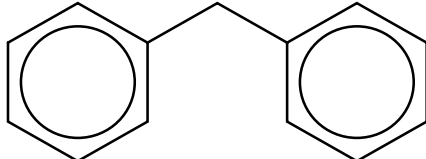
Question	Answer	Marks
3(a)	$3d$ 	1
3(b)	M1 d orbitals split into two levels/ lower and upper orbitals M2 electron(s) promoted / excited to a higher d-orbital M3 frequency of light absorbed M4 observed colour is complement of light absorbed	4
3(c)(i)	(addition of NH_3) increases $[\text{OH}^-]$ (due to ionisation of NH_3 in water) and shifts equilibrium 1 to the right (forming $\text{Ni}(\text{OH})_2$)	1
3(c)(ii)	(a large excess of NH_3) shifts eqm 2 to the right (forming $[\text{Ni}(\text{NH}_3)_6]^{2+}$) AND the $[\text{Ni}^{2+}]/[[\text{Ni}(\text{H}_2\text{O})_6]^{2+}]$ decreases and eqm 1 shifts to the left (causing the ppt to dissolve)	1
3(d)	M1 two correct structures cis & trans for $[\text{NiBr}_2(\text{CN})_2]^{2-}$   M2 type of stereoisomerism: cis-trans/geometric	2

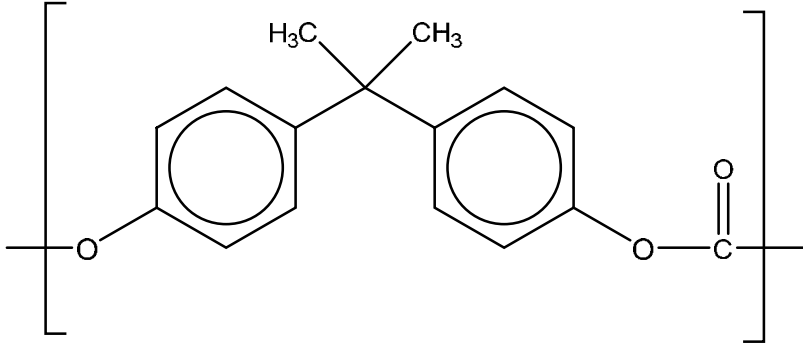
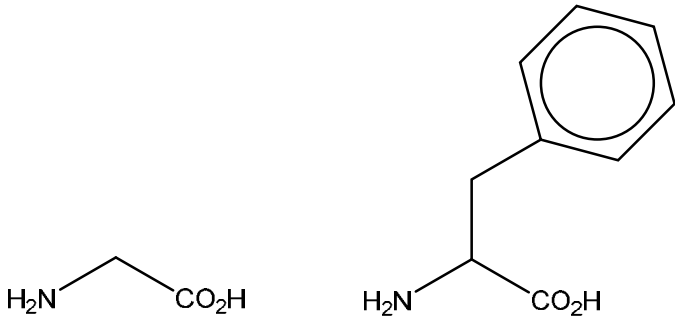
Question	Answer	Marks
4(a)(i)	- trigonal planar - tetrahedral. - trigonal planar Award one mark for two correct statements, award two marks for three correct statements	2

Question	Answer	Marks
4(a)(ii)	 Both structures required	1
4(b)	$\text{C}_{10}\text{H}_8 + 9[\text{O}] \rightarrow \text{C}_8\text{H}_4\text{O}_3 + 2\text{CO}_2 + 2\text{H}_2\text{O}$	1
4(c)	condensation/ addition-elimination	1
4(d)(i)	phenol AND ester	1
4(d)(ii)	 O⁻ +Na⁺ M1 correct hydrolysis product of ester M2 (di)phenoxide salt M3 bromination of both phenol rings at position 2 or/and 6 M4 hydrolysis AND (electrophilic) substitution	4

Question	Answer	Marks
4(e)	M1 $[H^+] = 10^{-8.8} = 1.585 \times 10^{-9}$ M2 $[In^-]/[HIn] = 5.0 \times 10^{-10}/1.585 \times 10^{-9} = 0.315$	2
4(f)(i)	bond circled between the two Ns, or N=N or –N=N–	1
4(f)(ii)		1
4(g)(i)	 R S Award one mark for each correct structure	2
4(g)(ii)	M1 step 1 Sn and HCl conc. and heat M2 step 2 NaNO ₂ and HCl and 0-10 °C	3

