

Chemistry A

Advanced GCE

Unit **F325**: Equilibria, Energetics and Elements

Mark Scheme for June 2013

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


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

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response
	Noted but no credit given
	Repeat

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

All questions should be annotated with ticks to show where marks have been awarded in the body of the text.

All questions where an ECF has been applied should also be annotated with the ECF annotation.

Use the omission mark where the answer is not sufficient to be awarded a mark.

The following questions should be annotated with full annotation (ie ticks, crosses etc) to show where marks have been awarded in the body of the text: **1(c), 3(a), 4(a), 4(d)(i), 4(d)(ii), 7(d), 8(c)**

Question		Answer	Marks	Guidance
1	(a)	(The enthalpy change that accompanies) the formation of one mole of a(n ionic) compound ✓ from its gaseous ions (under standard conditions) ✓	2	IGNORE 'energy needed' OR 'energy required' ALLOW as alternative for compound: lattice, crystal, substance, solid Note: 1st mark requires 1 mole 2nd mark requires gaseous ions IF candidate response has '1 mole of gaseous ions', award 2nd mark but NOT 1st mark
	(b) (i)	<p>Ca²⁺(g) + O²⁻(g) ✓</p> <p>Ca²⁺(g) + O(g) + 2e⁻ ✓</p> <p>step F</p> <p>step G</p>	2	Correct species AND state symbols required for both marks 2e ⁻ required for left-hand response ALLOW e for e ⁻ Mark each marking point independently
	(ii)	(enthalpy change of) formation (of calcium oxide) ✓ (enthalpy change of) atomisation of oxygen ✓ Second electron affinity (of oxygen) ✓	3	calcium oxide not required for this mark DO NOT ALLOW 'lattice formation' (<i>confusion with LE</i>) atomisation AND oxygen/O ₂ /½O ₂ /O both required (<i>atomisation of calcium is also in cycle</i>) IGNORE oxygen or oxygen species, e.g. O ⁻ DO NOT ALLOW calcium

Question			Answer	Marks	Guidance
1	(b)	(iii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-3454 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks</p> <p>-----</p> <p>$-635 = 178 + 249 + 590 + 1145 + (-141) + 798 + \Delta H_{LE}(\text{CaO})$ OR $\Delta H_{LE}(\text{CaO}) = -635 - [178 + 249 + 590 + 1145 + (-141) + 798]$ OR $-635 - 2819 \checkmark$ $= -3454 \checkmark \text{ (kJ mol}^{-1}\text{)}$</p>	2	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below. See list below for marking of answers from common errors</p> <p>-----</p> <p>1st mark for expression linking $\Delta H_{LE}(\text{CaO})$ with ΔH values ALLOW LE for ΔH_{LE}</p> <p>ALLOW for 1 mark:</p> <p>-3736 use of +141 instead of -141 (+)3454 all signs reversed (+)2184 wrong sign before 2819 -2184 wrong sign for 635 -1858 wrong sign for +798</p> <p>Any other number: CHECK for ECF from 1st marking point Award 1 mark for one transcription error only and everything else correct: e.g. +187 instead of +178 IF any value has been omitted, award zero</p>

Question		Answer	Marks	Guidance
1	(c)	<p>For first 2 marks,</p> <ul style="list-style-type: none"> • IGNORE nuclear attraction OR proton attraction • Property AND effect required • IGNORE 'atomic' and 'atoms' and 'molecules' and assume that 'size' and 'charge' refers to ions • IGNORE LE increases OR LE decreases • IGNORE bond strength; strength of ionic bonds 		
		<p><i>First 2 marks</i> Decrease in (ionic) size AND more negative LE OR more exothermic OR more attraction ✓</p> <p>Increase in (ionic) charge OR charge density AND more negative LE OR more exothermic OR more attraction ✓</p> <p>-----</p> <p><i>Link between LE and attraction</i> Lattice enthalpy correctly linked to attraction between IONS at least once ✓ <i>e.g. Greater attraction between ions gives more negative LE</i></p>	3	<p>ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>ORA throughout</p> <p>ALLOW pull for attraction IGNORE just 'greater force' (<i>could be repulsion</i>) IGNORE responses in terms of packing IGNORE electron density IGNORE lower/higher LE</p> <p>-----</p> <p>For 3rd marking point ONLY, IONS is essential; DO NOT ALLOW attraction between atoms or molecules DO NOT ALLOW nuclear attraction</p>
		Total	12	

