

CHEMISTRY A LEVEL PAPER 3 MARK SCHEME

Question Number	Answer	Additional guidance	Mark
1(a)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • step 2: insoluble impurities are removed by filtration of the hot solution (1) • step 4: soluble impurities remain in the solvent left after filtering the cooled mixture (1) • step 5: the solid product is washed so that no soluble impurities form on the product as it dries (1) 		3
1(b)	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • the melting temperature is over a larger range / is not sharp (1) • the measured melting temperature is less than for the pure solid (1) 		2

(Total Question 1 = 5 marks)

Question Number	Answer	Additional guidance	Mark
2(a)	<ul style="list-style-type: none"> • $\text{Fe}^{2+} / \text{Fe}(\text{H}_2\text{O})_6^{2+}$ • $\text{Cr}^{3+} / \text{Cr}(\text{H}_2\text{O})_6^{3+}$ 	Allow $\text{Ni}^{2+} / \text{Ni}(\text{H}_2\text{O})_6^{2+}$ $\text{V}^{3+} / \text{V}(\text{H}_2\text{O})_6^{3+}$ Ignore names	2
2(b)(i)	$\text{Cr}^{3+} / \text{Cr}(\text{H}_2\text{O})_6^{3+}$	Ignore names	1
2(b)(ii)	$\text{Cr}(\text{OH})_3 / \text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$	Ignore names	1
2(b)(iii)	$\text{Cr}(\text{OH})_6^{3-}$	Accept other correct species Ignore names (no ecf from (b)(i))	1
2(c)	Any one from: <ul style="list-style-type: none"> • purple to colourless • <u>purple</u> (solution) <u>decolourised</u> 	Allow final colour of solution to be orange Allow pink for purple	1
2(d)(i)	Cl^-	Reject Cl Ignore names	1

Question Number	Answer	Additional guidance	Mark
2(d)(ii)	<p>An explanation that makes reference to the following points:</p> <p>ammonia solution cannot be used because:</p> <ul style="list-style-type: none"> • ammonia reacts with the iron ions to form a precipitate (1) <p>or</p> <ul style="list-style-type: none"> • a precipitate of (Iron(II) hydroxide/ $\text{Fe}(\text{OH})_2$/ $\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2$ forms (1) <p>AND</p> <ul style="list-style-type: none"> • and so obscures the dissolving of the white precipitate (1) 		2

(Total Question 2 = 9 marks)

Question number	Answer	Additional guidance	Mark
3(a)(i)	<ul style="list-style-type: none"> evaluation of number of moles of propanone = $0.025 \times 2.0 = 0.050$ mol (1) which is greater than the amount of iodine, which is $0.050 \times 0.020 = 0.0010$ mol (1) 		2
3(a)(ii)	<ul style="list-style-type: none"> measuring cylinder/burette (1) 		1
3(a)(iii)	<ul style="list-style-type: none"> pipette (1) 		1
3(b)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> the order with respect to iodine is zero (1) because the graph is a straight line, showing that the change in iodine concentration is constant (1) 		2
3(c)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> 1st order with respect to H⁺ and propanone (1) H⁺ and propanone involved in reaction before rate determining step (therefore 1st order) (1) iodine involved after rate determining step / slow step (therefore zero order) (1) 		3

(Total Question 3 = 9 marks)

Question number	Answer	Additional guidance	Mark												
4(a)	<ul style="list-style-type: none"> axes: correct way round, labelled, suitable scale (1) all points plotted correctly, with best fit straight line (1) calculation of gradient of straight line (1) use of gradient = $-E_a / R$ to calculate E_a (in kJ mol^{-1}) (1) 	<p>Plotted points must cover at least half the graph paper on each axis Allow $\pm 1/2$ a square</p> <p>Gradient = (-) 5970 Allow ± 200</p> <p>Activation energy = $5970 \times 8.31 / 1000$ = $+49.6$ (kJ mol^{-1})</p> <p>Final answer must be positive.</p>	4												
*4(b)	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td>6</td> <td>4</td> </tr> <tr> <td>5-4</td> <td>3</td> </tr> <tr> <td>3-2</td> <td>2</td> </tr> <tr> <td>1</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> </tr> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	<p>Guidance on how the mark scheme should be applied:</p> <p>The mark for indicative content should be added to the mark for lines of reasoning.</p> <p>For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p>	6
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														