Question	Answer	Marks
5(a)	M1 ratio of the concentration of a solute in the two immiscible solvents /liquids M2 at equilibrium	2

Question	Answer	Marks						
5(b)(i)	M1 $79.4 = (0.4-x/25)/(x/125)$ M2 $x = 0.0237 \text{ g}$ [2] min 2sf	2						
5(b)(ii)	(higher as) benzophenone is more non-polar/more soluble in octan-1-ol ora	1						
5(c)(i)	J =  K =  Award one mark for each correct structure	2						
5(c)(ii)	step 1 PCl_5 OR SOCl_2 OR PCl_3 + heat	1						
5(d)(i)		1						
5(d)(ii)	M1 step 3 electrophilic substitution M2 step 3 benzene and AlCl_3 (and heat)	2						
5(d)(iii)	step 4 oxidation	1						
5(e)(i)	5 peaks	1						
5(e)(ii)	<table><tr><th>environment of carbon atom</th><th>chemical shift range (δ)</th></tr><tr><td>carbonyl / RCOR</td><td>190–220</td></tr><tr><td>arene / benzene</td><td>110–160</td></tr></table> Award one mark for each correct for each row	environment of carbon atom	chemical shift range (δ)	carbonyl / RCOR	190–220	arene / benzene	110–160	2
environment of carbon atom	chemical shift range (δ)							
carbonyl / RCOR	190–220							
arene / benzene	110–160							

Question	Answer	Marks
6(a)(i)	condensation	1
6(a)(ii)		1
6(a)(iii)	id-id forces/London forces AND permanent dipole-dipole forces	1
6(b)	M1 (secondary structure by) hydrogen bonding between CO and NH groups M2 (tertiary structure by) interactions between R groups and one example of a named intermolecular force	2
6(c)	M1 (hydrogen bonding between) base pairs M2 A with T and C with G	2
6(d)	hydrolysis and by action of light/UV	1
6(e)(i)	 Award one mark for each correct structure	2

Question	Answer	Marks
6(e)(ii)	correct labelling as shown	1
6(e)(iii)	electrophoresis and thin-layer / paper chromatography [1]	1

Question	Answer	Marks
7(a)(i)	• energy change • when one electron is added • to each atom /ion in one mole of • gaseous atoms /ions Award one mark for two correct statements. Award two marks for four correct statements	2
7(a)(ii)	M1 energy change when 1 mole of an ionic compound is formed M2 from gas phase ions/ gaseous ions	2

Question	Answer	Marks
7(b)	M1 use of data (with no multipliers) 31, 131, -2678 M2 extraction of data 908, 1730, 193 M3 use of (2 x -325) M4 evaluation of <u>their</u> expression correctly, as shown $\Delta H_f(\text{ZnBr}_2) = 131 + (908 + 1730) + 193 + 31 + (2 \times -325) + (-2678)$ $= -335 \text{ kJ mol}^{-1} \quad [4]$	4
7(c)(i)	Br ⁻ is a largest ion/larger ion than Cl ⁻ so attraction between Br ⁻ and Zn ²⁺ is smaller	1
7(c)(ii)	O²⁻ is a smallest ion/smaller ion than Cl⁻ AND O²⁻ has the highest charge/ higher charge than Cl⁻ (so attraction between O²⁻ and Zn²⁺ is larger)	1

Question	Answer	Marks
8(a)(i)	M1 potential difference between two half-cells/two electrodes in a cell M2 under conditions of 1 atm., 298 K, (all) solutions being 1 mol dm⁻³	2
8(a)(ii)	both platinum	1
8(a)(iii)	$E^\ominus_{\text{cell}} = 1.82 - 1.36 = (+)0.46 \text{ V}$	1
8(a)(iv)	$2\text{Co}^{3+} + 2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{Co}^{2+}$	1
8(b)	M1 Q = 2.5 x 30 x 60 C = 4500 C AND 96500 OR 579000 seen moles of CO₂ = 4500/579000 = 7.8 x 10⁻³ or 7.77 x 10⁻³ M2 volume of CO₂ = 7.77 x 10⁻³ x 24000 = 187 cm³	2



Cambridge International AS & A Level

CHEMISTRY

9701/43

Paper 4 A Level Structured Questions

May/June 2020

MARK SCHEME

Maximum Mark: 100

Published

Students did not sit exam papers in the June 2020 series due to the Covid-19 global pandemic.