Question			Answer	Marks	Guidance
2	(a)	(i)	Time for concentration (of reactant) to fall to half original value ✓	1	ALLOW time for concentration to fall by half DO NOT ALLOW concentration of product to fall by half ALLOW mass OR amount as alternative to concentration ALLOW time for reactant/substance/atoms to decrease by half
		(ii)	At least two half-lives correctly shown on graph AND half-life stated as approx. 54 s ✓ 1st order has a constant half-life ✓	2	ALLOW half-life in range 50–56 s ALLOW half-life shown on graph Care: Initial concentration is ~5.8 and NOT 6.0 For constant half-life, ALLOW 'half lives are the same', 'two half-lives are 54 s', etc. ALLOW 2 tangents drawn, one at half conc of first AND evidence that gradient (\equiv rate) halves
		(iii)	No change ✓	1	
	(b)	(i)	<i>Tangent</i> On graph, tangent drawn to curve at $t \sim 40$ s ✓ <i>Calculation of rate from the tangent drawn</i> e.g. rate = $\frac{5.2}{116} = 0.045$ OR 4.5×10^{-2} ✓ <i>Units</i> $\text{mol dm}^{-3} \text{s}^{-1}$ ✓ <i>Independent mark</i>	3	Annotate tangent on graph Note: This mark can only be awarded from a tangent ALLOW ECF for tangent drawn at different time from 40 s ALLOW $\pm 10\%$ of gradient of tangent drawn ALLOW 2 SF up to calculator value ALLOW trailing zeroes, e.g. 0.04 for 0.040 IGNORE '–' sign for rate Note: IF candidate calculates rate via ln 2 method (shown in (ii), consult with TL)

Question			Answer	Marks	Guidance
2	(b)	(ii)	$k = \frac{\text{answer to (b)(i)}}{3.45} \checkmark$ units: $\text{s}^{-1} \checkmark$ <i>Independent mark</i>	2	From 0.045, $k = \frac{0.045}{3.45} = 0.013$ ALLOW concentration range 3.4–3.5 ALLOW use of unrounded calculator answer from (b)(i) even if different from answer given on (b)(i) answer line <i>Many will keep this value in calculator for (b)(ii)</i> ALLOW $k = \ln 2/t_{1/2} = 0.693/\text{half life}$ from (a)(iii) For 54 s, $k = 0.693/54 = 0.013$ ALLOW 2 SF up to calculator value
	(c)		water is in excess OR concentration of H_2O is very large/does not change \checkmark	1	IGNORE water does not affect the rate
			Total	10	

Question	Answer	Marks	Guidance
3 (a)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 16.8 with 'no units', award 5 marks</p> <p>-----</p> <p>At equilibrium, $n(\text{I}_2)$ OR $[\text{I}_2(\text{g})]$ $= 4.00 \times 10^{-3} - 1.70 \times 10^{-3} = 2.30 \times 10^{-3} \text{ (mol / mol dm}^{-3}\text{)} \checkmark$</p> <p>$n(\text{HI})$ OR $[\text{HI}(\text{g})]$ $= 2 \times 1.70 \times 10^{-3} = 3.40 \times 10^{-3} \text{ (mol / mol dm}^{-3}\text{)} \checkmark$</p> <p>$(K_c =) \frac{(3.40 \times 10^{-3})^2}{3.00 \times 10^{-4} \times 2.30 \times 10^{-3}} \checkmark$ IGNORE $K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$</p> <p>$= 16.8$ (3 SF required) \checkmark</p> <p>no units \checkmark</p>	5	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>-----</p> <p>ANNOTATE WITH TICKS AND CROSSES, etc ALLOW ECF throughout</p> <p>For all parts, ALLOW numerical answers from 3 significant figures up to the calculator value ALLOW omission of trailing zeroes, i.e. 3.40 as 3.4 but final numerical answer for K_c must be to 3 SF</p> <p>ALLOW ECF using incorrect values for $[\text{I}_2]$ AND $[\text{HI}]$ BUT $[\text{H}_2]$ in K_c expression must be 3.00×10^{-4} (given in Q)</p> <p>ALLOW ECF from incorrect K_c expression for calculation to 3 SF and units</p> <p>For 'no units' ALLOW 'none' (ORA) OR '—' DO NOT ALLOW space to be left blank</p> <p>Common errors:</p> <p>Use of 1.70×10^{-3} for $n(\text{HI})$ (no factor of x 2) $K_c = 4.19$ (3SF) and no units: 4 marks</p> <p>Use of K_c expression used is upside down $K_c = 0.0597$ (3SF) and no units: 4 marks</p> <p>No square for $[\text{HI}]^2$ $K_c = 4930$ and $\text{dm}^3 \text{ mol}^{-1}$ 4 marks</p> <p>Note: different ECF units</p>

