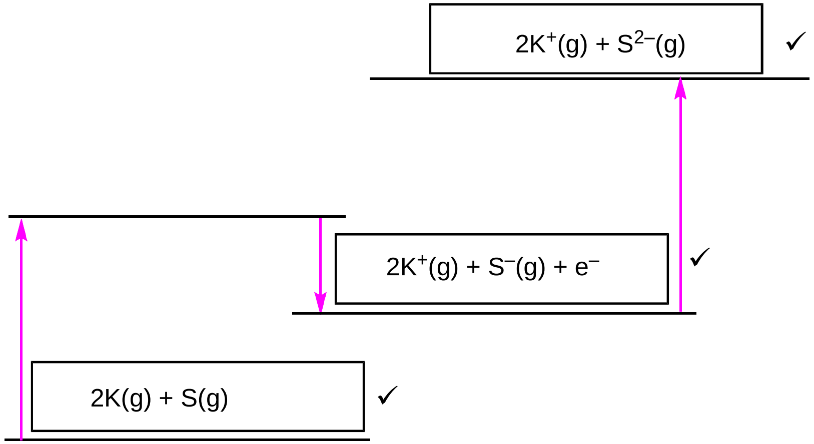
Question			Answer	Marks	Guidance
1	**(a)**	**(i)**		**3**	Mark each marking point independently Correct species **AND** state symbols required for each mark For S^{2-}, **DO NOT ALLOW** S^{-2} For e^-, **ALLOW** e For e^- **only**, **IGNORE** any state symbols added **ALLOW** k and s *It can be very difficult distinguishing K from k; S from s*

1	**(a)**	**(ii)**	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓✓ Award marks as follows. **1st mark: formation** of **compound** from **gaseous ions** **2nd mark: one mole** for compound **only** **DO NOT ALLOW** 2nd mark without 1st mark Note: A definition for enthalpy change of **formation** will receive **no** marks	**2**	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW one mole** of compound is **formed/made** from its **gaseous ions** **ALLOW** as alternative for compound: lattice, crystal, substance, solid **IGNORE**: $2K^+(g) + S^{2-}(g) \longrightarrow K_2S(s)$ (question asks for words) **ALLOW** 1 mark (special case) for absence of 'gaseous' only, i.e. the **formation** of **one mole** of a(n ionic) compound from its **ions** (under standard conditions) ✓

1	**(a)**	**(iii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2116 (kJ mol^{-1}) award 2 marks** --- –381 – (2 × +89 + 279 + 2 × +419 –200 + 640) ✓ –381 – 1735 = – 2116 ✓ (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** --- **ALLOW** for 1 mark **ONE** mistake with sign **OR** use of 2: –2027 (**2** × 89 not used for K) –1697 (**2** × 419 not used for K) –2516 (+200 rather than –200 for S 1st electron affinity) (+)2116 (wrong sign) –1354 (+381 instead of –381) (+)1354 (+1735 instead of –1735) –836 (–640 instead of +640) –1558 (–279 instead of +279) –1760 (–2 × 89 instead of +2 x 89) –439 (–2 × 419 instead of +2 x 419) –2120 (rounded to 3SF) **For other answers**, check for a **single** transcription error or calculator error which could merit 1 mark **DO NOT ALLOW** any other answers, e.g. –1608 (2 errors: **2** × 89 and **2 x** 419 not used for K) –846 (3 errors:)

1	**(b)**		Lowest melting point **KI** **RbC*l*** Highest melting point **NaBr** Correct order ✓ **Mark 2nd and 3rd marking points independently** **Attraction and ionic size linked:** Greater attraction from smaller ions/closer ions/larger charge density ✓ *Comparison needed* **Energy AND attraction/breaking bonds linked:** More **energy**/**heat** to overcome attraction (between ions) **OR** More **energy**/**heat** to break (ionic) bonds ✓	**3**	***FULL ANNOTATIONS MUST BE USED*** **--** **ORA** throughout Response must clearly refer to **ions** for explanation marks **2nd and 3rd marking point must be comparative** **DO NOT ALLOW incorrect named particles, e.g.** 'atoms', 'molecules', Na, Cl, Cl_2, 'atomic', etc **DO NOT ALLOW** responses using nuclear size or attraction **DO NOT ALLOW** responses linked with **loss** of electrons **IGNORE** larger **electron** density **ALLOW** smaller **sum** of radii gives a greater ionic attraction **IGNORE** NaBr has greater ionic attraction **IGNORE** NaBr has smallest ionic radius (*not focussing on size of **each** ion*) **ASSUME** bonds broken are ionic unless otherwise stated **DO NOT ALLOW incorrect named particles, e.g.** 'atoms', 'molecules', Na, Cl, Cl_2, 'atomic', etc **Note**: Comparison for energy **only** *(i.e. link between more energy and breaking bonds/overcoming attraction)*
			Total	**10**	