This mark scheme is published to support teachers and students and should be read together with the question paper. It shows the requirements of the exam. The answer column of the mark scheme shows the proposed basis on which Examiners would award marks for this exam. Where appropriate, this column also provides the most likely acceptable alternative responses expected from students. Examiners usually review the mark scheme after they have seen student responses and update the mark scheme if appropriate. In the June series, Examiners were unable to consider the acceptability of alternative responses, as there were no student responses to consider.

Mark schemes should usually be read together with the Principal Examiner Report for Teachers. However, because students did not sit exam papers, there is no Principal Examiner Report for Teachers for the June 2020 series.

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

Cambridge International is publishing the mark schemes for the June 2020 series for most Cambridge IGCSE™ and Cambridge International A & AS Level components, and some Cambridge O Level components.

This document consists of **15** printed pages.

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	<u>'List rule' guidance</u> (see examples below) For questions that require <i>n</i> responses (e.g. State two reasons ...): • The response should be read as continuous prose, even when numbered answer spaces are provided • Any response marked <i>ignore</i> in the mark scheme should not count towards <i>n</i> • Incorrect responses should not be awarded credit but will still count towards <i>n</i> • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should not be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response • Non-contradictory responses after the first <i>n</i> responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

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

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

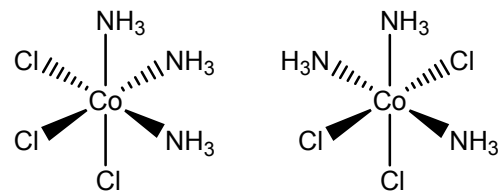
For answers given in standard form, (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

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

7 Guidance for chemical equations

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

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

Question	Answer	Marks
1(a)(i)	(a molecule or ion) formed by a (central) metal atom / ion surrounded by / bonded to (one or more) ligands	1
1(a)(ii)	M1: blue ppt/solid M2: $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{OH})_2 + 6\text{H}_2\text{O}$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$ M3: precipitation/ acid-base M4: blue solution M5: $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Co}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ M6: ligand exchange/displacement/substitution/replacement	6
1(b)	• solution turns blue $\rightarrow$ pink • a white ppt. of AgCl forms • equilibrium shifts to the left / $[\text{Cl}^-]$ decreases Two correct responses = 1 mark Three correct responses = 2 marks	2
1(c)	 geometric ALLOW cis-trans Two correct responses = 1 mark Three correct responses = 2 marks	2
1(d)(i)	each nitrogen / the four nitrogen's has a lone pair of electrons (to the metal ion) Two correct responses = 1 mark	1

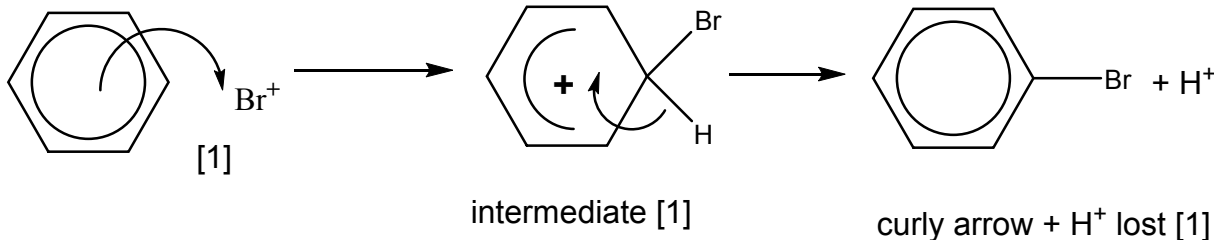
Question	Answer	Marks
1(d)(ii)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + \text{C}_6\text{H}_{18}\text{N}_4 \rightarrow [\text{Co}(\text{C}_6\text{H}_{18}\text{N}_4)]^{2+} + 6\text{H}_2\text{O}$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + \text{C}_6\text{H}_{18}\text{N}_4 \rightarrow [\text{Co}(\text{C}_6\text{H}_{18}\text{N}_4)(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$	1

