

GCE

Chemistry A

Unit **H432A/01**: Periodic table, elements and physical chemistry

Advanced GCE

Mark Scheme for June 2017

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.















All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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Annotations available in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

Subject-specific Marking Instructions**INTRODUCTION**

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

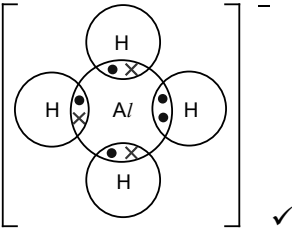
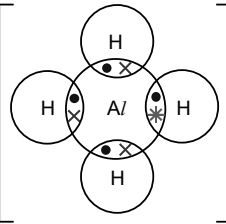
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

SECTION A

Question	Answer	Marks	Guidance
1	D	1	
2	D	1	
3	C	1	ALLOW +6 in the box
4	C	1	
5	B	1	ALLOW 20 in the box
6	C	1	
7	A	1	
8	D	1	
9	C	1	
10	A	1	
11	A	1	
12	C	1	ALLOW 4.1 in the box
13	B	1	ALLOW 0.426 in the box
14	C	1	
15	B	1	
	Total	15	

SECTION B

Question	Answer	Marks	Guidance
16 (a) (i)		1	<p>IGNORE no brackets, no charge or wrong charge Circles not needed</p> <p>ALLOW different sign for 'extra' electron, e.g.</p>  <p>DO NOT ALLOW 4 dots and 4 crosses</p>
(b)	<p>NH_4^+: tetrahedral AND 109.5° ✓</p> <p>NH_2^-: non-linear AND 104.5° ✓</p>	2	<p>ALLOW $109-110^\circ$</p> <p>ALLOW $104-105^\circ$</p> <p>ALLOW bent, v-shaped, angular IGNORE planar, 'not straight'</p>

Question		Answer	Marks	Guidance
	(c) (i)	<p>NH₃ has hydrogen bonding OR PH₃ does not have hydrogen bonding ✓</p> <p>Hydrogen bonding is stronger OR More energy to overcome hydrogen bonding ✓</p>	2	<p>ORA throughout</p> <p>Assume that comparison is with PH₃</p> <p>DO NOT ALLOW response that implies covalent or ionic bonds breaking</p>
	(ii)	<p>AsH₃ / As has more electrons (than PH₃ / P) ✓</p> <p>in AsH₃, stronger/more induced dipole–dipole interactions OR stronger/more London forces (than PH₃) OR more energy required to overcome induced dipole–dipole interactions ✓</p>	2	<p>ORA throughout ALLOW larger electron cloud</p> <p>ALLOW 'forces' OR 'bonds' for 'interactions' ALLOW instantaneous/temporary–induced dipole interactions ALLOW dispersion forces</p> <p>IGNORE van der Waals' / vdW IGNORE permanent dipole–dipole</p> <p>DO NOT ALLOW response that implies covalent or ionic bonds breaking</p>
		Total	7	

Question		Answer	Marks	Guidance
17	(a)	$\text{Ba(OH)}_2 + 2\text{HCl} \rightarrow \text{BaCl}_2 + 2\text{H}_2\text{O} \checkmark$	1	ALLOW multiples IGNORE state symbols (even if wrong)
	(b)	<p><i>Increasing size:</i> Atomic radius increases OR more shells OR more (electron) shielding \checkmark</p> <p><i>Attraction</i> Nuclear attraction decreases OR (outer) electron(s) experience less attraction \checkmark</p> <p><i>Ionisation energy</i> Ionisation energy decreases OR less energy needed to remove electron(s) \checkmark</p>	3	<p>FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED</p> <p>IGNORE more orbitals OR more sub-shells <i>Alternative must refer to shells</i></p> <p>ALLOW Energy levels for shells</p> <p>ALLOW more electron repulsion between shells IGNORE just 'shielding' (<i>more/greater needed</i>) IGNORE 'nuclear shielding'</p> <p>IGNORE 'pull' for attraction IGNORE 'electrons less tightly held' IGNORE 'nuclear charge' for 'nuclear attraction'</p> <p>IGNORE 'easier to remove electron' <i>Energy is required</i></p> <p>ALLOW less energy to oxidise</p>

