OCR
RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced GCE

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

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

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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.

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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).

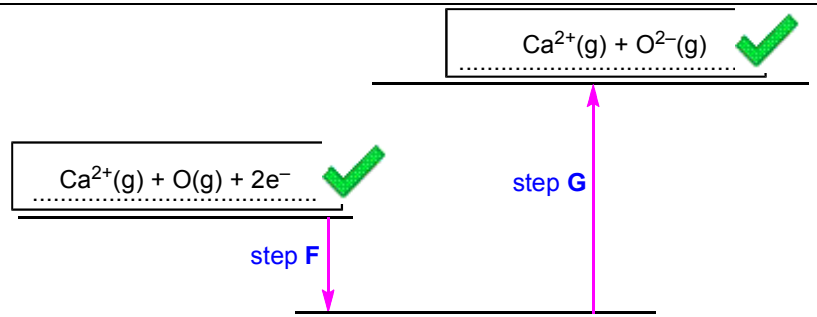
Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
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)		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' (*confusion with LE*) atomisation **AND** oxygen/O_2/½O_2/O both required (*atomisation of calcium is also in cycle)* **IGNORE** oxygen or oxygen species, e.g. O^- **DO NOT ALLOW** calcium

Question			Answer	Marks	Guidance
1	(b)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –3454 (kJ mol^{-1}) award 2 marks** --- –635 = 178 + 249 + 590 + 1145 + (–141) + 798 + ΔH_{LE}(CaO) **OR** ΔH_{LE}(CaO) = –635 – [178 + 249 + 590 + 1145 + (–141) + 798] **OR** –635 – 2819 ✓ = –3454 ✓ (kJ mol^{-1})	2	**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** --- 1st mark for expression linking ΔH_{LE}(CaO) with ΔH values **ALLOW** LE for ΔH_{LE} **ALLOW** for 1 mark: –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 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

Question			Answer	Marks	Guidance
1	(c)		**For first 2 marks,** • **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		
			First 2 marks Decrease in (ionic) size **AND** **more negative** LE **OR** more **exo**thermic **OR** more attraction ✓ Increase in (ionic) charge **OR** charge density **AND** **more negative** LE **OR** more **exo**thermic **OR** more attraction ✓ --- *Link between LE and attraction* Lattice enthalpy correctly linked to attraction between **IONS** at least once ✓ *e.g. Greater attraction between **ions** gives **more negative** LE*	3	**ANNOTATE WITH TICKS AND CROSSES, etc** **ORA** throughout **ALLOW** pull for attraction **IGNORE** just 'greater force' (*could be repulsion*) **IGNORE** responses in terms of packing **IGNORE** electron density **IGNORE** lower/higher LE --- **For 3rd marking point ONLY, IONS is essential;** **DO NOT ALLOW** attraction between atoms or molecules **DO NOT ALLOW** nuclear attraction
			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 (≡ rate) halves
		(iii)	No change ✓	1	
	(b)	(i)	*Tangent* On graph, tangent drawn to curve at t ~ 40 s ✓ *Calculation of rate from the tangent drawn* e.g. rate = $\frac{5.2}{116}$ = 0.045 **OR** 4.5 x 10^{-2} ✓ *Units* mol dm^{-3} s^{-1} ✓ *Independent mark*	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** ±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)	$k = \frac{\text{answer to (b)(i)}}{3.45}$ ✓ units: s^{-1} ✓ *Independent mark*	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 *Many will keep this value in calculator for **(b)(ii)*** **ALLOW** $k = \ln 2/t_{1/2} = 0.693$/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 ✓	1	**IGNORE** water does not affect the rate
			Total	**10**	