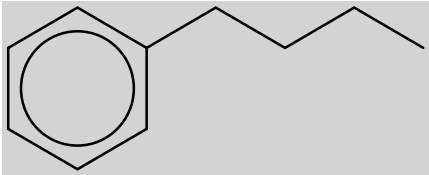
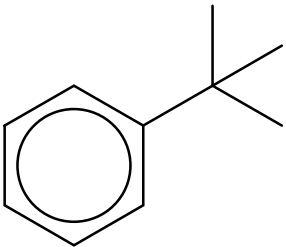
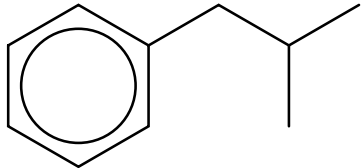
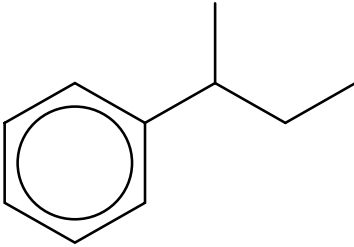
Question	Answer	Marks
2(a)(i)	M1 solubility increases down the group M2 ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative M3 ΔH_{latt} changes more (than ΔH_{hyd} as OH^- being smaller than M^{2+}) M4 ΔH_{sol} becomes more exothermic / more negative	4
2(a)(ii)	M1 $\text{Mg}(\text{OH})_2$ AND Mg^{2+} has a smaller ionic radii/ Mg^{2+} has a higher charge density M2 OH^- ion is polarised/distorted more	2

Question	Answer	Marks
3(a)(i)	$6\text{CO}_2 + 24\text{H}^+ + 24\text{e}^- \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O}$ ALLOW $6\text{CO}_2 + 12\text{H}^+ + 12\text{e}^- \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 3\text{O}_2$ for both marks ALLOW one mark for an unbalanced equation showing the correct species of either equation	2

Question	Answer	Marks
3(a)(ii)	salt bridge (indicated) voltmeter / V labelled O ₂ good delivery system H ₂ good delivery system Pt electrode H ⁺ / HCl / H ₂ SO ₄ solution labelled (at least once) 1 atm 1 mol dm ⁻³ quoted Every two correct responses = 1 mark	4
3(a)(iii)	$E^{\circ}_{\text{cell}} = (+) 1.23 \text{ V}$ AND positive electrode = O ₂ half-cell identified	1

Question	Answer	Marks
4(a)	M1 phenylmethanamine / U > phenylamine / T > benzamide / S [1] any two from: - alkyl group is electron donating so lone pair more able to accept a proton - lone pair on N overlaps with delocalised system so less able to accept a proton - presence of electron-withdrawing oxygen / carbonyl group means lone pair is not available to accept a proton OR amides are neutral	3
4(b)(i)	reaction 1 LiAlH ₄ reaction 2 heat NH ₃ under pressure/ heat NH ₃ in a sealed tube	2
4(b)(ii)	reaction 1 reduction reaction 2 nucleophilic substitution	2

Question	Answer	Marks
5(a)(i)	The substitution product is stabilised by delocalisation of (6) π -electrons OR The addition product is not stabilised by delocalisation of (6) π -electrons [1]	1
5(a)(ii)	 intermediate [1] curly arrow + H^+ lost [1] • first curly arrow • intermediate • 2nd curly arrow, product and H^+ formed / lost	3
5(a)(iii)	$A/Br_4^- + H^+ \rightarrow A/Br_3 + HBr$	1
5(b)	lone pair of oxygen is delocalised into the ring <u>any one from:</u> • phenol has a higher electron density in the ring • phenol can polarise/induce a dipole in Br_2	2
5(c)(i)	$CH_3CH_2CH^+CH_3$ $(CH_3)_2CHCH_2^+$ $(CH_3)_3C^+$ Each correct structure = 1 mark	3

Question	Answer	Marks
5(c)(ii)	 number of peaks in carbon-13 NMR = 8  number of peaks in carbon-13 NMR = 6  number of peaks in carbon-13 NMR = 7  number of peaks in carbon-13 NMR = 8 Two correct organic products = 1 mark three correct organic products = 2 marks all products linked correctly to NMR = 2 marks	4

Question	Answer	Marks
6(a)	M1 2-chloropropanoic acid > 3-chloropropanoic acid > propanoic acid [1] M2 CH₃CHClCO₂H / ClCH₂CH₂CO₂H (are more acidic) as they contain an electronegative Cl atom so weaken O-H bond / stabilise carboxylate anion [1] M3 CH₃CHClCO₂H (is more acidic than ClCH₂CH₂CO₂H) as the Cl atom is closer to CO₂H so weaken O-H bond more / stabilise carboxylate anion more [1]	3