Question		Answer	Marks	Guidance
(c)	(i)	<p><i>Disproportionation:</i> oxidation and reduction of the same element ✓</p> <p><i>Redox:</i> Cl is oxidised from +5 (in KClO_3) to +7 (in KClO_4) ✓</p> <p>Cl is reduced from +5 (in KClO_3) to -1 (in KCl) ✓</p>	3	<p>ALLOW 'chlorine' OR 'Cl' for same element IGNORE 'species' for 'element'</p> <p>ALLOW after number, e.g. 5+ IGNORE ionic charges, e.g. Cl^{5+}</p> <p>IGNORE '5' (signs required)</p> <p>IGNORE any reference to electron loss/gain (even if wrong)</p> <p>ALLOW one redox mark if oxidation numbers are correct but reduction/oxidation is incorrectly assigned</p>
	(ii)	potassium chlorate(VII) ✓	1	Brackets required
(d)	(i)	<p><i>Equation</i> $\text{Ba}(\text{NO}_3)_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NaNO}_3(\text{aq})$ ✓</p> <p><i>Entropy change and explanation</i> entropy decreases OR entropy change negative AND (BaSO_4) solid/ppt has less disorder/ more order/ fewer ways of arranging energy/ less freedom/ less random particles/dispersal of energy ✓</p>	2	<p>ALLOW multiples</p> <p>M2 is dependent on $\text{BaSO}_4(\text{s})$ (even if formula is incorrect – eg $\text{Ba}(\text{SO}_4)_2(\text{s})$ seen as a product in the attempted equation as long as reactants are not solid. BaSO_4 solid/ppt may be assumed from $\text{BaSO}_4(\text{s})$ seen in the attempted equation.</p>

Question		Answer	Marks	Guidance
	(ii)	<p><i>Equation</i> $\frac{1}{2}\text{I}_2(\text{s}) \rightarrow \text{I}(\text{g}) \checkmark$ <i>state symbols required</i></p> <p><i>Entropy change and explanation</i> entropy increases OR entropy change positive AND gas has more disorder/ less order/ more ways of arranging energy/ more freedom/ more random particles / more dispersal of energy \checkmark</p>	2	<p>DO NOT ALLOW $\text{I}_2(\text{s}) \rightarrow 2\text{I}(\text{g})$</p> <p>DEPENDENT on $\frac{1}{2}\text{I}_2(\text{s}) \rightarrow \text{I}(\text{g})$ OR $\text{I}_2(\text{s}) \rightarrow 2\text{I}(\text{g})$</p>
		Total	12	

Question		Answer	Marks	Guidance	
18	(a)	$\Delta G = \Delta H - T\Delta S$ linked to $y = mx + c$ (somewhere) ✓ gradient = $-\Delta S$ ✓ P: ΔH / enthalpy change ✓ Q: (temperature) for reaction to be feasible/unfeasible OR (temperature) at which feasibility changes ✓	4	Could be: $\Delta G = -\Delta S T + \Delta H$ – sign required ALLOW $\Delta S = -\text{gradient}$ ALLOW ‘point of feasibility’ For Feasibility: ALLOW can take place/happen OR is spontaneous IGNORE ‘minimum/maximum temperature’	
	(b)	(i)	(Species have) different states/phases ✓	1	
		(ii)	$(K_p =) p(\text{CO}(\text{g}))^4$ ✓	1	Allow species without state symbols and without brackets, e.g. p_{CO}^4 , $pp\text{CO}^4$, PCO^4 , $p(\text{CO}^4)$ etc. DO NOT ALLOW square brackets
		(iii)	ΔG at 25 C $\Delta G = \Delta H - T\Delta S = 676.4 - (298 \times 0.7031)$ = (+) 467 (kJ mol ⁻¹) OR (+) 466876 (J mol ⁻¹) ✓ <i>Non-feasibility statement</i> Non-feasible when $\Delta G > 0$ OR $\Delta G > 0$ OR $\Delta H > T\Delta S$ ✓ <i>Minimum temperature</i> minimum temperature = $\frac{\Delta H}{\Delta S} = \frac{676.4}{0.7031}$ = 962(.0) K ✓	3	IGNORE units ALLOW (+) 467 up to calculator value of 466.8762 correctly rounded ECF for any positive value determined in M1 ALLOW 962 up to calculator value of 962.0253165 correctly rounded