Question			Answer	Marks	Guidance
2	**(a)**	**(i)**	(entropy) decreases **AND** (solid/ice has) less disorder/ more order/ fewer ways of arranging energy/ less freedom/ less random molecules ✓	**1**	**ORA** **decreases and reason required for mark** **ASSUME change is for freezing of water unless otherwise stated** **DO NOT ALLOW** atoms are more ordered
2	**(a)**	**(ii)**	(entropy) increases **AND** (CO_2) **gas** is **formed** ✓ *Could be from equation with $CO_2(g)$*	**1**	**increases and reason required for mark** **ASSUME** gas is CO_2 unless otherwise stated **BUT DO NOT ALLOW** an incorrect gas (e.g. H_2) **ALLOW** more gas
2	**(a)**	**(iii)**	entropy decreases **AND** 3 mol O_2 form 2 mol O_3 **OR** $3O_2 \rightarrow 2O_3$ **OR** 3 mol gas form 2 mol gas ✓	**1**	**decreases and reason required for mark** For mol, **ALLOW** molecules **ALLOW** multiples, e.g. $1\frac{1}{2}O_2 \rightarrow O_3$; $O_2 + \frac{1}{2}O_2 \rightarrow O_3$ **ALLOW** $O_2 + O \rightarrow O_3$ **Note: DO NOT ALLOW** 2 mol gas forms 1 mol gas unless linked to $O_2 + O \rightarrow O_3$ **IGNORE** reaction forms fewer moles/molecules

2	**(b)**		**CARE: responses involve changes of negative values** -- **Feasibility AND ΔG** Reaction becomes/is less feasible/not feasible **AND** ΔG increases **OR** ΔG becomes/is less negative/more positive **OR** $\Delta G > 0$ **OR** $\Delta H - T\Delta S > 0$ **OR** $\Delta H - T\Delta S$ becomes/is less negative/more positive **OR** $\Delta H > T\Delta S$ ✓ **OR** $T\Delta S$ becomes/is more negative than ΔH ✓ **--** **Effect on $T\Delta S$** $T\Delta S$ becomes more negative **OR** $T\Delta S$ decreases **OR** $-T\Delta S$ becomes more positive **OR** $-T\Delta S$ increases **OR magnitude** of $T\Delta S$ increases **OR** $\lvert T\Delta S \rvert$ increases ✓ **--**	**2**	***FULL ANNOTATIONS MUST BE USED*** **--** As alternative for 'less feasible' **ALLOW 'less** spontaneous' **OR** a comment that implies 'reaction no longer take place' **ALLOW for ΔG increases** $\Delta G < 0$ **only** at low T **DO NOT ALLOW** $T\Delta S > \Delta H$ (*comparison wrong way round*) **NOTE: Last statement automatically scores 2nd mark ALSO** **IGNORE** significance **IGNORE** magnitude for 1st marking point **------------------** **DO NOT ALLOW** $T\Delta S$ increases **IGNORE** significance **--** ***APPROACH BASED ON TOTAL ENTROPY:*** **Feasibility with increasing temperature** Reaction becomes less feasible/not feasible **AND** $\Delta S - \Delta H/T$ **OR** ΔS_{total} decreases/ less positive ✓ **Effect on $\Delta H/T$** $\Delta H/T$ is less negative **OR** $\Delta H/T$ increases **OR** $-\Delta H/T$ decreases **OR** magnitude of $\Delta H/T$ decreases ✓

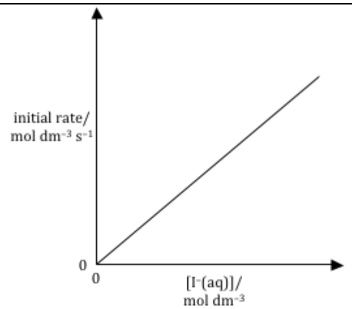
2	**(c)**	**(i)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 75.962 **OR** 75.96 **OR** 76.0 **OR** 76, award **2 marks** -- ΔS = (33 + 3 × 189) – (76 + 3 × 131) = (+)131 (J K^{-1} mol^{-1}) ✓ ΔG = 115 – (298 × 0.131) = (+) 75.962 **OR** 75.96 **OR** 76.0 **OR** 76 (kJ K^{-1} mol^{-1}) ✓	**2**	**DO NOT ALLOW** –131 **ALLOW ECF** from incorrect calculated value of ΔS
2	**(c)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 878 **OR** 877.9 **OR** 877.86, award **2 marks** -- (Minimum temperature when) $\Delta G = 0$ **OR** $\Delta H - T\Delta S = 0$ **OR** (For feasibility) $\Delta G = 0$ **OR** $\Delta G < 0$ **OR** $\Delta H - T\Delta S < 0$ **OR** $T = \frac{\Delta H}{\Delta S}$ ✓ $T = \frac{115}{0.131}$ = 878 K ✓	**2**	**ALLOW** total entropy statement: ΔS(total) = 0 **OR** ΔS(total) >0 **ALLOW ECF** from incorrect calculated value of ΔS from **2(c)(i)** **ALLOW** 878 up to calculator value of 877.862595 correctly rounded
			Total	**9**	