Question			Answer	Marks	Guidance
3	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 16.8 with 'no units', award **5 marks** --- At equilibrium, $n(I_2)$ **OR** $[I_2(g)]$ = $4.00 \times 10^{-3} - 1.70 \times 10^{-3} = 2.30 \times 10^{-3}$ (mol / mol dm^{-3}) ✓ n(HI) **OR** [HI(g)] = $2 \times 1.70 \times 10^{-3}$ = 3.40×10^{-3} (mol / mol dm^{-3}) ✓ (K_c =) $\frac{(3.40 \times 10^{-3})^2}{3.00 \times 10^{-4} \times 2.30 \times 10^{-3}}$ ✓ **IGNORE** $K_c = \frac{[HI]^2}{[H_2]\,[I_2]}$ = 16.8 (**3 SF** required) ✓ no units ✓	5	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW ECF** throughout 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 **ALLOW ECF** using incorrect values for $[I_2]$ **AND** [HI] **BUT** $[H_2]$ in K_c expression must be 3.00×10^{-4} (given in Q) **ALLOW ECF** from incorrect K_c expression for calculation to 3 SF and units **For 'no units' ALLOW 'none' (ORA) OR '—'** **DO NOT ALLOW** space to be left blank **Common errors:** Use of 1.70×10^{-3} for n(HI) (no factor of x 2) K_c = 4.19 (3SF) and no units: 4 marks Use of K_c expression used is upside down K_c = 0.0597 (3SF) and no units: 4 marks No square for $[HI]^2$ K_c = 4930 and $dm^3\ mol^{-1}$ 4 marks **Note:** different ECF units

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>3</td><td>(b)</td><td>(i)</td><td>
<table>
<tr><th></th><th>$H_2(g)$</th><th>$I_2(g)$</th><th>HI(g)</th></tr>
<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>
</table>
Each column should have only one box ticked

Correct ticks for $H_2(g)$ AND $I_2(g)$ AND HI(g) two marks ✓✓
i.e. all three columns correct

Ticks for two of $H_2(g)$, $I_2(g)$ and HI(g) correct one mark ✓
i.e. two columns correct
</td><td>2</td><td>DO NOT ALLOW more than one box ticked in a column (response is a CON)</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>K_c is smaller
AND
(forward) reaction is exothermic OR ΔH is negative ✓</td><td>1</td><td>Link to ΔH/exothermic essential
ALLOW reverse reaction is endothermic
DO NOT ALLOW equilibrium shifts to the right (CON)</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>K_c is the same
AND
K_c is temperature dependent OR K_c is not changed by pressure ✓</td><td>1</td><td>ALLOW K_c is only changed by temperature
IGNORE same number of moles on both side</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>9</td><td></td></tr>
</table>

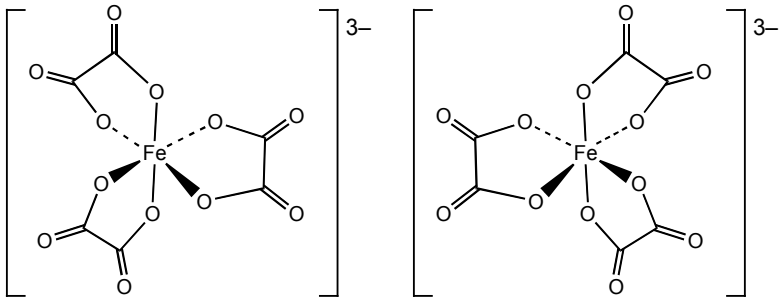
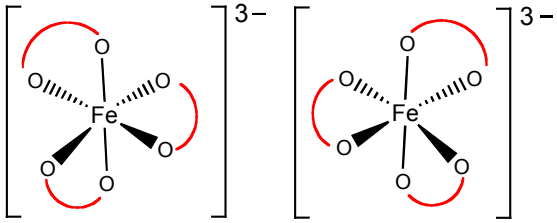
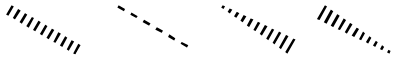
Question	Answer	Marks	Guidance
4 (a)	HC*l* is a strong acid **AND** HC*l*O is a weak acid ✓ **HC*l***: pH = –log 0.14 = 0.85 (**2 DP** required) ✓ **HC*l*O**: **CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 4.14, award all three calculation marks --- $K_a = 10^{-7.43}$ **OR** 3.7×10^{-8} (mol dm^{-3})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