Question number	Answer	Additional guidance	Mark								
*4 (b) Cont.	<p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table border="1" data-bbox="352 891 895 1756"> <thead> <tr> <th data-bbox="352 1245 533 1756"></th> <th data-bbox="352 891 533 1245">Number of marks awarded for structure of answer and sustained line of reasoning</th> </tr> </thead> <tbody> <tr> <td data-bbox="533 1245 713 1756">Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td> <td data-bbox="533 891 713 1245">2</td> </tr> <tr> <td data-bbox="713 1245 823 1756">Answer is partially structured with some linkages and lines of reasoning.</td> <td data-bbox="713 891 823 1245">1</td> </tr> <tr> <td data-bbox="823 1245 895 1756">Answer has no linkages between points and is unstructured.</td> <td data-bbox="823 891 895 1245">0</td> </tr> </tbody> </table> <p>Indicative content:</p> <ul data-bbox="986 869 1337 1715" style="list-style-type: none"> • activation energy (E_A) for the formation of A is lower than that for B (E_B) • hence at 40 °C more collisions exceed E_A than exceed E_B • so A is formed more quickly than B at 40 °C • at 160 °C more collisions exceed E_B (and E_A) than at 40 °C • therefore both isomers are formed • but the reactions are reversible and B is the more stable isomer, therefore A will convert to B 		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	Answer is partially structured with some linkages and lines of reasoning.	1	Answer has no linkages between points and is unstructured.	0		
	Number of marks awarded for structure of answer and sustained line of reasoning										
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2										
Answer is partially structured with some linkages and lines of reasoning.	1										
Answer has no linkages between points and is unstructured.	0										

(Total Question 4 = 10 marks)

Question Number	Answer	Additional guidance	Mark
5(a)	<ul style="list-style-type: none"> • substitution into ΔS^\ominus equation (1) • evaluation of ΔS^\ominus (1) • substitution into $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$, using ΔS^\ominus in $\text{kJ K}^{-1} \text{mol}^{-1}$ (1) • correct answer to 3 sf (1) • since ΔG^\ominus is negative, the reaction is feasible (1) 	<p>Example of calculation</p> $\Delta S^\ominus = (2 \times 193) - 192 - (3 \times 131)$ $= -199 \text{ J K}^{-1} \text{ mol}^{-1} / - 0.199 \text{ kJ K}^{-1} \text{ mol}^{-1}$ $\Delta G^\ominus = - 92.0 - (298 \times - 0.199)$ $= - 32.7 \text{ kJ mol}^{-1} / - 32 700 \text{ J mol}^{-1}$ <p>The first four marking points can be awarded for a correct answer to 3 sf with no working</p>	5
5(b)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • (as temperature increases) $T\Delta S$ becomes more negative (1) • (eventually) $\Delta H - T\Delta S$ becomes positive (1) 		2

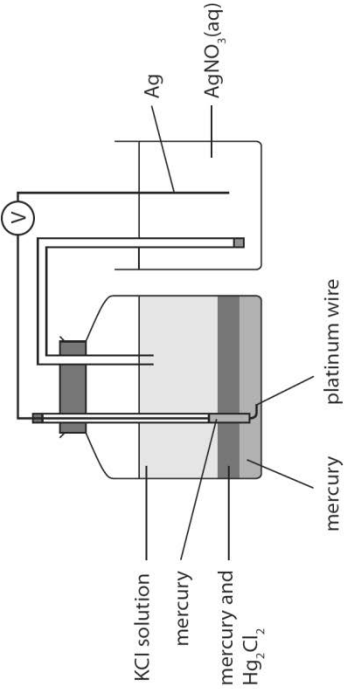
Question Number	Answer	Additional guidance	Mark
5(c)	<ul style="list-style-type: none"> • Correct expression for K_p (1) • Calculation of mole fractions for N_2, H_2 and NH_3 (1) • Calculation of partial pressures for N_2, H_2 and NH_3 (1) • Substitution and evaluation of K_p (1) • Units: atm^{-2} (1) 	<p>Example of calculation (total number of moles = 18)</p> <p>mf N_2 = $2.88 \div 18 = 0.16$ mf H_2 = $8.64 \div 18 = 0.48$ mf NH_3 = $6.48 \div 18 = 0.36$</p> <p>$p_{N_2} = 0.16 \times 200 = 32 \text{ atm}$ $p_{H_2} = 0.48 \times 200 = 96 \text{ atm}$ $p_{NH_3} = 0.36 \times 200 = 72 \text{ atm}$</p> $K_p = \frac{p^2_{NH_3(g)}}{p_{N_2(g)} \cdot p^3_{H_2(g)}}$ $K_p = \frac{72^2}{32 \times 96^3} = 1.83 \times 10^{-4} \text{ atm}^{-2}$ <p>Alternative method for calculation: $\frac{0.36^2}{0.16 \times 0.48^3} (= 7.32421875)$</p> $K_p = \frac{0.36^2}{0.16 \times 0.48^3} \times \frac{1}{200^2} = 1.83 \times 10^{-4} \text{ atm}^{-2}$ <p>Correct answer with no working with units scores 5 marks</p>	5