Question	Answer	Marks	Guidance
(iv)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = -110.5, Award 3 marks.</p> <p>-----</p> <p>Correct expression $-13.5 = (4 \times -393.5) - (-1118.5 + 4 \times \Delta_f H(\text{CO})) \checkmark$</p> <p>Correct subtraction using ΔH and $\Delta_f H(\text{Fe}_3\text{O}_4)$ $4 \times \Delta_f H(\text{CO}) = (4 \times -393.5) - (-1118.5) + 13.5$ $= -442(.0) \text{ (kJ mol}^{-1}\text{)} \checkmark$</p> <p>Calculation of $\Delta_f H(\text{CO})$ formation</p> $\Delta_f H(\text{CO}) = -\frac{442}{4} = -110.5 \text{ (kJ mol}^{-1}\text{)} \checkmark$	3	<p>For answer, ALLOW -111 (kJ mol⁻¹)</p> <p>-----</p> <p>NOTE: IF any values are omitted, DO NOT AWARD any marks. e.g. -393.5 OR -13.5 may be missing</p> <p>-----</p> <p>Common errors</p> <p>(+)110.5 <i>wrong/omitted sign</i> 2 marks</p> <p>(+)184.625 / 184.63 / 184.6 / 185 2 marks <i>No 4CO₂</i></p> <p>(+)738.5 / 739 <i>No 4CO₂ and no CO/4</i> 1 mark</p> <p>-117.25 / -117.3 / -117 <i>Wrong cycle</i> 2 marks</p> <p>-469 <i>Wrong cycle, no CO/4</i> 1 mark</p> <p>(+)177.875 / 177.88 / 177.9 / 178 1 mark <i>Wrong cycle, no 4CO₂</i></p> <p>-360.5 <i>Used 118.5</i> 2 marks</p> <p>Any other number: CHECK for ECF from 1st marking point for expressions using ALL values with ONE error only e.g. one transcription error:, e.g. 395.3 for 393.5</p>
	Total	12	

Question		Answer	Marks	Guidance
19	(a)	$n(\text{H}_2\text{O}_2) = 2.30 \times \frac{25.0}{1000}$ OR = 0.0575 (mol) ✓ $\text{vol O}_2 = \frac{0.0575}{2} \times 24000 = 690 \text{ cm}^3$ ✓ Collect in 1000 cm ³ /1 dm ³ measuring cylinder ✓	3	<p>ALLOW 0.69(0) dm³ 2nd mark subsumes 1st mark</p> <p>ALLOW 1000 cm³/1 dm³ syringe Needs a name of actual apparatus, not just 'container' 'measuring cylinder' without volume is insufficient</p> <p>DO NOT ALLOW burette For other possible apparatus, contact Team Leader</p> <p>ALLOW volumes from 700–1000 cm³ but should be realistic apparatus, e.g. 700, 750, 800, 850, 900, 950.</p>
	(b)	Measure mass (loss) ✓	1	<p>ALLOW weight for mass</p> <p>ALLOW take samples and titrate (remaining H₂O₂)</p>