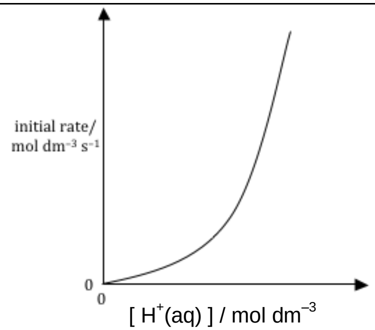
Question			Answer	Marks	Guidance
3	**(a)**		$(K_c =)\ \dfrac{[C_2H_2]\,[H_2]^3}{[CH_4]^2}$ ✓	**1**	Square brackets are **essential** State symbols **not** required. **IGNORE** incorrect state symbols
3	**(b)**	**(i)**	amount of $H_2 = 3 \times 0.168$ = 0.504 (mol) ✓	**1**	

3	**(b)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 0.153 $mol^2\ dm^{-6}$, award **3 marks** **IF** answer = 0.153 with incorrect units, award **2 marks** -- **IF answer from 3(b)(i) for $n(H_2) \neq 0.504$, mark by ECF.** **Equilibrium concentrations** (from $n(H_2)$ = 0.504 $mol\ dm^{-3}$) $[CH_4] = 2.34 \times 10^{-2}$ ($mol\ dm^{-3}$) **AND** $[C_2H_2] = 4.20 \times 10^{-2}$ ($mol\ dm^{-3}$) **AND** $[H_2]$ = 0.126 ($mol\ dm^{-3}$) ✓ **Calculation of K_c and units** $K_c = \dfrac{4.20 \times 10^{-2} \times (0.126)^3}{(2.34 \times 10^{-2})^2}$ = 0.153 ✓ $mol^2\ dm^{-6}$ ✓ **3 significant figures** are required	**3**	***FULL ANNOTATIONS MUST BE USED*** **--** **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ALLOW** ÷ by 4 of equilibrium amounts in all expressions, i.e. **ALLOW** $[CH_4] = \dfrac{9.36 \times 10^{-2}}{4}$ $mol\ dm^{-3}$ **AND** $[C_2H_2] = \dfrac{0.168}{4}$ $mol\ dm^{-3}$ **AND** $[H_2] = \dfrac{0.504}{4}$ $mol\ dm^{-3}$ ✓ **ALLOW ECF** from incorrect concentrations or from moles From moles: 9.36×10^{-2}, 0.168 and 0.504, K_c = 2.45 by **ECF** **ALLOW** $dm^{-6}\ mol^2$ **DO NOT ALLOW** mol^2/dm^6 **ALLOW ECF** from incorrect K_c expression for both calculation and units --- **COMMON ECF** From **3(b)(i)** answer of 0.1404, $K_c = 3.32 \times 10^{-3}$ 2 marks + units K_c = 0.0531 No ÷ 4 throughout 1 mark + units
3	**(b)**	**(iii)**	**Initial amount of CH_4** amount of $CH_4 = 9.36 \times 10^{-2} + 2 \times 0.168$ = 0.4296 **OR** 0.43(0) (mol) ✓	**1**	**NO ECF** possible (all data given in question)

Question			Answer	Marks	Guidance
3	(c)		<table><tr><th>Change</th><th>K_c</th><th>Equilibrium amount of C_2H_2 / mol</th><th>Initial rate</th></tr><tr><td>temperature increased</td><td>greater</td><td>greater</td><td>greater</td></tr><tr><td>smaller container</td><td>same</td><td>smaller</td><td>greater</td></tr><tr><td>catalyst added</td><td>same</td><td>same</td><td>greater</td></tr><tr><td></td><td>✓</td><td>✓</td><td>✓</td></tr></table>	3	Mark by **COLUMN** **ALLOW** obvious alternatives for greater/smaller/same, e.g. increases/decreases; more/less
3	(d)		**ONE** mark only **USE ONE TICK ONLY** ✓ from **TWO** uses: **1.** fuel cells **2.** manufacture of margarine **OR** hydrogenation of alkenes/unsaturated fats/unsaturated oils/unsaturated molecules **3.** making of ammonia **OR** Haber process **4.** making of HCl/hydrochloric acid **5.** making of methanol	1	**IGNORE** just 'fuel' **IGNORE** hydrogenation of margarine **ALLOW** hydrogenation of fats/oils **DO NOT ALLOW** explosives **OR** fertilisers
			Total	**10**	

Question			Answer	Marks	Guidance
4	**(a)**	**(i)**	5 **OR** 5th (order) ✓	**1**	
4	**(a)**	**(ii)**	(stoichiometry in) rate equation does not match (stoichiometry) in **overall** equation ✓ Collision unlikely with more than 2 ions/species/particles ✓	**2**	**ALLOW** moles/ions/species/particles/molecules/atoms throughout (*i.e. emphasis on particles)* **IGNORE** more reactants in overall equation **If number of species is stated, ALLOW 3–5 only** *(rate equation contains 5 ions)* **DO NOT ALLOW** negative ions would repel (*there is a mixture of positive and negative ions*) **IGNORE** more than two **reactants** collide (*not related to rate equation*)
4	**(b)**		Straight upward line **AND** starting at 0,0 ✓ Curve with increasing gradient, **AND** starting at 0,0 ✓	**2**	**ALLOW** lines starting close to 0,0 **ALLOW** 2nd order line with 'straight' section early or late as long as an upward curve is seen between.
4	**(c)**	**(i)**	5.4(0) ✓ 614.4(0) ✓	**2**	**IGNORE** sign **ALLOW** 614 **OR** 610