Question			Answer	Marks	Guidance																
3	(b)	(i)	<table border="1"> <thead> <tr> <th></th> <th>H₂(g)</th> <th>I₂(g)</th> <th>HI(g)</th> </tr> </thead> <tbody> <tr> <td>greater</td> <td>✓</td> <td></td> <td>✓</td> </tr> <tr> <td>smaller</td> <td></td> <td>✓</td> <td></td> </tr> <tr> <td>the same</td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>Each column should have only one box ticked</p> <p>Correct ticks for H₂(g) AND I₂(g) AND HI(g) two marks ✓✓ <i>i.e. all three columns correct</i></p> <p>Ticks for two of H₂(g), I₂(g) and HI(g) correct one mark ✓ <i>i.e. two columns correct</i></p>		H ₂ (g)	I ₂ (g)	HI(g)	greater	✓		✓	smaller		✓		the same				2	DO NOT ALLOW more than one box ticked in a column (response is a CON)
	H ₂ (g)	I ₂ (g)	HI(g)																		
greater	✓		✓																		
smaller		✓																			
the same																					
		(ii)	<p>K_c is smaller AND (forward) reaction is exothermic OR ΔH is negative ✓</p>	1	<p>Link to ΔH/exothermic essential ALLOW reverse reaction is endothermic DO NOT ALLOW equilibrium shifts to the right (CON)</p>																
		(iii)	<p>K_c is the same AND K_c is temperature dependent OR K_c is not changed by pressure ✓</p>	1	<p>ALLOW K_c is only changed by temperature IGNORE same number of moles on both side</p>																
			Total	9																	

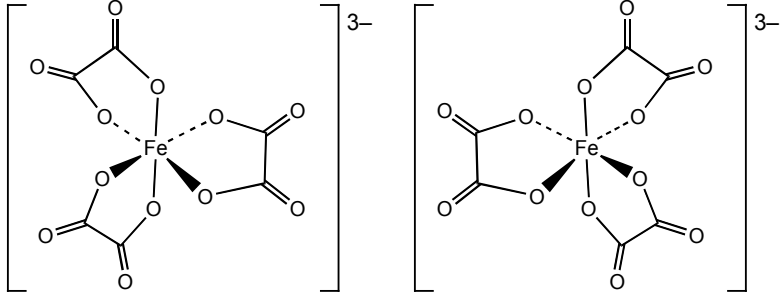
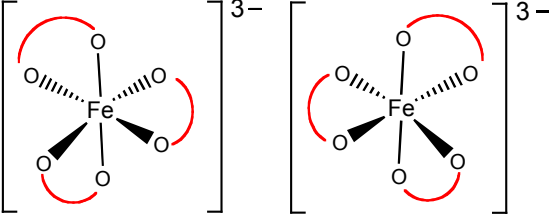

Question	Answer	Marks	Guidance
4 (a)	<p>HCl is a strong acid AND HClO is a weak acid ✓</p> <p>HCl: pH = $-\log 0.14 = 0.85$ (2 DP required) ✓</p> <p>HClO: CHECK THE ANSWER ON ANSWER LINE IF answer = 4.14, award all three calculation marks</p> <p>-----</p> <p>$K_a = 10^{-7.43}$ OR 3.7×10^{-8} (mol dm⁻³) ✓</p> <p>$[H^+] = \sqrt{K_a \times [HClO]}$ OR $\sqrt{K_a \times [HA]}$ OR $\sqrt{K_a \times 0.14}$ OR $\sqrt{3.7 \times 10^{-8} \times 0.14}$ ✓</p> <p>pH = 4.14 (2 DP required) ✓</p>	5	<p>ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>ALLOW HCl completely dissociates AND HClO partially dissociates</p> <p>ALLOW $HCl \rightarrow H^+ + Cl^-$ AND $HClO \rightleftharpoons H^+ + ClO^-$</p> <p>IGNORE HCl is a stronger acid than HClO IGNORE HCl produces more H⁺</p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>-----</p> <p>ALLOW 2 SF to calculator value: $3.715352291 \times 10^{-8}$, correctly rounded</p> <p>IGNORE 'HCl' if it is clear that it is a 'slip'</p> <p>Always ALLOW calculator value irrespective of working as number may have been kept in calculator.</p> <p>Note: pH = 4.14 is obtained from all three values above</p> <p>From no square root, pH = 8.28. Worth K_a mark only</p>