Question	Answer	Marks	Guidance
(c)*	<p><i>Please refer to the marking instructions on page 5 of mark scheme for guidance on marking this question.</i></p> <p>Level 3 (5–6 marks) A comprehensive conclusion using quantitative data from the graph to correctly determine initial rate AND half lives/gradient with 1st order conclusion for H₂O₂ AND determination of <i>k</i>. <i>There is a well-developed line of reasoning which is clear and logically structured.</i> <i>Clear working for initial rate, half life/gradient and order and <i>k</i>.</i> <i>Units mostly correct throughout.</i></p> <p>Level 2 (3–4 marks) Attempts to describe all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with few omissions. <i>There is a line of reasoning with some structure and supported by some evidence. The scientific points are supported by evidence from the graph.</i></p> <p>Level 1 (1–2 marks) Reaches a simple conclusion using at least one piece of quantitative data from the graph. Attempts to calculate initial rate OR half life. <i>There is an attempt at a logical structure with a reasoned conclusion from the evidence.</i></p> <p>0 marks No response worthy of credit.</p>	6	<p>Indicative scientific points may include:</p> <p>Initial rate</p> <ul style="list-style-type: none"> Tangent shown on graph as line at $t = 0$ s Gradient determined in range: $1.5 - 2.0 \times 10^{-3}$ e.g. $\frac{2.3}{1300} = 1.77 \times 10^{-3}$ <i>initial rate</i> as gradient value with units: $\text{mol dm}^{-3} \text{s}^{-1}$ <i>For other methods contact TL</i> <p>Evidence for 1st order 2 methods</p> <ul style="list-style-type: none"> 1st order clearly linked to half-life OR 2 gradients: <p>1. Half life</p> <ul style="list-style-type: none"> Half life shown on graph Half life range 800–1000 s Two ‘constant’ half lives ± 50 s <p>2. Two gradients → two rates</p> <ul style="list-style-type: none"> 2 tangents shown on graph at c and $c/2$ Gradient at $c/2$ is half gradient at c e.g. $c = 2.3 \text{ mol dm}^{-3}$, gradient = 1.6×10^{-3} AND $c = 1.15 \text{ mol dm}^{-3}$, gradient = 0.8×10^{-3} <ul style="list-style-type: none"> For chosen method, conclusion: H₂O₂ is 1st order <p>Determination of <i>k</i> 2 methods</p> <ul style="list-style-type: none"> <i>k</i> clearly linked to rate OR half-life: $k = \frac{\text{rate}}{[\text{H}_2\text{O}_2]}$ e.g. $k = \frac{1.6 \times 10^{-3}}{2.3} = 7 \times 10^{-4} \text{ s}^{-1}$ <p>OR $k = \frac{\ln 2}{t_{1/2}}$ e.g. $k = \frac{0.693}{950} = 7.3 \times 10^{-4} \text{ s}^{-1}$</p>
	Total	10	

Question		Answer	Marks	Guidance
20	(a)	<p>Conditions Low/decreased pressure AND high/increased temperature ✓</p> <p>Pressure: Right-hand/product side has more (gaseous) moles/molecules OR left-hand side/reactant side has fewer (gaseous) moles/molecules ✓</p> <p>Temperature: (Forward) reaction is endothermic / takes in heat OR reverse reaction is exothermic / gives out heat ✓</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>DO NOT ALLOW more atoms on right-hand side OR fewer atoms on left-hand side. DO NOT ALLOW incorrect shift direction</p>
		<p>Low pressure gives a slow rate OR High temperature uses a large amount of energy/fuel ✓</p>		<p>ORA</p> <p>IGNORE 'expensive'</p> <p>IGNORE use of catalyst</p>
	(b)	(i)	2	<p>IGNORE state symbols in K_c expression, even if wrong.</p> <p>For units, ALLOW $\text{mol}^{-1} \text{dm}^3$ DO NOT ALLOW dm^3/mol</p> <p>NOTE: If K_c upside down, units become mol dm^{-3} by ECF No other ECF allowed for units.</p>

Question	Answer	Marks	Guidance
(ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 2.45, Award 4 marks.</p> <p>-----</p> <p>Equilibrium concentrations (moles × 2.5) 1 MARK</p> <p>SO₂ = 0.135 (mol dm⁻³) AND O₂ = 0.0675 (mol dm⁻³) ✓</p> <p>Calculation of [SO₃(g)] 2 MARKS</p> <p>[SO₃] = √(K_c × [SO₂]² × O₂) OR √((3.045 × 10⁴) × 0.135² × 0.0675) ✓</p> <p>= 6.12039291 (mol dm⁻³) ✓ <i>Answer scores both [SO₃] marks automatically</i></p> <p>Calculation of n(SO₃) in 400 cm³ 1 MARK</p> <p>n(SO₃) = 6.12039291/2.5 = 2.45 (mol) ✓</p> <p>3SF required (Appropriate number)</p>	<p>4</p>	<p>FULL ANNOTATIONS NEEDED IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>-----</p> <p>ALLOW ECF from incorrect concentrations of SO₂ and/or O₂</p> <p>ALLOW ECF from incorrect [SO₃]</p> <p>ALLOW 3 SF, 6.12, up to calculator value of 6.12039291 correctly rounded.</p> <p>Common errors</p> <p>37.5 1 mark <i>No √ for [SO₃]² and no scaling by 1/2.5</i></p> <p>15.0 2 marks <i>No √ for [SO₃]²</i></p> <p>0.619 3 marks <i>Use of mol of SO₂ and O₂</i></p> <p>1.55 2 marks <i>No conc used and Use of mol of SO₂ and O₂</i></p>
	Total	11	

