CHEMISTRY A LEVEL PAPER 3 MARK SCHEME

Question Number	Answer	Additional guidance	Mark
1(a)	An answer that makes reference to the following points: • 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)	A description that makes reference to the following points: • 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)	• Fe^{2+} / $Fe(H_2O)_6^{2+}$ (1) • Cr^{3+} / $Cr(H_2O)_6^{3+}$ (1)	Allow Ni^{2+} / $Ni(H_2O)_6^{2+}$ V^{3+} / $V(H_2O)_6^{3+}$ Ignore names	**2**
2(b)(i)	Cr^{3+} / $Cr(H_2O)_6^{3+}$ (1)	Ignore names	**1**
2(b)(ii)	$Cr(OH)_3$/ $Cr(H_2O)_3(OH)_3$ (1)	Ignore names	**1**
2(b)(iii)	$Cr(OH)_6^{3-}$ (1)	Accept other correct species Ignore names (no ecf from (b)(i))	**1**
2(c)	Any **one** from: • purple to colourless • purple (solution) decolourised (1)	 Allow final colour of solution to be orange Allow pink for purple	**1**
2(d)(i)	Cl^- (1)	Reject Cl Ignore names	**1**

Question Number	Answer	Additional guidance	Mark
2(d)(ii)	An explanation that makes reference to the following points: ammonia solution cannot be used because: • ammonia reacts with the iron ions to form a precipitate (1) **or** • a precipitate of (Iron(II) hydroxide/ $Fe(OH)_2$/ $Fe(H_2O)_4(OH)_2$ forms (1) **AND** • 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)	• evaluation of number of moles of propanone = 0.025 × 2.0 = 0.050 mol (1) • which is greater than the amount of iodine, which is 0.050 × 0.020 = 0.0010 mol (1)		**2**
3(a)(ii)	• measuring cylinder/burette (1)		**1**
3(a)(iii)	• pipette (1)		**1**
3(b)	An explanation that makes reference to the following points: • 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)	An answer that makes reference to the following points: • 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)

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>4(a)</td><td>• 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)</td><td>Plotted points must cover at least half the graph paper on each axis
Allow ±½ a square

Gradient = (-) 5970 Allow ± 200

Activation energy = 5970 x 8.31 / 1000
= +49.6 (kJ mol^{-1})
Final answer must be positive.</td><td>4</td></tr>
<tr><td>*4(b)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<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>
</table></td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning.
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).
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).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*4(b) Cont.</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table>
Indicative content:

activation energy (E_A) for the formation of A is lower than that for B (E_B)
hence at 40 ºC more collisions exceed E_A than exceed E_B
so A is formed more quickly than B at 40 ºC
at 160 ºC more collisions exceed E_B (and E_A) than at 40 ºC
therefore both isomers are formed
but the reactions are reversible and B is the more stable isomer, therefore A will convert to B
</td><td></td><td></td></tr>
</table>

(Total Question 4 = 10 marks)

Question Number	Answer	Additional guidance	Mark
5(a)	• substitution into $\Delta S^{\ominus}$ equation (1) • evaluation of $\Delta S^{\ominus}$ (1) • substitution into $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$, using $\Delta S^{\ominus}$ in kJ K^{-1} mol^{-1} (1) • correct answer to 3 sf (1) • since $\Delta G^{\ominus}$ is negative, the reaction is feasible (1)	<u>Example of calculation</u> $\Delta S^{\ominus}$ = (2 x 193) - 192 -(3 x 131) = −199 J K^{-1} mol^{-1} / − 0.199 kJ K^{-1} mol^{-1} $\Delta G^{\ominus}$ = − 92.0 - (298 x − 0.199) = − 32.7 kJ mol^{-1} / – 32 700 J mol^{-1} The first four marking points can be awarded for a correct answer to 3 sf with no working	**5**
5(b)	An explanation that makes reference to the following points: • (as temperature increases) $T\Delta S$ becomes more negative (1) • (eventually) $\Delta H - T\Delta S$ becomes positive (1)		**2**