Question		Answer	Marks	Guidance
4	(b)	$2Al + 6CH_3COOH \longrightarrow 2(CH_3COO)_3Al + 3H_2 \checkmark$ $2Al + 6H^+ \longrightarrow 2Al^{3+} + 3H_2 \checkmark$	2	<p>IGNORE state symbols ALLOW correct multiples, e.g.: $Al + 3CH_3COOH \longrightarrow (CH_3COO)_3Al + 1.5H_2$ ALLOW any unambiguous formula for $(CH_3COO)_3Al$, <i>i.e.</i> $(CH_3CO_2)_3Al$, $Al(CH_3CO_2)_3$, $(CH_3COO^-)_3Al^{3+}$, etc. Note: IF charges are shown, they must be correct with both – and 3+ shown</p> <p>ALLOW multiples, e.g.: $Al + 3H^+ \longrightarrow Al^{3+} + 1.5H_2$</p>
	(c)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 13.6(0), award 2 marks</p> <p>-----</p> $[H^+] = \frac{K_w}{[OH^-]} \text{ OR } \frac{1.0 \times 10^{-14}}{[OH^-]} \text{ OR } \frac{1.0 \times 10^{-14}}{0.4(0)}$ <p>OR $2.5 \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Correctly calculates $pH = -\log 2.5 \times 10^{-14} = 13.6(0) \checkmark$</p>	2	<p>ALLOW alternative approach using pOH: $pOH = 0.4(0) \checkmark$</p> <p>$pH = 14 - 0.40 = 13.6(0) \checkmark$</p> <p>ALLOW ECF from $[H^+]$ derived using K_w and $[OH^-]$ BUT DO NOT ALLOW an acid pH. ALLOW one or more decimal places</p>

Question			Answer	Marks	Guidance
4	(d)	(i)	<p>A buffer solution minimises pH changes ✓</p> <p>on addition of small amounts of acid/H⁺ or alkali/OH⁻/base ✓</p> <p>-----</p> <p>HCOOH \rightleftharpoons H⁺ + HCOO⁻ ✓ <i>Equilibrium sign essential</i></p>	7	<p>ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>ALLOW resists pH changes ALLOW buffer solutions maintains a nearly/virtually constant pH DO NOT ALLOW a response that implies that the pH is actually constant, e.g. does not change pH; maintains pH</p> <p>-----</p> <p>DO NOT ALLOW COOH⁻ OR CHOOH OR COOH DO NOT ALLOW HA \rightleftharpoons H⁺ + A⁻</p>
			<p>For effect of acid and alkali, ALLOW wrong carboxylic acid (e.g. CH₃COOH) OR HA; ALLOW CHOOH for acid (effectively ECF) ALLOW COOH⁻ for base ALLOW responses based on COOH \rightleftharpoons H⁺ + COO⁻ DO NOT ALLOW other incorrect formula, e.g. CH₃OOH</p>		<p>Quality of written communication, QWC 2 marks are for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H⁺ and OH⁻</p>
			<p>Added alkali HCOOH reacts with added alkali/base/OH⁻ OR added alkali/OH⁻ reacts with H⁺ ✓</p> <p>QWC: Equilibrium shifts forming HCOO⁻ OR H⁺ OR (HCOOH) Equilibrium → right ✓</p> <p>Added acid HCOO⁻ reacts with added acid/H⁺ ✓</p> <p>QWC: Equilibrium shifts forming HCOOH OR (HCOOH) Equilibrium → left ✓</p>		<p>ALLOW HA OR weak acid reacts with added alkali</p> <p>DO NOT ALLOW this mark if there is no equilibrium system shown, e.g. HCOOH \rightleftharpoons H⁺ + HCOO⁻ is absent</p> <p>ALLOW A⁻ OR conjugate base reacts with added acid IGNORE salt reacts with added acid</p> <p>DO NOT ALLOW this mark if there is no equilibrium system shown, e.g. HCOOH \rightleftharpoons H⁺ + HCOO⁻ is absent</p>