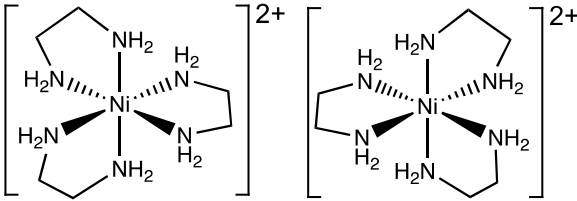
Question	Answer	Marks	Guidance
21 (a)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 0.753, award 3 marks</p> <p>-----</p> $[\text{H}^+] = 10^{-\text{pH}} = 10^{-2.440} = 3.63 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$ $[\text{CH}_3\text{COOH}] = \frac{[\text{H}^+]^2}{K_a} \text{ OR } \frac{(3.63 \times 10^{-3})^2}{1.75 \times 10^{-5}} \checkmark$ $= 0.753 \text{ (mol dm}^{-3}\text{)} \checkmark$	3	<p>ALLOW use of HA and A⁻</p> <p>ALLOW 3 SF up to calculator value of $3.630780548 \times 10^{-3}$ correctly rounded</p> <p>NOTE: Answer is same from unrounded [H⁺] calculator value and 3 SF [H⁺] value</p> <p>ALLOW 0.749 if [H⁺] has been subtracted from [CH₃COOH] for greater accuracy at end</p>
(b)	$\text{CH}_3\text{COOH} + \text{FCH}_2\text{COOH} \rightleftharpoons \text{CH}_3\text{COOH}_2^+ + \text{FCH}_2\text{COO}^- \checkmark$ <p style="text-align: center;"> B2 A1 A2 B1 OR B1 A2 A1 B2 ✓ <i>i.e. labels other way round</i> </p>	2	<p>Watch for opposite order on RHS, i.e.: $\text{FCH}_2\text{COO}^- + \text{CH}_3\text{COOH}_2^+$</p> <p>Take great care matching labels</p> <p>ALLOW ECF for incorrect proton transfer as below. This is the ONLY ECF</p> $\text{CH}_3\text{COOH} + \text{FCH}_2\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{FCH}_2\text{COOH}_2^+ \times$ <p style="text-align: center;"> A1 B2 B1 A2 OR A2 B1 B2 A1 ✓ECF <i>i.e. labels other way round</i> </p>