(Total Question 5 = 12 marks)

Question Number	Answer	Additional guidance	Mark
6(a)	<p>An answer that makes reference to the following:</p> <ul style="list-style-type: none"> • suitable volumes of ethanol and water (1) • evidence of calculation to show one component of mixture in excess (1) • mixed together in simple calorimeter / polystyrene cup with lid (1) • stir and measure maximum temperature change (1) • calculate energy change using $Q = mc\Delta T$ (1) • calculate strength of hydrogen bond per mole by scaling up from the amount of limiting component of mixture (i.e. component not in excess) (1) 		6
6(b)(i)	<ul style="list-style-type: none"> • evaluation of number of moles of 2-hydroxybenzoic acid used (1) • calculation of mass of aspirin at 100% yield (1) • calculation of mass of aspirin at 65% yield (1) 	<p><u>Example of calculation</u> $2 / 138 = 0.0145 \text{ mol}$ $0.0145 \times 180 = 2.61 \text{ g}$ $2.61 / 100 \times 65 = 1.70 \text{ g}$</p> <p>Correct answer with no working scores 3 marks</p>	3

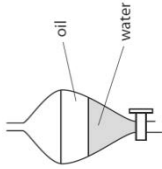
Question Number	Answer	Additional guidance	Mark
6(b)(ii)	<p>The mark for each reason must be linked with the correct improvement.</p> <ul style="list-style-type: none"> • Improvement: swap the water inflow and outflow in the condenser (1) • Reason: to improve efficiency of condensing process (1) • Improvement: add anti-bumping granules to flask (1) • Reason: to promote smooth boiling/to prevent material escaping from top of condenser (1) • Improvement: insert condenser into neck of flask (1) • Reason: to prevent escape of reagents (1) 		6

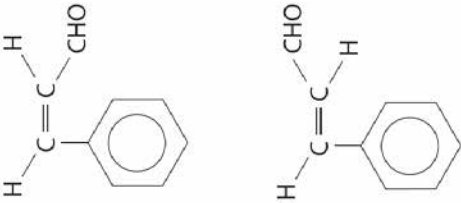
(Total for question 6 = 15 marks)

Question Number	Answer	Additional guidance	Mark
7(a)(i)	<ul style="list-style-type: none"> • (saturated) potassium nitrate (1) 	Allow potassium chloride	1
7(a)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • to complete the circuit (1) • by allowing movement of (positive and negative) ions (1) 		2
7(b)(i)	<ul style="list-style-type: none"> • container/beaker containing the side arm and silver, both dipping into silver nitrate solution (1) • connecting wire from silver and calomel electrode to complete the circuit (1) • (high resistance/digital) voltmeter (1) 		3
7(b)(ii)	<ul style="list-style-type: none"> • solution concentration 1.0 mol dm^{-3} (1) • temperature 298 K (1) 	Ignore mention of pressure	2