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

Question			Answer	Marks	Guidance
4	(d)	(i)	A buffer solution minimises pH changes ✓ on addition of **small** amounts of acid/H^+ or alkali/OH^-/base ✓ --- $HCOOH \rightleftharpoons H^+ + HCOO^-$ ✓ *Equilibrium sign essential*	7	**ANNOTATE WITH TICKS AND CROSSES, etc** **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 --- **DO NOT ALLOW** $COOH^-$ **OR** CHOOH **OR** COOH **DO NOT ALLOW** $HA \rightleftharpoons H^+ + A^-$
			For effect of acid and alkali, **ALLOW** wrong carboxylic acid (e.g. CH_3COOH) **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. CH_3OOH		**<u>Quality of written communication, QWC</u>** *2 marks are for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^-*
			Added alkali HCOOH reacts with added alkali/base/OH^- **OR** added alkali/OH^- reacts with H^+ ✓ **QWC**: Equilibrium shifts forming $HCOO^-$ **OR** H^+ **OR** (HCOOH) Equilibrium → right ✓ **Added acid** $HCOO^-$ reacts with added acid/H^+ ✓ **QWC**: Equilibrium shifts forming HCOOH **OR** (HCOOH) Equilibrium → left ✓		**ALLOW** HA **OR** weak acid reacts with added alkali **DO NOT ALLOW** this mark if there is no equilibrium system shown, e.g. $HCOOH \rightleftharpoons H^+ + HCOO^-$ is absent **ALLOW** A^- **OR** conjugate base reacts with added acid **IGNORE** salt reacts with added acid **DO NOT ALLOW** this mark if there is no equilibrium system shown, e.g. $HCOOH \rightleftharpoons H^+ + HCOO^-$ is absent

Question			Answer	Marks	Guidance
4	(d)	(ii)	**HCOOH** reacts with **NaOH** forming **$HCOO^-$/HCOONa** **OR** $HCOOH + NaOH \rightarrow HCOONa + H_2O$ ✓ *Equilibrium sign allowed* (Some) HCOOH/(weak) acid remains **OR** HCOOH/(weak) acid is in excess ✓	6	**ANNOTATE WITH TICKS AND CROSSES, etc** **DO NOT ALLOW** just 'methanoate/$HCOO^-$ forms' *formulae or names of reactants also required* **ALLOW** $HCOOH + OH^- \rightarrow HCOO^- + H_2O$ ✓ **IGNORE** conjugate base/**salt forms** **IGNORE** HCOOH has been partially neutralised
			Calculation **CHECK THE ANSWER** **IF** answer = 3.99, award all **four** calculation marks		
			n(HCOOH) **OR** [HCOOH] = 0.24(0) (mol / mol dm^{-3}) ✓ *n*($HCOO^-$) **OR** [$HCOO^-$] **OR** [HCOONa] = 0.4(00) (mol / mol dm^{-3}) ✓ $[H^+] = K_a \times \frac{[HCOOH]}{[HCOO^-]}$ ✓ $pH = -\log [H^+] = -\log(1.70 \times 10^{-4} \times \frac{0.24}{0.4}) = 3.99$ ✓ --- **OR** use of Henderson–Hasselbalch equation: $pH = pK_a + \log \frac{[HCOO^-]}{[HCOOH]}$ **OR** $pH = -\log K_a + \log \frac{[HCOO^-]}{[HCOOH]}$ ✓ = 3.77 + 0.22 = 3.99 ✓		**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 **ALLOW** HA/acid and A^-/salt for HCOOH and $HCOO^-$ **DO NOT ALLOW ECF for this mark:** **3.99 is the ONLY correct answer** --- **ALLOW** HA/acid and A^-/salt for HCOOH and $HCOO^-$ **ALLOW** $pH = pK_a - \log \frac{[HCOOH]}{[HCOO^-]}$ **OR** $pH = -\log K_a - \log \frac{[HCOOH]}{[HCOO^-]}$ **ALLOW** = 3.77 – (–0.22) = 3.99 **DO NOT ALLOW ECF for this mark:** **3.99 is the ONLY correct answer**
			Total	**22**	