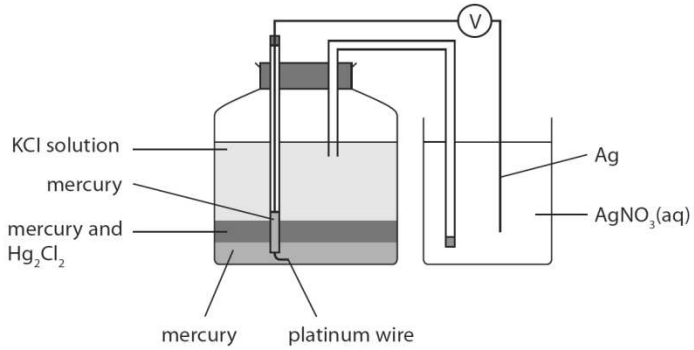
Question Number	Answer	Additional guidance	Mark
5(c)	• Correct expression for K_p (1) • Calculation of mole fractions for N_2, H_2 and NH_3 (1) • Calculation of partial pressures for N_2, H_2 and NH_3 (1) • Substitution and evaluation of K_p (1) • Units: atm^{-2} (1)	Example of calculation (total number of moles = 18) mf N_2 = 2.88 ÷ 18 = 0.16 mf H_2 = 8.64 ÷ 18 = 0.48 mf NH_3 = 6.48 ÷ 18 = 0.36 pN_2 = 0.16 x 200 = 32 atm pH_2 = 0.48 x 200 = 96 atm pNH_3 = 0.36 x 200 = 72 atm $K_p = \frac{p^2NH_3(g)}{pN_2(g).p^3H_2(g)}$ $K_p = \frac{72^2}{32 \text{ x } 96^3} = 1.83 \text{ x } 10^{-4}$ atm^{-2} Alternative method for calculation: $\frac{0.36^2}{0.16 \text{ x } 0.48^3}$ (= 7.32421875) $K_p = \frac{0.36^2}{0.16 \text{ x } 0.48^3} \text{ x } \frac{1}{200^2} = 1.83 \text{ x } 10^{-4}$ atm^{-2} Correct answer with no working with units scores 5 marks	**5**

(Total Question 5 = 12 marks)

Question Number	Answer	Additional guidance	Mark
6(a)	An answer that makes reference to the following: • 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=mcΔT (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)	• 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)	<u>Example of calculation</u> 2 / 138 = 0.0145 mol 0.0145 x 180 = 2.61 g 2.61/100 x 65 = 1.70 g Correct answer with no working scores 3 marks	**3**

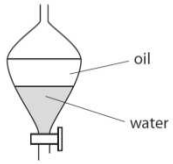
Question Number	Answer	Additional guidance	Mark
6(b)(ii)	The mark for each reason must be linked with the correct improvement. • Improvement: swap the water inflow and outflow in the condenser (1) • Reason: to improve efficiency of condensing process (1) • Improvement: add anti-bumping granules to flask (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**

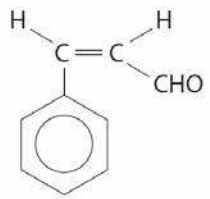
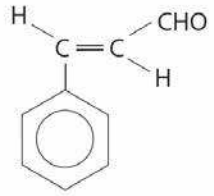
(**Total for question 6 = 15 marks)**

Question Number	Answer	Additional guidance	Mark
7(a)(i)	• (saturated) potassium nitrate (1)	Allow potassium chloride	**1**
7(a)(ii)	An explanation that makes reference to the following points: • to complete the circuit (1) • by allowing movement of (positive and negative) ions (1)		**2**
7(b)(i)	• 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)	• 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)	• correct equation (1) • emf = 0.80 – (+)0.27 = (+)0.53 (V) (1)	No sign in answer scores 1 mark, a minus sign given scores 0 marks Correct answer with no working scores 2 marks	**2**
7(c)(ii)	• (+)0.03 (V) (1)		**1**
7(c)(iii)	• $Fe^{2+}(aq) + Ag^{+}(aq) \rightarrow Fe^{3+}(aq) + Ag(s)$ (1)	Allow reversible arrows	**1**
7(c)(iv)	• rearrangement and substitution into equation (1) • evaluation of ln *K* and conversion to *K* (1)	Example of calculation $\ln K = \frac{2892}{8.31 \times 298} = (+)1.1678$ $K = 3.21502 = 3.22$ Ignore sf except 1 Note if ln *K* = 1.1678 is used answer is 3.21 Correct answer with no working scores 2 marks	**2**

(**Total for question 7 = 14 marks)**

Question Number	Answer	Additional guidance	Mark
8(a) (i)	 • cinnamon oil upper layer (1) • separating funnel (1)	Funnel must be suitable for a stopper	**2**
8(a)(ii)	• addition of (anhydrous) sodium sulfate / calcium chloride / magnesium sulfate (1)		**1**
8(a)(iii)	• from cloudy to clear (1)	Do not accept colourless in place of clear	**1**
8(b)(i)	• contains C=C/alkene (1)		**1**
8(b)(ii)	• contains carbonyl group/ aldehyde or ketone (1)	C=O alone	**1**
8(b)(iii)	• aldehyde/ -CHO (1)		**1**

Question Number	Answer	Additional guidance	Mark
8(c)(i)	• 77 $C_6H_5^+$ (1) • 103 $C_8H_7^+$ (1)	Must show a charge but only penalise omission once Allow structural, displayed or skeletal formulae	**2**
8(c)(ii)	 	Allow non-displayed benzene C-Hs	**2**
8(c)(iii)	• The peak is due to the presence of an atom of a (^{13}C) isotope (1)	Allow reference to other named isotope of H or O	**1**