Question Number	Answer	Additional guidance	Mark
7(c)(i)	<ul style="list-style-type: none"> correct equation $\text{emf} = 0.80 - (+)0.27 = (+)0.53 \text{ (V)}$ 	<p>No sign in answer scores 1 mark, a minus sign given scores 0 marks</p> <p>Correct answer with no working scores 2 marks</p>	2
7(c)(ii)	<ul style="list-style-type: none"> $(+)0.03 \text{ (V)}$ 		1
7(c)(iii)	<ul style="list-style-type: none"> $\text{Fe}^{2+}(\text{aq}) + \text{Ag}^+(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{Ag}(\text{s})$ 	Allow reversible arrows	1
7(c)(iv)	<ul style="list-style-type: none"> rearrangement and substitution into equation evaluation of $\ln K$ and conversion to K 	<p><u>Example of calculation</u></p> $\ln K = \frac{-2892}{8.31 \times 298} = (+)1.1678$ $K = 3.21502 = 3.22$ <p>Ignore sf except 1</p> <p>Note if $\ln K = 1.1678$ is used answer is 3.21</p> <p>Correct answer with no working scores 2 marks</p>	2

(Total for question 7 = 14 marks)

Question Number	Answer	Additional guidance	Mark
8(a) (i)	 <ul style="list-style-type: none"> • cinnamon oil upper layer (1) • separating funnel (1) 	Funnel must be suitable for a stopper	2
8(a) (ii)	<ul style="list-style-type: none"> • addition of (anhydrous) sodium sulfate / calcium chloride / magnesium sulfate (1) 		1
8(a) (iii)	<ul style="list-style-type: none"> • from cloudy to clear (1) 	Do not accept colourless in place of clear	1
8(b) (i)	<ul style="list-style-type: none"> • contains C=C/alkene (1) 		1
8(b) (ii)	<ul style="list-style-type: none"> • contains carbonyl group/ aldehyde or ketone (1) 	C=O alone	1
8(b) (iii)	<ul style="list-style-type: none"> • aldehyde/ -CHO (1) 		1

Question Number	Answer	Additional guidance	Mark
8(c)(i)	<ul style="list-style-type: none"> • 77 $C_6H_5^+$ • 103 $C_8H_7^+$ 	<p>Must show a charge but only penalise omission once</p> <p>Allow structural, displayed or skeletal formulae</p> <p>Allow non-displayed benzene C-Hs</p>	2
8(c)(ii)			2
8(c)(iii)	<ul style="list-style-type: none"> • The peak is due to the presence of an atom of a ^{13}C isotope 	Allow reference to other named isotope of H or O	1

Question Number	Answer	Additional guidance	Mark
8(d)	<ul style="list-style-type: none"> • initial moles of NaOH in 250 cm³ (1) • excess moles of NaOH in 25.0 cm³ (1) • expression for moles of total NaOH reacted (1) • evaluation of moles of cinnamic acid (1) • evaluation of M_r of cinnamic acid to 1 dp (1) 	<p>Example calculation</p> <p>Initial moles of NaOH = $(250 \div 1000) \times 0.500$ = 0.125</p> <p>Moles of excess NaOH in 25.0 cm³ = $(28.25 \div 1000) \times 0.400 = 0.0113$</p> <p>Moles of NaOH reacted = $0.125 - (10 \times 0.0113)$</p> <p>Moles of cinnamic acid = moles of NaOH reacted = 0.012</p> <p>M_r of cinnamic acid = $1.78 \div 0.012 = 148.3$</p> <p>Allow ecf from 2nd mark</p> <p>Correct answer to 1 dp with no working scores 5 marks</p>	5

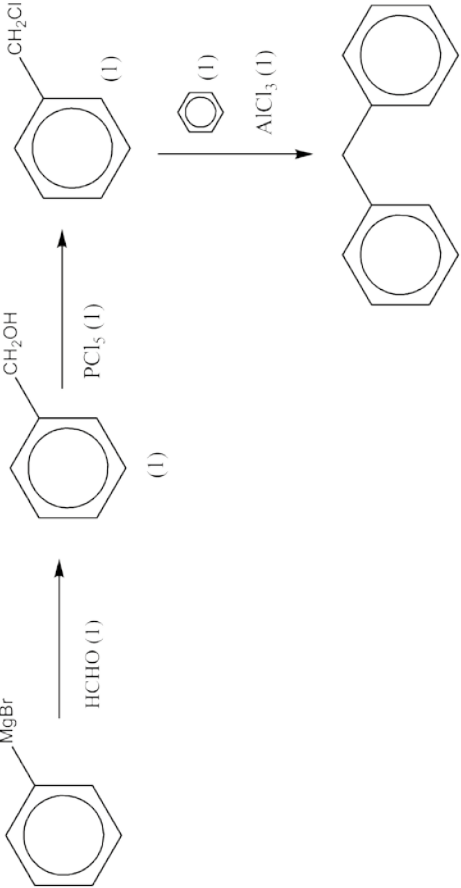
(Total for Question 8 = 17 marks)