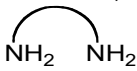
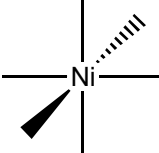
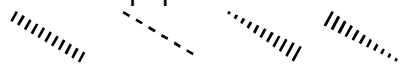
Question	Answer	Marks	Guidance
(c) (i)	<p>[CH₃COO⁻]</p> $n(\text{CH}_3\text{COONa}) = \frac{9.08}{82.0} \text{ OR } 0.111 \checkmark \text{ (Calc: } 0.1107317073)$ $[\text{CH}_3\text{COO}^-] = \frac{9.08}{82.0} \times \frac{1000}{250} = 0.443 \text{ (mol dm}^{-3}\text{)}$ <p>OR $n(\text{CH}_3\text{COOH}) = 0.800 \times \frac{250}{1000} = 0.200 \text{ (mol)} \checkmark$</p> <p>[H⁺]</p> $[\text{H}^+] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]} \text{ OR } K_a \times \frac{n(\text{CH}_3\text{COOH})}{n(\text{CH}_3\text{COO}^-)}$ $= 1.75 \times 10^{-5} \times \frac{0.800}{0.443} \text{ OR } 1.75 \times 10^{-5} \times \frac{0.200}{0.111} \checkmark$ $= 3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>pH (must come from <i>calculated</i> [H⁺])</p> $\text{pH} = -\log(3.16 \times 10^{-5}) = 4.50 \checkmark$ <hr/> <p>LAST 3 marks are NOT available using</p> <ul style="list-style-type: none"> • K_a square root approach (weak acid pH) • $K_w/10^{-14}$ approach (strong base pH) <hr/> <p>Henderson–Hasselbalch (HH) alternative</p> $\text{p}K_a = -\log 1.75 \times 10^{-5} = 4.757 \text{ (or } 4.756961951\dots)$ $\text{pH} = \text{p}K_a + \log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} \text{ OR } \text{p}K_a - \log \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$ $\text{OR } \text{p}K_a + \log \frac{0.443}{0.800} \text{ OR } \text{p}K_a - \log \frac{0.800}{0.443} \checkmark$ $= \text{p}K_a - 0.257 \checkmark$ $= 4.757 - 0.257 = 4.50 \checkmark$	5	<p>ALLOW 2 sig fig ALLOW use of HA and A⁻</p> <p>Mark by ECF</p> <hr/> <p>Alternative method (If both methods are attempted, mark the method which produces the higher mark)</p> <p>[H⁺]</p> $[\text{H}^+] = 10^{-\text{pH}} = 10^{-4.50}$ $= 3.16 \times 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>[CH₃COO⁻]</p> $[\text{CH}_3\text{COO}^-] = K_a \times \frac{[\text{CH}_3\text{COOH}]}{[\text{H}^+]}$ <p>OR $1.75 \times 10^{-5} \times \frac{0.800}{3.16 \times 10^{-5}} \checkmark$</p> $= 0.443 \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>mass of CH₃COONa</p> $\text{mass CH}_3\text{COONa} = 0.443 \times \frac{250}{1000}$ <p>OR 0.111 \checkmark</p> $0.111 \times 82.0 = \mathbf{9.08} \text{ (g)} \checkmark$ <hr/> <p>Common errors</p> <p>4.64 Use of $M(\text{CH}_3\text{COONa}) = 60$ 4 marks</p> <p>2.40 Use of K_a of FCH_2COOH 4 marks</p>

Question			Answer	Marks	Guidance
		(ii)	pH is the same/constant ✓ ratio/proportion $[HA]/[A^-]$ is the same ✓	2	M2 is dependent upon M1 ALLOW Change in $[HA]$ and $[A^-]$ is proportional
			Total	12	

Question			Answer	Marks	Guidance
22	(a)	(i)	<p><i>Circuit:</i> complete circuit AND voltmeter AND <i>labelled</i> salt bridge linking two half-cells ✓</p> <p><i>Half cells:</i> Pt AND Fe²⁺ AND Fe³⁺ ✓</p> <p>Zn AND Zn²⁺ ✓</p> <p><i>Standard conditions:</i> 1 mol dm⁻³ (solution(s)) AND 298 K / 25°C ✓</p>	4	<p>Electrodes / salt bridge must at least touch the surface ALLOW small gaps in circuit wires</p> <p>ALLOW half cells drawn either way around</p> <p>ALLOW 1 mol/dm³ OR 1 M ALLOW 1 mol dm⁻³/1M if omitted here but shown for just one solution in diagram IGNORE pressure DO NOT ALLOW 1 mol(e) for concentration</p>
		(ii)	1.53 (V) ✓	1	IGNORE sign
	(b)		<p><i>strongest reducing agent:</i> Zn ✓</p> <p><i>strongest oxidising agent:</i> MnO₄⁻ ✓</p>	2	NOTE: H ⁺ has been ignored
	(c)		<p>AWARD 2 marks for correct balancing AND all species cancelled on both sides of equation: 2MnO₄⁻ + 6H⁺ + 5SO₃²⁻ → 2Mn²⁺ + 3H₂O + 5SO₄²⁻ ✓ ✓</p> <p>AWARD 1 mark for correct balancing but not all species (H₂O, H⁺) cancelled on both sides of equation ✓ e.g. 2MnO₄⁻ + 16H⁺ + 5SO₃²⁻ + 5H₂O → 2Mn²⁺ + 8H₂O + 5SO₄²⁻ + 10H⁺</p>	2	<p>ALLOW correct multiples e.g. MnO₄⁻ + 3H⁺ + 2½SO₃²⁻ → Mn²⁺ + 1½H₂O + 2½SO₄²⁻</p> <p>IGNORE state symbols</p> <p>e.g. MnO₄⁻ + 8H⁺ + 2½SO₃²⁻ + 2½H₂O → Mn²⁺ + 4H₂O + 2½SO₄²⁻ + 5H⁺</p>
			Total	9	