Question			Answer	Marks	Guidance
5	(a)		$2Fe + 3Cl_2 \longrightarrow 2FeCl_3$ ✓	1	**ALLOW** $2Fe + 3Cl_2 \longrightarrow Fe_2Cl_6$ **ALLOW** multiples, e.g. $Fe + 1½Cl_2 \longrightarrow FeCl_3$ **IGNORE** state symbols **DO NOT ALLOW** $2Fe + 3Cl_2 \longrightarrow 2Fe^{3+} + 6Cl^-$
	(b)		$Fe^{3+} + 3OH^- \longrightarrow Fe(OH)_3$ ✓	1	**IGNORE** state symbols **ALLOW** $[Fe(H_2O)_6]^{3+} + 3OH^- \longrightarrow Fe(H_2O)_3(OH)_3 + 3H_2O$ **ALLOW** $[Fe(H_2O)_6]^{3+} + 3OH^- \longrightarrow Fe(OH)_3 + 6H_2O$
	(c)	(i)	$2[Fe(H_2O)_6]^{3+} + Zn \longrightarrow 2[Fe(H_2O)_6]^{2+} + Zn^{2+}$ 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: $2Fe^{3+} + Zn \longrightarrow 2Fe^{2+} + Zn^{2+}$
		(ii)	redox ✓	1	**ALLOW** reduction **AND** oxidation **CARE**: possible confusion with **(d)(ii)**
	(d)	(i)	Formula of **E** as $[Fe(CN)_6]^{3-}$ shown as product in equation ✓ Correct balanced equation: $[Fe(H_2O)_6]^{3+} + 6CN^- \longrightarrow [Fe(CN)_6]^{3-} + 6H_2O$ ✓ Notice different charges on complex ions: LHS 3+, RHS 3– state symbols **not** required	2	**ALLOW** equations with KCN, i.e.: $[Fe(H_2O)_6]^{3+} + 6KCN \rightarrow [Fe(CN)_6]^{3-} + 6K^+ + 6H_2O$ $[Fe(H_2O)_6]^{3+} + 6K^+ + 6CN^- \rightarrow [Fe(CN)_6]^{3-} + 6K^+ + 6H_2O$ **ALLOW** ECF for an equation showing formation of $[Fe(CN)_6]^{4-}$ from $[Fe(H_2O)_6]^{2+}$: $[Fe(H_2O)_6]^{2+} + 6CN^- \longrightarrow [Fe(CN)_6]^{4-} + 6H_2O$ 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)		**F** and **G**:  1 mark for each isomer ✓✓ *Bonds **must** go to O ligand atoms on **EACH** structure* ***IGNORE** charges on Fe^{3+} and O^{-} at this stage* 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 ✓	3	**ALLOW** any attempt to show bidentate ligand Bottom line is the diagram below.  **IGNORE** structure between two Os in ligand even if slightly different Must contain 2 out wedges, 2 in wedges and 2 lines in plane of paper. For bond into paper, **ALLOW**: 
	(f)		FeO_4^{2-} ✓	1	Formula **AND** charge needed **ALLOW** other 2– ions containing: Fe **AND** O **AND** Fe has ox no of +6 i.e. **ALLOW** $Fe_2O_7^{2-}$, $Fe_3O_{10}^{2-}$, etc.
			Total	**12**	

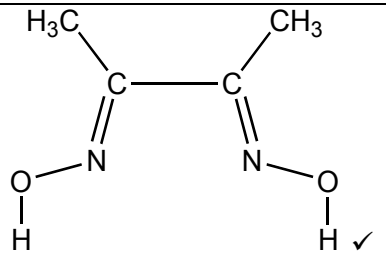
Question			Answer	Marks	Guidance
6	(a)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 218, award **2 marks** --- $-256 = (6 \times 205) + S(C_6H_{12}O_6) - (6 \times 214 + 6 \times 70)$ **OR** $S(C_6H_{12}O_6) = -256 - (6 \times 205) + (6 \times 214 + 6 \times 70)$ **OR** –256 + 474 ✓ = 218 (J K^{-1} mol^{-1}) ✓	2	**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** --- **ALLOW** 1 mark for –218 **ALLOW** 1 mark for +730 (*products – reactants*) **Note:** –3190 for simple addition of products + reactants scores zero marks
		(ii)	ΔG = +2879 – 298 × –0.256 ✓ = (+)2955 (kJ mol^{-1}) ✓	2	**ALLOW** 3 SF: 2960 to calculator value of 2955.288 **Award 1 mark for the following:** • ΔG = 2890 to calculator value of 2885.4 *25 °C used rather than 298 K:* • ΔG = 79200 to calculator value of 79167 *ΔS not converted from J K^{-1} mol^{-1} to kJ $K^{-1}mol^{-1}$* • expressions with **one** transcription error: e.g. +2897 instead of +2879; 0.265 instead of 0.256 • ΔG = 2814.036 *use of 218 rather than –256* • 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** $\Delta G > 0$ ✓	1	**ALLOW** ΔH is endothermic for ΔH is +ve **ALLOW** ΔG will never be less than 0 **DO NOT ALLOW** *S* or *H* i.e. **change** in entropy, ΔS and change in enthalpy ΔH are essential