Question Number	Answer	Additional guidance	Mark
9(a)(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • copper forms an ion with an incomplete d-sub-shell / with a configuration of $3d^9$ (1) • but the <u>only</u> ion formed by zinc has a completely filled d-sub-shell (1) 		2
9(a)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> • (in brass) the layers of positive ions can slide over one another (1) • and there are (always) electrons between the layers preventing repulsion between the ions in one layer and those in another layer (1) • (in sodium chloride) when a layer of ions is displaced, ions with the same charge become close to one another and repel (1) 		3
9(b)(i)	<ul style="list-style-type: none"> • brown fumes (1) • a green/blue solution forming (1) 		2

Question Number	Answer	Additional guidance	Mark
9(b)(ii)	<ul style="list-style-type: none"> $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$ (1) 	State symbols must be present	1
9(b)(iii)	<ul style="list-style-type: none"> amount of thiosulfate (1) uses amount of thiosulfate = amount of iodine to determine amount of thiosulfate = amount of copper(II) ions in 25 cm³ portion (1) evaluation of number of moles of Cu in sample (1) calculates mass of Cu (1) percentage copper to 3 sf (1) 	<p><u>Example of calculation</u> amount of thiosulfate = $\frac{22.7 \times 0.25}{1000}$ = 5.675×10^{-3} (mol)</p> <p>5.675×10^{-3} (mol) = amount of copper(II) ions in 25 cm³ portion</p> <p>amount of Cu in sample = $5.675 \times 10^{-3} \times 10$ = 5.675×10^{-2} (mol)</p> <p>mass of Cu = $5.675 \times 10^{-2} \times 63.5$ = 3.603625</p> <p>percentage copper = $\frac{3.603625}{5.00} \times 100$ = 72.1%</p> <p>Allow ecf from 2nd mark</p> <p>Correct answer to 3 sf with no working scores 5 marks</p>	5
9(b)(iv)	<ul style="list-style-type: none"> calculation of percentage uncertainty from balance = $\pm 0.005 \times 2 \times 100 / 5.00 = 0.2\%$ percentage uncertainty in mean titre from burette = $2 \times \pm 0.05 \times 100 / 22.7 = 0.44\%$ so burette reading is most significant (1) <p>and</p> <ul style="list-style-type: none"> (1) 		2

(Total for Question 9 = 15 marks)

Question Number	Answer	Additional guidance	Mark
10(a)	<ul style="list-style-type: none"> $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaCO_3$ 	Accept $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaO + CO_2$	1
10(b)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> -2 in cyclohexane and -1 in benzene (1) so (carbon is) oxidised (1) 	2nd mark stands alone	2
10(c)	<p>spectrum 1 is methylbenzene, because</p> <ul style="list-style-type: none"> it contains an absorption at $2962 - 2853 \text{ cm}^{-1}$ (1) owing to alkyl C—H stretching (1) 	Identification unqualified gains no marks	2
10(d)	<p>$nC_6H_5CH=CH_2 \rightarrow \left\{ \underset{\text{C}_6\text{H}_5}{\text{CH}-\text{CH}_2} \right\}_n$</p> <ul style="list-style-type: none"> correct product formula (1) balanced equation (1) 		2
10(e)(i)	Iron / iron(III) bromide	Allow aluminium / aluminium bromide Allow correct formulae	1

Question Number	Answer	Additional guidance	Mark
10(e)(ii)	<ul style="list-style-type: none"> • reagent for step 1 (1) • product of step 1 (1) • reagent for step 2 (1) • product of step 2 (1) • reagent for step 3 (1) • catalyst for step 3 (1) 		6
	<p>Example of synthesis:</p> 		

(Total for Question 10 = 14 marks)

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