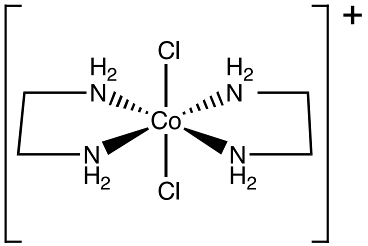




4	(c)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 6.7×10^{8} **OR** 670000000 $dm^{12}\ mol^{-4}\ s^{-1}$, award **3 marks** **IF** answer = 6.7×10^{8} **OR** 670000000 with incorrect units, award **2 marks** *k* to >2 SF: 666666666.7 ✓ **OR** *k* to 2 SF: 6.7×10^{8} **OR** 670000000 ✓✓ units: $dm^{12}\ mol^{-4}\ s^{-1}$ ✓	3	**ALLOW ECF** from incorrect initial rates if 1st experimental results have **not** been used. **(Look to 4(c)(i) to check)** *i.e.* **IF** other rows have been used, then calculate the rate constant from data chosen. For *k*, **ALLOW** 1 mark for the following: 6.6×10^{8} recurring 6.6×10^{8} 2 SF answer for *k* **BUT** one power of 10 out i.e. 6.7×10^{9} **OR** 6.7×10^{7} **ALLOW** units in any order, e.g. $mol^{-4}\ dm^{12}\ s^{-1}$
4	(c)	(iii)	(K_a =) $10^{-3.75}$ **OR** 1.78×10^{-4} ($mol\ dm^{-3}$) ✓ $[H^{+}]$ **=** $\sqrt{1.78 \times 10^{-4} \times 0.0200}$ = 1.89×10^{-3} ($mol\ dm^{-3}$) ✓ initial rate = 6.7×10^{8} x 0.01 x 0.015^{2} x $(1.89 \times 10^{-3})^{2}$ = 5.33×10^{-3} to 5.38×10^{-3} ($mol\ dm^{-3}\ s^{-1}$) **OR** 5.3×10^{-3} to 5.4×10^{-3} ($mol\ dm^{-3}\ s^{-1}$) ✓ Actual value will depend on amount of acceptable rounding in steps and whether figures kept in calculator even if rounding is written down. **ALLOW** any value in range given above.	3	***FULL ANNOTATIONS MUST BE USED*** **---** **For ALL marks, ALLOW 2 SF** up to calculator value correctly rounded $1.77827941 \times 10^{-4}$ **ALLOW** $\sqrt{10^{-3.75} \times 0.0200}$ for first marking point **ALLOW** 1.88×10^{-3} ($mol\ dm^{-3}$) **ALLOW ECF** from calculated $[H^{+}(aq)]$ and calculated answer for *k* from **4(c)(ii)** e.g. If no square root taken, $[H^{+}] = 3.56 \times 10^{-6}\ mol\ dm^{-3}$ and *rate* = 1.91×10^{-8} **OR** 1.9×10^{-8} by **ECF**
			Total	**13**	

Question			Answer	Marks	Guidance
5	(a)		(Transition element) has **an ion** with an incomplete/partially-filled d **sub-shell/d-orbital** ✓ Scandium/Sc and zinc/Zn are not transition elements ✓ *Electron configurations of ions* Sc^{3+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓ Zn^{2+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ ✓ Sc^{3+} **AND** d **sub-shell** empty **/ d orbital(s) empty** ✓ ***Note**: Sc^{3+} must be the **ONLY** scandium ion shown for this mark* Zn^{2+} **AND** d **sub-shell** full **/ALL d-orbitals** full ✓ ***Note**: Zn^{2+} must be the **ONLY** zinc ion shown for this mark*	6	***FULL ANNOTATIONS MUST BE USED*** **---** **ALLOW** capital **'**D' within definition **DO NOT ALLOW** d shell **ALLOW** if **ONLY** Sc and Zn are used to illustrate d block elements that are **NOT** transition elements This can be from anywhere in the overall response in terms of Sc, Sc^{3+}, Zn, Zn^{2+} **OR** incorrect charges, i.e. only Sc^{+}, Sc^{2+}, Zn^{+} In electron configurations, **IF** subscripts **OR** caps used, **DO NOT ALLOW** when first seen but credit subsequently **ALLOW** $4s^0$ in electron configurations **IGNORE** [Ar] **IGNORE** electron configurations for other Sc and Zn ions **ALLOW** for Sc^{3+}: Sc forms a 3+ ion; **ALLOW** Sc^{+3} **ALLOW** for Zn^{2+}: Zn forms a 2+ ion; **ALLOW** Zn^{+2} **ALLOW** Sc^{3+} has no d sub-shell **DO NOT ALLOW** 'd sub-shell is incomplete' *(in definition)* **DO NOT ALLOW** 'd sub-shell is incomplete' *(in definition)*