Question			Answer	Marks	Guidance
4	(d)	(ii)	<p>HCOOH reacts with NaOH forming HCOO⁻/HCOONa OR $\text{HCOOH} + \text{NaOH} \rightarrow \text{HCOONa} + \text{H}_2\text{O} \checkmark$ <i>Equilibrium sign allowed</i></p> <p>(Some) HCOOH/(weak) acid remains OR HCOOH/(weak) acid is in excess \checkmark</p> <p>Calculation CHECK THE ANSWER IF answer = 3.99, award all four calculation marks</p> <p>$n(\text{HCOOH})$ OR $[\text{HCOOH}]$ $= 0.24(0) \text{ (mol / mol dm}^{-3}\text{)} \checkmark$</p> <p>$n(\text{HCOO}^-)$ OR $[\text{HCOO}^-]$ OR $[\text{HCOONa}]$ $= 0.4(00) \text{ (mol / mol dm}^{-3}\text{)} \checkmark$</p> <p>$[\text{H}^+] = K_a \times \frac{[\text{HCOOH}]}{[\text{HCOO}^-]} \checkmark$</p> <p>$\text{pH} = -\log [\text{H}^+] = -\log(1.70 \times 10^{-4} \times \frac{0.24}{0.4}) = 3.99 \checkmark$</p> <p>----- OR use of Henderson–Hasselbalch equation: $\text{pH} = \text{p}K_a + \log \frac{[\text{HCOO}^-]}{[\text{HCOOH}]}$</p> <p>OR $\text{pH} = -\log K_a + \log \frac{[\text{HCOO}^-]}{[\text{HCOOH}]} \checkmark$</p> <p>$= 3.77 + 0.22 = 3.99 \checkmark$</p>	6	<p>ANNOTATE WITH TICKS AND CROSSES, etc DO NOT ALLOW just ‘methanoate/HCOO⁻ forms’ <i>formulae or names of reactants also required</i></p> <p>ALLOW $\text{HCOOH} + \text{OH}^- \rightarrow \text{HCOO}^- + \text{H}_2\text{O} \checkmark$ IGNORE conjugate base/salt forms</p> <p>IGNORE HCOOH has been partially neutralised</p> <p>Note: There must be a clear statement that 0.24 and 0.4 apply to moles or concentrations of HCOOH and HCOO⁻. DO NOT ALLOW these values if unlabelled</p> <p>ALLOW HA/acid and A⁻/salt for HCOOH and HCOO⁻</p> <p>DO NOT ALLOW ECF for this mark: 3.99 is the ONLY correct answer</p> <p>----- ALLOW HA/acid and A⁻/salt for HCOOH and HCOO⁻ ALLOW $\text{pH} = \text{p}K_a - \log \frac{[\text{HCOOH}]}{[\text{HCOO}^-]}$</p> <p>OR $\text{pH} = -\log K_a - \log \frac{[\text{HCOOH}]}{[\text{HCOO}^-]}$</p> <p>ALLOW $= 3.77 - (-0.22) = 3.99$ DO NOT ALLOW ECF for this mark: 3.99 is the ONLY correct answer</p>
			Total	22	

Question		Answer	Marks	Guidance
5	(a)	$2\text{Fe} + 3\text{Cl}_2 \longrightarrow 2\text{FeCl}_3$ ✓	1	ALLOW $2\text{Fe} + 3\text{Cl}_2 \longrightarrow \text{Fe}_2\text{Cl}_6$ ALLOW multiples, e.g. $\text{Fe} + 1\frac{1}{2}\text{Cl}_2 \longrightarrow \text{FeCl}_3$ IGNORE state symbols DO NOT ALLOW $2\text{Fe} + 3\text{Cl}_2 \longrightarrow 2\text{Fe}^{3+} + 6\text{Cl}^-$
	(b)	$\text{Fe}^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{OH})_3$ ✓	1	IGNORE state symbols ALLOW $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O}$ ALLOW $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{OH})_3 + 6\text{H}_2\text{O}$
	(c) (i)	$2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + \text{Zn} \longrightarrow 2[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{Zn}^{2+}$ All chemical species correct (IGNORE e^- for 1st mark) ✓ Balancing with '2' in front of both Fe complex ions ✓	2	IGNORE state symbols For 1 mark, ALLOW balancing if (aq) species have been used instead of complex ions: $2\text{Fe}^{3+} + \text{Zn} \longrightarrow 2\text{Fe}^{2+} + \text{Zn}^{2+}$
	(ii)	redox ✓	1	ALLOW reduction AND oxidation CARE: possible confusion with (d)(ii)
	(d) (i)	Formula of E as $[\text{Fe}(\text{CN})_6]^{3-}$ shown as product in equation ✓ Correct balanced equation: $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{CN}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{H}_2\text{O}$ ✓ Notice different charges on complex ions: LHS 3+, RHS 3- state symbols not required	2	ALLOW equations with KCN, i.e.: $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{KCN} \longrightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{K}^+ + 6\text{CN}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ ALLOW ECF for an equation showing formation of $[\text{Fe}(\text{CN})_6]^{4-}$ from $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$: $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 6\text{CN}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{4-} + 6\text{H}_2\text{O}$ Notice different charges on complex ions: LHS 2+, RHS 4-
	(ii)	ligand substitution ✓	1	ALLOW ligand exchange OR ligand replacement CARE: possible confusion with (c)(ii)