Question			Answer	Marks	Guidance
23	(a)	(i)	<p>CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$ ✓ yellow solution</p> <p>$\text{Cu}(\text{OH})_2$ ✓ pale blue precipitate</p> <p>$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ ✓ deep blue solution</p> <p>CuI ✓ I_2 ✓ white solid brown solution</p>	5	<p>ALLOW $\text{Cu}(\text{Cl})_4^{2-}$</p> <p>ALLOW $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$</p> <p>Brackets required for $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$</p> <p>NOTE: Take great care to check that subscripted numbers and brackets are correct</p>
		(ii)	<p>Reaction 1: ligand substitution ✓</p> <p>Reaction 2: redox ✓</p>	2	<p>ALLOW ligand exchange</p> <p>ALLOW reduction AND oxidation</p> <p>ALLOW precipitation</p>

Question	Answer	Marks	Guidance
(b)*	<p>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</p> <p>Level 3 (5–6 marks) A comprehensive conclusion using all data to obtain correct formulae for A, B, C and D AND optical isomers shown</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured with use of 3D structures for both optical isomers of C, use of wedges and bonding to N. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Reaches a sound conclusion for the formula of B AND obtains the correct formula of the hydrated complex A OR a 3D diagram of one optical isomer of cation C</p> <p><i>There is a line of reasoning and supported by some evidence. Calculations are clear and can be followed to obtain correct conclusions. 3D diagram, if present, should use wedges mostly correctly. Formula of A to show water separately or formula of C to show ligands separately, as appropriate.</i></p> <p>Level 1 (1–2 marks) Reaches a simple conclusion to obtain the correct formula of anhydrous complex B OR shows that A contains 2H₂O</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. Attempts more than one part of the problem.</i></p> <p>0 marks No response or no response worthy of credit.</p>	6	<p>Indicative scientific points may include:</p> <p>1. Formula of anhydrous complex B NiC₆N₆H₂₄Cl₂ <i>Example of working</i> $\begin{array}{cccccc} \text{Ni} & : & \text{C} & : & \text{N} & : & \text{H} & : & \text{Cl} \\ = & \frac{18.95}{58.7} & : & \frac{23.25}{12.0} & : & \frac{27.12}{14.0} & : & \frac{7.75}{1.00} & : & \frac{22.93}{35.5} \end{array}$ There may be other methods</p> <p>2. Formula of hydrated complex A NiC₆N₆H₂₄Cl₂•2H₂O OR NiC₆N₆H₂₄Cl₂(H₂O)₂ <i>Example of working</i> $n(\text{anhydrous salt}) = \frac{7.433}{309.7} = 0.02400 \text{ (mol)}$ $n(\text{H}_2\text{O}) = \frac{0.864}{18.0} = 0.04800 \text{ (mol)} \checkmark$ There may be other methods</p> <p>3. Formula of cation C [NiC₆N₆H₂₄]²⁺ OR [Ni(H₂NCH₂CH₂NH₂)₃]²⁺ (could be in structures) 2+ charge can be shown on cation OR optical isomers (i.e. seen somewhere)</p> <ul style="list-style-type: none"> Bidentate ligand D H₂NCH₂CH₂NH₂ or displayed so that structure is clearly unambiguous. Optical isomers <div style="text-align: center;">  </div> <p><i>Accuracy of structures</i></p>

Question			Answer	Marks	Guidance
					Bonding shown from Ni to N of $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ ALLOW $\text{CH}_3\text{CH}(\text{NH}_2)_2$ for ligand For $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ in optical isomers, ALLOW C–C without Hs and 
					Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge':  Bond into paper can be shown as: 
			Total	13	

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