Question			Answer	Marks	Guidance
6	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 3.12 x 10^{17} g, award **2 marks** --- amount of CO_2 removed = $3.4 \times 10^{18} \times 6 / 2879$ **OR** 7.09×10^{15} (mol) ✓ mass of $CO_2 = 44.0 \times 7.09 \times 10^{15} = 3.12 \times 10^{17}$ g ✓	2	**ALLOW** 2 SF (7.1×10^{15} (mol)) up to calculator value of 7.085793678, correctly rounded **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 **ALLOW** 1 mark for 3.1×10^{17} with no unit **ALLOW** ECF from incorrectly calculated amount of CO_2 provided that both 3.4 x 10^{18} **AND** 2879 have been used e.g. Omission of x 6 gives 1.181 x 10^{15} mol CO_2 and 5.196 x 10^{16} g CO_2
			Total	**7**	

Question			Answer	Marks	Guidance
7	(a)		**Definition** The e.m.f. (of a half-cell) compared with a (standard) hydrogen half-cell/(standard) hydrogen electrode ✓ **Standard conditions** Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} / 1M **AND** pressure of 101 kPa **OR** 100 kPa ✓	2	**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) **ALLOW** 1 atmosphere/1 atm **OR** 10^5 Pa **OR** 1 bar
	(b)		2.71 V ✓	1	**IGNORE** any sign
	(c)	(i)	$Al + 3Fe^{3+} \longrightarrow Al^{3+} + 3Fe^{2+}$ ✓ $2Al + 3I_2 \longrightarrow 2Al^{3+} + 6I^-$ ✓ $2I^- + 2Fe^{3+} \longrightarrow I_2 + 2Fe^{2+}$ ✓	3	Correct species **AND** balancing needed for each mark **IGNORE** state symbols **ALLOW** equilibrium sign (i.e. assume reaction is to right) **ALLOW** correct multiples **IF** there are **more than** three equations • mark a maximum of three equations • mark incorrect equations first
		(ii)	High activation energy **OR** slow rate ✓ Conditions not standard **OR** concentrations not 1 mol dm^{-3} ✓	2	 **DO NOT ALLOW** 'standard conditions' are different

Question			Answer	Marks	Guidance
7	(d)		**ANNOTATE WITH TICKS, CROSSES, etc**	4 max	**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
			General (2 marks – assumed to be acid) • (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 ✓		**Note**: identification of systems 6 and 7 could be from use of relevant half equations/overall equation **ALLOW** 'greater' or 'higher' for 'more positive' **ALLOW** correct eqn: $Cl^- + ClO^- + 2H^+ \rightarrow Cl_2 + H_2O$ **IGNORE** uncancelled electrons **ALLOW** multiples, e.g. $2Cl^- + 2ClO^- + 4H^+ \rightarrow 2Cl_2 + 2H_2O$ **Note**: **IF** equilibrium shifts are correct, **IGNORE** incorrectly balanced equation but **CON** an equation in wrong direction
			In alkali (3 marking points), • 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 ✓		**ALLOW** correct eqn: $Cl_2 + H_2O \rightarrow Cl^- + ClO^- + 2H^+$ **IGNORE** uncancelled electrons **ALLOW** multiples, e.g. $2Cl_2 + 2H_2O \rightarrow 2Cl^- + 2ClO^- + 4H^+$ **Note**: **IF** equilibrium shifts are correct, **IGNORE** incorrectly balanced equation but **CON** an equation in wrong direction