Question	Answer	Marks	Guidance
5 (e)	<p>F and G:</p>  <p>1 mark for each isomer ✓✓ Bonds must go to O ligand atoms on EACH structure IGNORE charges on Fe³⁺ and O⁻ at this stage</p> <p>3- charge outside brackets of BOTH isomers AND NO charges shown on Fe or O within brackets Note: This mark is only available from structures with three bidentate ligands bonded to Fe via two Os on each ligand ✓</p>	3	<p>ALLOW any attempt to show bidentate ligand Bottom line is the diagram below.</p>  <p>IGNORE structure between two Os in ligand even if slightly different</p> <p>Must contain 2 out wedges, 2 in wedges and 2 lines in plane of paper. For bond into paper, ALLOW:</p> 
(f)	FeO_4^{2-} ✓	1	<p>Formula AND charge needed</p> <p>ALLOW other 2- ions containing: Fe AND O AND Fe has ox no of +6 i.e. ALLOW $\text{Fe}_2\text{O}_7^{2-}$, $\text{Fe}_3\text{O}_{10}^{2-}$, etc.</p>
	Total	12	

Question			Answer	Marks	Guidance
6	(a)	(i)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 218, award 2 marks</p> <p>----- $-256 = (6 \times 205) + S(\text{C}_6\text{H}_{12}\text{O}_6) - (6 \times 214 + 6 \times 70)$ OR $S(\text{C}_6\text{H}_{12}\text{O}_6) = -256 - (6 \times 205) + (6 \times 214 + 6 \times 70)$ OR $-256 + 474 \checkmark$ $= 218 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$</p>	2	<p>IF there is an alternative answer, check to see if there is any ECF credit possible. Note that ALL 4 S values must be used for ECF</p> <p>----- ALLOW 1 mark for -218 ALLOW 1 mark for $+730$ (<i>products – reactants</i>) Note: -3190 for simple addition of products + reactants scores zero marks</p>
		(ii)	$\Delta G = +2879 - 298 \times -0.256 \checkmark$ $= (+)2955 \text{ (kJ mol}^{-1}) \checkmark$	2	<p>ALLOW 3 SF: 2960 to calculator value of 2955.288</p> <p>Award 1 mark for the following:</p> <ul style="list-style-type: none"> $\Delta G = 2890$ to calculator value of 2885.4 <i>25 °C used rather than 298 K:</i> $\Delta G = 79200$ to calculator value of 79167 <i>ΔS not converted from $\text{J K}^{-1} \text{ mol}^{-1}$ to $\text{kJ K}^{-1} \text{ mol}^{-1}$</i> expressions with one transcription error: e.g. $+2897$ instead of $+2879$; 0.265 instead of 0.256 $\Delta G = 2814.036$ <i>use of 218 rather than -256</i> Use of 'answer to (a)(i)'/1000 (by ECF)
		(iii)	ΔH is positive OR $\Delta H > 0$ AND ΔS is negative OR $T\Delta S$ is negative OR $\Delta S < 0$ OR $T\Delta S < 0$ AND ΔG will always be positive OR $\Delta G > 0 \checkmark$	1	<p>ALLOW ΔH is endothermic for ΔH is +ve</p> <p>ALLOW ΔG will never be less than 0</p> <p>DO NOT ALLOW S or H i.e. change in entropy, ΔS and change in enthalpy ΔH are essential</p>