5	**(b)**	**(i)**	Donates **two** electron/lone pairs to a metal ion **OR** Co^{3+} ✓ ***DO NOT ALLOW*** *metal (complex contains* Co^{3+}*)* Electron/lone pair on N **OR** NH_2 (groups) ✓	**2**	**ALLOW** 'forms **two** coordinate bonds/dative covalent/dative bonds' as an alternative for 'donates **two** electron/lone pairs' *Two is required for 1st marking point* *Two can be implied using words such as 'both' or 'each'* For metal ion, **ALLOW** transition (metal) ion Second mark is for the atom that donates the electron/lone pairs **ALLOW** both marks for a response that communicates the same using N as the focus: e.g. The two N atoms each donate an electron pair to metal ion
5	**(b)**	**(ii)**	$[Co(H_2NCH_2CH_2NH_2)_2Cl_2]^+$ ✓	**1**	Square brackets **AND** + charge required **DO NOT ALLOW** any charges included within square brackets **ALLOW** $[Co(C_2H_8N_2)_2Cl_2]^+$ **OR** $[CoC_4H_{16}N_4Cl_2]^+$ **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** $[Co(en)_2Cl_2]^+$ *simplifies question* Within formula, **ALLOW** ….$(Cl)_2$, (Cl_2) **ALLOW** CO Within the context of the question, CO is Co
5	**(b)**	**(iii)**	6 ✓	**1**	

<table>
<tr>
<td>5</td>
<td>(b)</td>
<td>(iv)</td>
<td>

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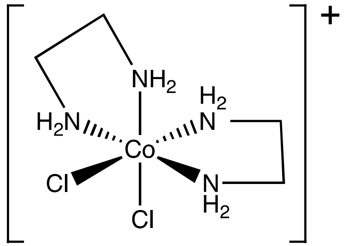
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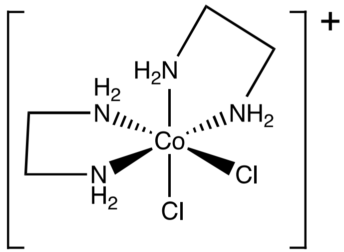
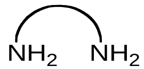
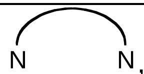

✓

Note: For each structure, ALL NH_2 groups must be shown AND bonding between Co AND N of NH_2.

For $H_2NCH_2CH_2NH_2$, ALLOW C–C without Hs and 
<hr>
IF NH_2 shown without Hs, e.g. , penalise first time ONLY

IF ALL 3 isomers are ‘correct’, but 2 x Cl AND no Ns, e.g.

 AWARD 1 mark
</td>
<td>3</td>
<td>
FULL ANNOTATIONS MUST BE USED

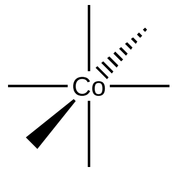
IGNORE charges (anywhere) and labels (even if wrong)

Square brackets NOT required

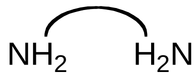
Must contain 2 ‘out wedges’, 2 ‘in wedges’ and 2 lines in plane of paper OR 4 lines, 1 ‘out wedge’ and 1 ‘in wedge’:

For bond into paper, ALLOW:

ALLOW following geometry throughout:



TAKE CARE: structures may be in different orientations.

For $H_2NCH_2CH_2NH_2$, ALLOW 

(connectivity within ‘loop’ only)

If Cl_2s are shown instead of Cl, penalise 1st time only
</td>
</tr>
</table>

5	**(c)**	**(i)**	O_2/oxygen **bonds** to Fe^{2+}/Fe(II) ✓ *Fe^{2+}/Fe(II) essential for 1st marking point* (When required,) O_2 substituted **OR** O_2 released ✓ *Fe^{2+} not required for 2nd marking point (e.g.* ***IGNORE*** *Fe)*	**2**	**ASSUME that 'it' refers to oxygen** **ALLOW** O_2 **binds** to Fe^{2+} **OR** O_2 donates electron pair to Fe^{2+} **OR** O_2 is a ligand with Fe^{2+} **IGNORE** O_2 reacts with Fe^{2+} **OR** O_2 is around Fe^{2+} **ALLOW** bond to O_2 breaks when O_2 required **OR** H_2O replaces O_2 **OR** vice versa **ALLOW** CO_2 replaces O_2 **OR** vice versa **ALLOW** O_2 bonds/binds reversibly
5	**(c)**	**(ii)**	$(K_{stab} =)\ \dfrac{[HbO_2(aq)]}{[Hb(aq)]\,[O_2(aq)]}$ ✓ **ALL Square brackets essential**	**1**	**ALLOW** expression without state symbols (*given in question*)
5	**(c)**	**(iii)**	**Both marks require a comparison** Stability constant/K_{stab} value with CO is **greater** (than with complex in O_2) ✓ (Coordinate) bond with CO is **stronger** (than O_2) **OR** CO binds more strongly ✓	**2**	**IGNORE** (complex with) CO is more stable **ALLOW** bond with CO is less likely to break (than O_2) **OR** CO is a stronger ligand (than O_2) **OR** CO has greater affinity for ion/metal/haemoglobin (than O_2) **ALLOW** CO bond formation is irreversible **OR** CO is not able to break away **IGNORE** CO bonds more easily **OR** CO complex forms more easily
			Total	**18**	