Question	Answer	Marks												
6(b)(i)	$K_{eq} = 4.07 \times 10^{-3} / 1.78 \times 10^{-4} = 22.9$	1												
6(b)(ii)	3 rd box ticked [to the right] AND as the K_{eq} is greater than one ecf on K_{eq}	1												
6(b)(iii)	pK_a 1.23 $HO_2CCO_2H + H_2O \rightleftharpoons HO_2CCO_2^- + H_3O^+$ OR $HO_2CCO_2H \rightleftharpoons HO_2CCO_2^- + H^+$ pK_a 4.19 $HO_2CCO_2^- + H_2O \rightleftharpoons ^-O_2CCO_2^- + H_3O^+$ OR $HO_2CCO_2^- \rightleftharpoons ^-O_2CCO_2^- + H^+$	2												
6(b)(iv)	$pK_a = -\log K_a$	1												
6(c)	<table border="1"> <thead> <tr> <th></th><th>reagents and conditions</th><th>observed change</th></tr> </thead> <tbody> <tr> <td>test 1</td><td>M1 Tollen's reagent, warm OR Fehling's solution, warm</td><td>silver mirror (brick)-red ppt.</td></tr> <tr> <td>test 2</td><td>M2 aqueous alkaline iodine OR 2,4-DNPH</td><td>yellow ppt. orange ppt.</td></tr> <tr> <td>test 3</td><td>M3 acidified MnO_4^-, warm</td><td>decolourises (and bubbles)</td></tr> </tbody> </table> Two correct observations = 1 mark Three correct observations = 2 marks		reagents and conditions	observed change	test 1	M1 Tollen's reagent, warm OR Fehling's solution, warm	silver mirror (brick)-red ppt.	test 2	M2 aqueous alkaline iodine OR 2,4-DNPH	yellow ppt. orange ppt.	test 3	M3 acidified MnO_4^- , warm	decolourises (and bubbles)	5
	reagents and conditions	observed change												
test 1	M1 Tollen's reagent, warm OR Fehling's solution, warm	silver mirror (brick)-red ppt.												
test 2	M2 aqueous alkaline iodine OR 2,4-DNPH	yellow ppt. orange ppt.												
test 3	M3 acidified MnO_4^- , warm	decolourises (and bubbles)												

Question	Answer				Marks
6(d)	chemical shift (δ)	environment of the carbon atom	hybridisation of the carbon atom		2
	27	CH ₃ circled	sp ³		
	163	COOH circled	sp ²		
	192	C=O(COOH) circled	sp ²		
	Award one mark for each correct column				
6(e)	chemical shift (δ)	group responsible for the peak	splitting pattern	number of ¹ H atoms responsible for the peak	3
	1.3	alkane / CH / CH ₃	triplet	3	
	2.2	CH ₃ CO or alkyl / CH next to C=O	singlet	3	
	4.0	CH ₂ O or alkyl / CH next to electronegative atom / C=O	quartet / quadruplet	2	
	Award one mark for every three correct responses.				
6(f)	CH AND CH ₃ circled these protons do not exchange with D ₂ O OR OH and NH protons exchange with D ₂ O				2
6(g)(i)	K _w = [D ⁺][DO ⁻]				1
6(g)(ii)	M1 [D ⁺] = √1.35 x 10 ⁻¹⁵ = 3.67 x10 ⁻⁸ M2 pH = -log [D ⁺] = 7.4(3) min 2sf				2

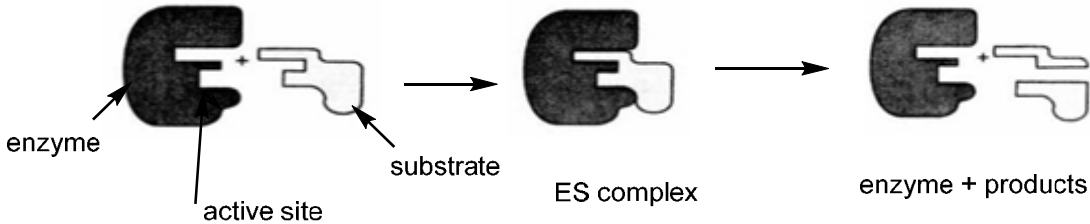
Question	Answer	Marks
7(a)(i)	M1 $K_{sp} = [Ag^+]^2[CO_3^{2-}]$ M2 units = $mol^3 dm^{-9}$	2
7(a)(ii)	$x = \sqrt[3]{6.3 \times 10^{-12}/4} = 1.16 \times 10^{-4} (mol dm^{-3})$ $[Ag^+] = 1.16 \times 10^{-4} \times 2 = \mathbf{2.33 \times 10^{-4}} (mol dm^{-3})$ min 2sf	1
7(a)(iii)	$6.3 \times 10^{-12} = [0.05]^2[CO_3^{2-}]$ $[CO_3^{2-}] = \mathbf{2.52 \times 10^{-9}} (mol dm^{-3})$ min 2sf	1
7(a)(iv)	M1 $E = E^\ominus + 0.059 \log[Ag^+]$ M2 $E = 0.80 + 0.059 \log(1.2 \times 10^{-4}) = \mathbf{0.57 V}$ ecf from (a)(ii) min 2sf	2
7(b)(i)	$\Delta S^\ominus = 72.7 + 56.5 - 96.2 = \mathbf{+33.0 J K^{-1} mol^{-1}}$	1
7(b)(ii)	M1 $\Delta G = \Delta H^\ominus - T\Delta S^\ominus$ M2 $\Delta G = (65.5) - (298 \times 0.033) = \mathbf{+55.7 kJ mol^{-1}}$ min 3sf M3 $\Delta G =$ positive so not feasible/spontaneous	3