Question			Answer	Marks	Guidance
	(e)	(i)	IO_3^- has removed/gained electrons from Sn^{2+} **OR** IO_3^- has been reduced to I_2 / reduced to 0 **OR** IO_3^- has oxidised Sn^{2+} ✓	1	**ALLOW** IO_3^- is the oxidising agent as I has been reduced **DO NOT ALLOW** just IO_3^- has been reduced **DO NOT ALLOW** I is the oxidising agent
		(ii)	$5Sn^{2+} + 2IO_3^- + 12H^+ \longrightarrow I_2 + 5Sn^{4+} + 6H_2O$ All chemical species correct with **no extra** chemical species ✓ Correct balancing with no electrons shown ✓	2	**ALLOW** correct multiples eg $2½\ Sn^{2+} + IO_3^- + 6H^+ \rightarrow ½\ I_2 + 2½\ Sn^{4+} + 3H_2O$ **IGNORE** e^- for 1st marking point
			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)	Acts as a base **OR** alkali **AND** removes/accepts a proton (from DMGH) ✓	1	
		(ii)	4 ✓	1	
		(iii)	(Each) DMG has 1– charge which **cancel** 2+ charge on Ni^{2+} ✓	1	**ALLOW** 2 x –1 + 2 = 0 For Ni^{2+}, **ALLOW** Ni has an oxidation number of (+)2 **ALLOW** Ni^{2+} cancelled out by 2 DMG^- **ALLOW** 'balanced' for cancelled
		(iv)	 ✓	1	**ALLOW** OH for O—H **ALLOW** CH_3— **DO NOT ALLOW** —H—O

Question			Answer	Marks	Guidance
8	(c)		**Marks are for correctly calculated values** *amount of Ni* ---------- amount $Ni(DMG)_2$ **OR** amount hydrated salt **OR** amount Ni^{2+} $= \frac{2.57}{288.7}$ = **$8.9(0) \times 10^{-3}$** mol ✓ *M values* ---------- *M*(hydrated salt) = $\frac{2.50}{8.90 \times 10^{-3}}$ = **280.9** (g mol^{-1}) ✓ *M*(anhydrous salt) = $\frac{1.38}{8.90 \times 10^{-3}}$ = **155.0** (g mol^{-1}) ✓ *H_2O* ---------- mass H_2O = 2.50 – 1.38 = **1.12 g** ✓ *n*(H_2O) from mass or *M* values $= \frac{1.12}{18.0}$ = **$6.2(2) \times 10^{-2}$ OR** 280.9 – 155.0 **~125.9** ✓ waters of crystallisation $= \frac{6.22 \times 10^{-2}}{8.90 \times 10^{-3}}$ = **7** **OR** $\frac{125.9}{18.0}$ = **7** ✓ *Anion* ---------- Molar mass of anion = 280.9 – (58.7 + 7 x 18) = **96.1** (g mol^{-1}) **OR** Molar mass of anion = 155.0 – 58.7 = **96.3** (g mol^{-1}) ✓ *Formula* ---------- Formula of salt is **$NiSO_4 \bullet 7H_2O$** ✓	**7 max**	**ANNOTATE WITH TICKS AND CROSSES, etc** **Note:** The answers incorporate three different approaches to solving this problem. **IF candidate attempts calculation via another method, consult your TL** **ECF** answer above **ALLOW** numerical answers 280.8 – 280.9 (**ALLOW** 281) **IGNORE** further figures **ALLOW** numerical answers 155.0 – 155.1 (**ALLOW** 155) **IGNORE** further figures **ASSUME** that 'unlabelled 1.12 g' applies to H_2O unless contradicted **ALLOW** numerical answers 125.7 – 125.9 (**ALLOW** 126) **ECF** answer above **7** as whole number is required **Note:** Mark for 7 can be credited within formula **BUT** there must be some relevant working to derive ~7, e.g. 6.99 **ALLOW** numerical answers 96.0 – 96.4 (**ALLOW** 96)
			Total	**13**	

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