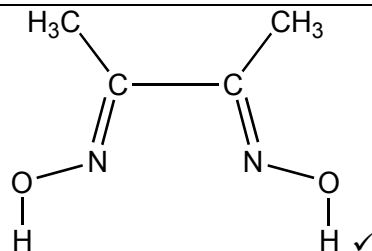
Question		Answer	Marks	Guidance
6	(b)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.12×10^{17} g, award 2 marks</p> <p>-----</p> <p>amount of CO₂ removed $= 3.4 \times 10^{18} \times 6 / 2879$ OR 7.09×10^{15} (mol) ✓</p> <p>mass of CO₂ = $44.0 \times 7.09 \times 10^{15} = 3.12 \times 10^{17}$ g ✓</p>	2	<p>ALLOW 2 SF (7.1×10^{15} (mol)) up to calculator value of 7.085793678, correctly rounded</p> <p>ALLOW 2 SF (3.1×10^{17} g) up to calculator value, correctly rounded Correct units required for 2nd mark e.g. 3.12×10^{14} kg; 3.12×10^{11} tonne</p> <p>ALLOW 1 mark for 3.1×10^{17} with no unit</p> <p>ALLOW ECF from incorrectly calculated amount of CO₂ provided that both 3.4×10^{18} AND 2879 have been used</p> <p>e.g. Omission of x 6 gives 1.181×10^{15} mol CO₂ and 5.196×10^{16} g CO₂</p>
		Total	7	

Question		Answer	Marks	Guidance
7	(a)	<p>Definition The e.m.f. (of a half-cell) compared with a (standard) hydrogen half-cell/(standard) hydrogen electrode ✓</p> <p>Standard conditions Temperature of 298 K / 25°C AND (solution) concentrations of 1 mol dm⁻³ / 1M AND pressure of 101 kPa OR 100 kPa ✓</p>	2	<p>ALLOW voltage OR potential difference OR p.d. OR electrode potential OR reduction potential OR redox potential as alternative for e.m.f. IGNORE S.H.E. (as abbreviation for standard hydrogen electrode)</p> <p>ALLOW 1 atmosphere/1 atm OR 10⁵ Pa OR 1 bar</p>
	(b)	2.71 V ✓	1	IGNORE any sign
	(c)	(i)	3	<p>Correct species AND balancing needed for each mark IGNORE state symbols ALLOW equilibrium sign (i.e. assume reaction is to right) ALLOW correct multiples</p> <p>IF there are more than three equations</p> <ul style="list-style-type: none"> • mark a maximum of three equations • mark incorrect equations first
		(ii)	2	<p>High activation energy OR slow rate ✓</p> <p>Conditions not standard OR concentrations not 1 mol dm⁻³ ✓</p> <p>DO NOT ALLOW 'standard conditions' are different</p>

Question		Answer	Marks	Guidance
7	(d)	<p>ANNOTATE WITH TICKS, CROSSES, etc</p> <p>General (2 marks – assumed to be acid)</p> <ul style="list-style-type: none"> (E of) 7 (ClO^-/Cl_2) is more positive/less negative (than 6) OR E_{cell} is (+)0.27 (V) OR E_{cell} is positive ✓ 6 (Cl_2/Cl^-) moves to left AND 7 (ClO^-/Cl_2) to right ✓ <hr/> <p>In alkali (3 marking points),</p> <ul style="list-style-type: none"> H^+ in 7 (ClO^-/Cl_2) is removed by/reacts with OH^-/alkali ✓ (E of) 7 (ClO^-/Cl_2) less positive/more negative (than 6) ✓ 6 (Cl_2/Cl^-) moves to right AND 7 (ClO^-/Cl_2) to left ✓ 	4 max	<p>ORA throughout Minimum identification for system 6 is Cl^- Minimum identification for system 7 is ClO^- Note: Cl_2 is unsuitable as an identifier as it features in both system 6 and system 7 IGNORE reference to gaining and losing electrons; oxidation and reduction</p> <hr/> <p>Note: identification of systems 6 and 7 could be from use of relevant half equations/overall equation ALLOW 'greater' or 'higher' for 'more positive'</p> <p>ALLOW correct eqn: $\text{Cl}^- + \text{ClO}^- + 2\text{H}^+ \rightarrow \text{Cl}_2 + \text{H}_2\text{O}$ IGNORE uncanceled electrons ALLOW multiples, e.g. $2\text{Cl}^- + 2\text{ClO}^- + 4\text{H}^+ \rightarrow 2\text{Cl}_2 + 2\text{H}_2\text{O}$</p> <p>Note: IF equilibrium shifts are correct, IGNORE incorrectly balanced equation but CON an equation in wrong direction</p> <hr/> <p>ALLOW correct eqn: $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{Cl}^- + \text{ClO}^- + 2\text{H}^+$ IGNORE uncanceled electrons ALLOW multiples, e.g. $2\text{Cl}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{Cl}^- + 2\text{ClO}^- + 4\text{H}^+$</p> <p>Note: IF equilibrium shifts are correct, IGNORE incorrectly balanced equation but CON an equation in wrong direction</p>