Question Number	Answer	Additional guidance	Mark
8(d)	• initial moles of NaOH in 250 cm^3 (1) • excess moles of NaOH in 25.0 cm^3 (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)	<u>Example calculation</u> Initial moles of NaOH = (250 ÷ 1000) x 0.500 = 0.125 Moles of excess NaOH in 25.0 cm^3 = (28.25 ÷ 1000) x 0.400 = 0.0113 Moles of NaOH reacted = 0.125 – (10 x 0.0113) Moles of cinnamic acid = moles of NaOH reacted = 0.012 M_r of cinnamic acid = 1.78 ÷ 0.012 = 148.3 Allow ecf from 2nd mark Correct answer to 1 dp with no working scores 5 marks	**5**

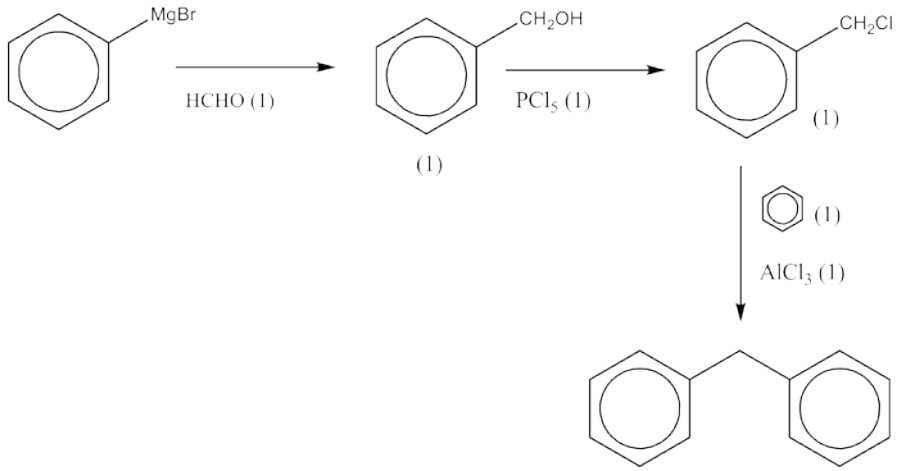
(Total for Question 8 = 17 marks)

Question Number	Answer	Additional guidance	Mark
9(a)(i)	An explanation that makes reference to the following points: • 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)	An explanation that makes reference to the following points: • (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)	• brown fumes (1) • a green/blue solution forming (1)		**2**

Question Number	Answer	Additional guidance	Mark
9(b)(ii)	• $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$ (1)	State symbols must be present	**1**
9(b)(iii)	• amount of thiosulfate (1) • uses amount of thiosulfate = amount of iodine to determine amount of thiosulfate = amount of copper(II) ions in 25 cm^3 portion (1) • evaluation of number of moles of Cu in sample (1) • calculates mass of Cu (1) • • percentage copper to 3 sf (1)	Example of calculation amount of thiosulfate = $\frac{22.7 \times 0.25}{1000}$ = 5.675×10^{-3} (mol) 5.675×10^{-3} (mol) = amount of copper(II) ions in 25 cm^3 portion amount of Cu in sample = $5.675 \times 10^{-3} \times 10$ = 5.675×10^{-2} (mol) mass of Cu = $5.675 \times 10^{-2} \times 63.5$ = 3.603625 percentage copper = 3.603625 x 100 /5.00 = 72.0725 = 72.1% Allow ecf from 2nd mark Correct answer to 3 sf with no working scores 5 marks	**5**
9(b)(iv)	• calculation of percentage uncertainty from balance = ±0.005x 2 x100/5.00 = 0.2% **and** percentage uncertainty in mean titre from burette = 2x±0.05 x 100 /22.7 = 0.44% (1) • so burette reading is most significant (1)		**2**

(Total for Question 9 = 15 marks)

Question Number	Answer	Additional guidance	Mark
10(a)	• $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaCO_3$ (1)	Accept $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaO + CO_2$	**1**
10(b)	An answer that makes reference to the following points: • -2 in cyclohexane <u>and</u> -1 in benzene (1) • so (carbon is) oxidised (1)	 2nd mark stands alone	**2**
10(c)	spectrum 1 is methylbenzene, because • it contains an absorption at 2962 – 2853 cm^{-1} (1) • owing to alkyl C—H stretching (1)	 Identification unqualified gains no marks	**2**
10(d)	$nC_6H_5CH{=}CH_2 \rightarrow \{-CH(C_6H_5)-CH_2-\}_n$ • 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)	• 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**
	Example of synthesis:  		

(Total for Question 10 = 14 marks)