Question			Answer	Marks	Guidance
6	(a)		CH_3COOH + H_2O ⇌ H_3O^+ + CH_3COO^- ✓ Acid 1 Base 2 Acid 2 Base 1 ✓	2	**IGNORE** state symbols (even if incorrect) **ALLOW** 1 **AND** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels if linked by lines so that it is clear what the acid–base pairs are **ALLOW** A and B for 'acid' and 'base' **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, *i.e.* CH_3COOH + H_2O ⇌ $CH_3COOH_2^+$ + OH^- ✗ Base 2 Acid 1 Acid 2 Base 1 ✓ **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF** *i.e., **NO ECF** from impossible chemistry*
6	(b)	(i)	Water dissociates/ionises **OR** $H_2O \rightleftharpoons H^+ + OH^-$ **OR** $2H_2O \rightleftharpoons H_3O^+ + OH^-$ ✓	1	**ALLOW** $K_w = [H^+]\,[OH^-]$ **OR** $[H^+]\,[OH^-] = 10^{-14}$ ($mol^2\ dm^{-6}$) **IGNORE** breaking for dissociation **IGNORE** water contains H^+ and OH^- **IGNORE** $H_2O \rightarrow H^+ + OH^-$ *i.e. no equilibrium sign* **IGNORE** $2H_2O \rightarrow H_3O^+ + OH^-$ *i.e. no equilibrium sign*

6	**(b)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 1.15 × 10^{-11}, award 2 marks** --- $[H^+] = 10^{-3.06} = 8.71 \times 10^{-4}$ (mol dm^{-3}) ✓ $[OH^-] = \dfrac{1.00 \times 10^{-14}}{8.71 \times 10^{-4}} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓ **ALLOW** answer to two or more significant figures 2SF: 1.1×10^{-11}; 4SF: 1.148×10^{-11}; calculator $1.148153621 \times 10^{-11}$	**2**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. --- **ALLOW 2 SF:** 8.7×10^{-4} up to calculator value of 8.7096359×10^{-4} correctly rounded **ALLOW** alternative approach using pOH: pOH = 14 – 3.06 = 10.94 ✓ $[OH^-] = 10^{-10.94} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓
6	**(c)**	**(i)**	$2CH_3COOH + CaCO_3 \rightarrow (CH_3COO)_2Ca + CO_2 + H_2O$ ✓	**1**	**IGNORE** state symbols **ALLOW** $\rightleftharpoons$ provided that reactants on LHS For $CO_2 + H_2O$, **ALLOW** H_2CO_3 **ALLOW** $Ca(CH_3COO)_2$ **ALLOW** $(CH_3COO^-)_2Ca^{2+}$ **BUT DO NOT ALLOW** if either charge is missing or incorrect

6	**(c)**	**(ii)**	solution contains CH_3COOH **AND** CH_3COO^- ✓	**1**	**ALLOW** names: ethanoic acid for CH_3COOH ethanoate for CH_3COO^- **ALLOW** calcium ethanoate **OR** $(CH_3COO)_2Ca$ for CH_3COO^- **IGNORE** ‘acid, salt, conjugate base; responses must identify the acid and conjugate base as ethanoic acid and ethanoate **IGNORE** ethanoic acid is in excess (*in question*) **BUT DO ALLOW** some ethanoic acid is left over/present/some ethanoic acid has reacted **IGNORE** equilibrium: $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ *Dissociation of ethanoic acid only*

6	**(c)**	**(iii)**	**Quality of written communication, QWC** 2 marks are available for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^- (see below) --- $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ ✓ --- CH_3COOH reacts with added alkali **OR** $CH_3COOH + OH^- \rightarrow$ **OR** added alkali reacts with H^+ **OR** $H^+ + OH^- \rightarrow$ ✓ Equilibrium → right **OR** Equilibrium → CH_3COO^- ✓ (**QWC**) CH_3COO^- reacts with added acid ✓ Equilibrium → left **OR** Equilibrium → CH_3COOH ✓ (**QWC**)	**5**	***FULL ANNOTATIONS MUST BE USED*** **---** **Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2** **DO NOT ALLOW** $HA \rightleftharpoons H^+ + A^-$ **DO NOT ALLOW** more than one equilibrium equation. **---** **ALLOW** response in terms of H^+, A^- and HA **IF** more than one equilibrium shown, it **must** be clear which one is being referred to by labeling the equilibria. **ALLOW** weak acid reacts with added alkali **DO NOT ALLOW** acid reacts with added alkali **ALLOW** conjugate base reacts with added acid **DO NOT ALLOW** salt/base reacts with added acid