Question	Answer	Marks
8(a)	M1 a solution that resists changes in pH M2 when small amounts of acid and alkali are added to it	2
8(b)(i)	$K_a = \frac{[NH_3][H^+]}{[NH_4^+]}$	1
8(b)(ii)	M1 $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ M2 $NH_3 + H_3O^+ \rightarrow NH_4^+ + H_2O$	2

Question	Answer	Marks
8(b)(iii)	M1 moles $\text{NH}_3(\text{initial}) = 0.25 \times 0.80 = 0.200$ AND moles $\text{HCl} = 0.20 \times 0.20 = 0.040$ (= moles $\text{NH}_4^+_{\text{eqm}}$) M2 moles $\text{NH}_3(\text{eqm}) = 0.20 - 0.04 = 0.160$ $[\text{H}^+] = (5.6 \times 10^{-10} \times 0.04)/(0.16) = 1.4 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ ecf on M1 M3 $\text{pH} = -\log(1.4 \times 10^{-10}) = 9.85$ ecf on M2 min 2sf	3

Question	Answer	Marks
9(a)	M1 data seen $\text{H}_2\text{O}_2/\text{H}_2\text{O} +1.77\text{V}$ and $\text{MnO}_2/\text{Mn}^{2+} +1.23 \text{ V}$ and $\text{O}_2/\text{H}_2\text{O}_2 +0.68 \text{ V}$ OR $E_{\text{cell}} = 0.55 \text{ V}$ (first step) and 0.54 V (second step) M2 $\text{MnO}_2 + \text{H}_2\text{O}_2 + 2\text{H}^+ \rightarrow \text{Mn}^{2+} + \text{O}_2 + 2\text{H}_2\text{O}$ M3 $\text{Mn}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{MnO}_2 + 2\text{H}^+$	3
9(b)	rate = $2.0 \times 10^{-6} \times 0.75 = 1.5 \times 10^{-6}$	1
9(c)(i)	slowest step in overall reaction	1
9(c)(ii)	$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{I}^- \rightarrow \text{I}_2 + 2\text{H}_2\text{O}$ OR $\text{H}_2\text{O}_2 + 2\text{HI} \rightarrow \text{I}_2 + 2\text{H}_2\text{O}$	1
9(c)(iii)	$\text{H}_2\text{O}_2 = 1$ AND $\text{I}^- = 1$ AND $\text{H}^+ = 0$	1

Question	Answer	Marks
10(a)	+4 and any of +1, +2, +3	1
10(b)	close similarity of energy of the 4s and 3d sub-shells	1

Question	Answer	Marks
10(c)	diagrams  The diagram illustrates the process of enzyme action in three stages. In the first stage, an enzyme (represented by a dark grey shape with a white 'active site') and a substrate (represented by a light grey shape) are shown. Labels with arrows point to the 'enzyme', 'active site', and 'substrate'. An arrow points to the second stage, where the substrate is bound within the enzyme's active site, forming the 'ES complex'. A second arrow points to the third stage, where the enzyme is shown with two small white shapes (products) being released, labeled 'enzyme + products'. M1 (can be in words or diagram) substrate shape is complementary to active site M2 (can be in words or diagram) the substrate bind / bonds / fits into the active site M3 (can be in words or diagram) products are released M4 (words) lower E_A / bonds weakened (in substrate) Any three points	3