Question		Answer	Marks	Guidance
	(e)	(i)	1	<p>ALLOW IO_3^- is the oxidising agent as I has been reduced</p> <p>DO NOT ALLOW just IO_3^- has been reduced</p> <p>DO NOT ALLOW I is the oxidising agent</p>
		(ii)	2	<p>ALLOW correct multiples</p> <p>eg $2\frac{1}{2} \text{Sn}^{2+} + \text{IO}_3^- + 6\text{H}^+ \rightarrow \frac{1}{2} \text{I}_2 + 2\frac{1}{2} \text{Sn}^{4+} + 3\text{H}_2\text{O}$</p> <p>IGNORE e^- for 1st marking point</p>
			Total	15

Question		Answer	Marks	Guidance
8	(a)	$(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^8 4s^2$ ✓ $(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^8$ ✓	2	ALLOW 4s before 3d, i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ IF candidate has used subscripts OR caps, DO NOT ALLOW when first seen but credit subsequently, i.e. $1s_2 2s_2 2p_6 3s_2 3p_6 3d_8 4s_2$ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3D^8$ For Ni^{2+} ALLOW $4s^0$ in electron configuration
	(b)	(i)	1	
		(ii)	1	
		(iii)	1	
		(iv)	1	



Question	Answer	Marks	Guidance
8 (c)	<p>Marks are for correctly calculated values</p> <p><i>amount of Ni</i> -----</p> <p>amount Ni(DMG)₂ OR amount hydrated salt OR amount Ni²⁺</p> $= \frac{2.57}{288.7} = \mathbf{8.9(0) \times 10^{-3}} \text{ mol } \checkmark$ <p><i>M values</i> -----</p> $M(\text{hydrated salt}) = \frac{2.50}{8.90 \times 10^{-3}} = \mathbf{280.9} \text{ (g mol}^{-1}\text{)} \checkmark$ $M(\text{anhydrous salt}) = \frac{1.38}{8.90 \times 10^{-3}} = \mathbf{155.0} \text{ (g mol}^{-1}\text{)} \checkmark$ <p><i>H₂O</i> -----</p> $\text{mass H}_2\text{O} = 2.50 - 1.38 = \mathbf{1.12 g} \checkmark$ <p><i>n(H₂O) from mass or M values</i></p> $= \frac{1.12}{18.0} = \mathbf{6.2(2) \times 10^{-2}} \text{ OR } 280.9 - 155.0 \sim \mathbf{125.9} \checkmark$ <p><i>waters of crystallisation</i></p> $= \frac{6.22 \times 10^{-2}}{8.90 \times 10^{-3}} = \mathbf{7} \text{ OR } \frac{125.9}{18.0} = \mathbf{7} \checkmark$ <p><i>Anion</i> -----</p> <p>Molar mass of anion = 280.9 – (58.7 + 7 × 18) = 96.1 (g mol⁻¹)</p> <p>OR</p> <p>Molar mass of anion = 155.0 – 58.7 = 96.3 (g mol⁻¹) ✓</p> <p><i>Formula</i> -----</p> <p>Formula of salt is NiSO₄•7H₂O ✓</p>	7 max	<p>ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>Note: The answers incorporate three different approaches to solving this problem.</p> <p>IF candidate attempts calculation via another method, consult your TL</p> <p>ECF answer above</p> <p>ALLOW numerical answers 280.8 – 280.9 (ALLOW 281)</p> <p>IGNORE further figures</p> <p>ALLOW numerical answers 155.0 – 155.1 (ALLOW 155)</p> <p>IGNORE further figures</p> <p>ASSUME that ‘unlabelled 1.12 g’ applies to H₂O unless contradicted</p> <p>ALLOW numerical answers 125.7 – 125.9 (ALLOW 126)</p> <p>ECF answer above</p> <p>7 as whole number is required</p> <p>Note: Mark for 7 can be credited within formula BUT there must be some relevant working to derive ~7, e.g. 6.99</p> <p>ALLOW numerical answers 96.0 – 96.4 (ALLOW 96)</p>
	Total	13	

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