6	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 11.48 OR 11.5 (g), award 5 marks** --- $[H^+] = 10^{-5}$ (mol dm^{-3}) ✓ --- **$[CH_3COO^-]$** = $\frac{1.75 \times 10^{-5}}{10^{-5}}$ ✓ × 0.200 = 0.350 mol dm^{-3} ✓ *n*(**CH_3COONa/CH_3COO^-**) in 400 cm^3 = 0.350 × $\frac{400}{1000}$ = 0.14(0) (mol) ✓ --- mass **CH_3COONa** = 0.140 × 82.0 = 11.48 **OR** 11.5 (g) ✓ For **ECF**, ***n*(CH₃COONa/CH₃COO⁻) must** have been calculated in step before	5	***FULL ANNOTATIONS MUST BE USED*** --- **IF** there is an alternative answer, check to see if there is any **ECF** credit possible. **Incorrect use of $[H^+] = \sqrt{([CH_3COOH] \times K_a)}$ scores zero** **BUT IGNORE** if an alternative successful method is present **Incorrect use of K_w, 1 max for $[H^+] = 10^{-5}$ (mol dm^{-3})** **BUT IGNORE** if an alternative successful method is present --- **ALLOW** *n*(**CH_3COONa/CH_3COO^-**) = $\frac{1.75 \times 10^{-5}}{10^{-5}}$ ✓ × 0.08 = 0.14(0) (mol) ✓✓ **Note: There is no mark just for** *n*(**CH_3COOH**) in 400 cm^3 = 0.200 × $\frac{400}{1000}$ = 0.08 (mol) --- As alternative for the 4th and 5th marks, **ALLOW**: mass of CH_3COONa in 1 dm^3 = 0.350 × 82.0 = 28.7 g ✓ mass of CH_3COONa in 400 cm^3 = 28.7 × $\frac{400}{1000}$ = 11.48 g ✓ --- **COMMON ECF** 4.592 **OR** 4.6 g **AWARD** 4 marks *use of 400/1000 twice*

					ALLOW variants of Henderson–Hasselbalch equation. pK_a = –log(1.75 x 10^{-5}) = 4.757 ✓ *Calc: 4.75696…..* $\log \frac{[CH_3COO^-]}{[CH_3COOH]}$ = pH – pK_a = 5 – 4.757 = 0.243 $\frac{[CH_3COO^-]}{[CH_3COOH]} = 10^{0.243} = 1.75$ ✓ $[CH_3COO^-]$ = 1.75 × 0.200 = 0.350 mol dm^{-3} ✓ *n*(**CH_3COONa/CH_3COO^-**) in 400 cm^3 = 0.350 × $\frac{400}{1000}$ = 0.14(0) (mol) ✓ -- mass **CH_3COONa** = 0.140 × 82.0 = 11.48 **OR** 11.5 (g) ✓
			Total	**17**	

Question			Answer	Marks	Guidance
7	(a)		**Definition** The e.m.f. (of a half-cell) compared with/connected to a (standard**)** hydrogen half-cell/(standard**)** hydrogen electrode ✓ **Standard conditions** *Units essential* Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} **AND** pressure of 100 kPa **OR** 10^5 Pa **OR** 1 bar ✓	2	As alternative for e.m.f., **ALLOW** voltage **OR** potential difference **OR** p.d. **OR** electrode potential **OR** reduction potential **OR** redox potential **ALLOW** /(standard) hydrogen cell **IGNORE** S.H.E. (as abbreviation for standard hydrogen electrode) **ALLOW** 1M **DO NOT ALLOW** 1 mol **ALLOW** 1 atmosphere/1 atm **OR** 101 kPa **OR** 101325 Pa
7	(b)	(i)	$2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$ ✓	1	State symbols **not** required **ALLOW** $\rightleftharpoons$ provided that reactants on LHS
7	(b)	(ii)	**Assume Cu^{2+}|Cu OR Cu half cell unless otherwise stated.** [Cu^{2+}] decreases **OR** < 1 mol dm^{-3} **AND** Equilibrium (shown in table) shifts to left ✓ more electrons are released by Cu ✓ The cell has a bigger **difference** in *E* ✓	3	***FULL ANNOTATIONS MUST BE USED*** **--** **ALLOW** [Cu^{2+}] less than standard concentration/1 mol dm^{-3} **DO NOT ALLOW** water reacts with Cu^{2+} **OR** Cu **ALLOW** *E* (for Cu^{2+}|Cu) is less positive / more negative /decreases **IGNORE standard** electrode potential (*Cell no longer standard*) **IGNORE** E° decreases **CARE** **DO NOT ALLOW** statements about silver *E* changing (**CON**) **IGNORE** just 'cell potential increases' (in the question) *The final mark is more subtle and is a consequence of the less positive E value of the copper half cell*

7	**(c)**	**(i)**	no/less CO_2 **OR** H_2O is **only** product **OR** greater efficiency ✓	**1**	**IGNORE** less pollution **IGNORE** less carbon emissions **IGNORE** less fossil fuels used **IGNORE** no/less greenhouse gas **OR** no global warming (*H_2O vapour is a greenhouse gas)*
7	**(c)**	**(ii)**	liquefied/as a liquid **AND** under pressure/pressurised ✓	**1**	**IGNORE** adsorption or absorption **IGNORE** low temperature **DO NOT ALLOW** liquidise *processes are described in the question*
7	**(d)**	**(i)**	E = –2.31 (V) ✓	**1**	**–** sign **AND** 2.31 **required** for the mark
7	**(d)**	**(ii)**	$4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4^-(aq)$ species ✓ balance ✓	**2**	**IGNORE** state symbols **ALLOW** multiples **ALLOW** 1 mark for an equation in which OH^- are balanced but have not been cancelled, e.g. $4Al(s) + 16OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4^-(aq) + 12OH^-(aq)$ **ALLOW** 1 mark if charge on $Al(OH)_4$ is omitted, i.e $4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4(aq)$ **ALLOW** 1 mark for an 'correct equation' reversed, i.e. $4Al(OH)_4^-(aq) \rightarrow 4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l)$
			Total	**11**	

Question			Answer	Marks	Guidance
8	(a)		$Fe_2O_3 + 3Cl_2 + 10OH^- \rightarrow 2FeO_4^{2-} + 6Cl^- + 5H_2O$ ✓✓ First mark for all 6 species Second mark for balancing	2	**ALLOW** multiples **ALLOW** oxidation half equation for two marks $Fe_2O_3 + 10OH^- \rightarrow 2FeO_4^{2-} + 5H_2O + 6e^-$ Correct species would obtain 1 mark – *question: equation for oxidation* **ALLOW variants forming H^+ for 1 mark, e.g:** $Fe_2O_3 + 3Cl_2 + 5OH^- \rightarrow 2FeO_4^{2-} + 6Cl^- + 5H^+$ $Fe_2O_3 + 3Cl_2 + 5OH^- \rightarrow 2FeO_4^{2-} + 5HCl + Cl^-$
8	(b)		$Ba^{2+}(aq) + FeO_4^{2-}(aq) \rightarrow BaFeO_4(s)$ ✓	1	Balanced **ionic** equation **AND** state symbols required **DO NOT ALLOW** +2 or –2 for ionic charges
8	(c)		**Reason can ONLY be correct from correct reducing agent** **--** ***reducing agent***: I^- **OR** KI ✓ I^- adds/donates/loses electrons **AND** to FeO_4^{2-} **OR** to $BaFeO_4$ **OR** to Fe(VI) or to Fe(+6) ✓ ***ALLOW*** *Fe(6+)* ***OR*** *Fe^{6+}*	2	 **IGNORE** H^+ **OR** acidified **ALLOW** iodide/potassium iodide but **DO NOT ALLOW** iodine **ALLOW** I^- loses electrons **AND** to form I_2 **ALLOW** Fe(6+) **OR** Fe^{6+}

8	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 51.8%, award **4 marks.** -- $n(S_2O_3^{2-})$ used = $0.1000 \times \frac{26.4}{1000} = 2.64 \times 10^{-3}$ (mol) ✓ $n(FeO_4^{2-})$ = ½ x 2/3 x 2.64×10^{-3} = $8.8(0) \times 10^{-4}$ (mol) ✓ Mass $BaFeO_4$ in sample = $8.8 \times 10^{-4} \times 257.1$ g = 0.226248 g ✓ % purity = $\frac{0.226248}{0.437} \times 100$ = 51.8% ✓ **MUST** be to **one** decimal place (in the question) -- As an alternative for the final two marks, **ALLOW**: Theoretical amount of $BaFeO_4$ = $\frac{0.437}{257.1}$ = 0.00170 (mol) ✓ % purity = $\frac{8.8 \times 10^{-4}}{1.70 \times 10^{-3}} \times 100$ = 51.8% ✓	4	***FULL ANNOTATIONS MUST BE USED*** -- For alternative answers, look first at common **ECFs** below. Then check for **ECF** credit possible using working below **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step -- **Working must be to at least 3 SF throughout until final % mark** **BUT** ignore trailing zeroes, ie for 0.880 allow 0.88 **ECF** answer above × ½ × 2/3 This mark may be seen in 2 steps via I_2 but the mark is for both steps combined **ECF** 257.1 × answer above **ECF** $\frac{\text{answer above}}{0.437} \times 100$ **ALLOW** 51.7% FROM 0.226 g $BaFeO_4$ (earlier rounding) -- **Common ECFs:** No × 2/3 for $n(FeO_4^{2-})$: % purity = 77.7%/77.6% 3 marks No ÷ 2 for $n(FeO_4^{2-})$: % purity = 25.9% 3 marks 24.6 used instead of 26.4: % purity = 48.2% 3 marks

8	**(e)**		**gas**: O_2 ✓ **precipitate**: $Fe(OH)_3$ ✓ **equation**: $2FeO_4^{2-} + 5H_2O \rightarrow 1\frac{1}{2}O_2 + 2Fe(OH)_3 + 4OH^-$ **OR** $2FeO_4^{2-} + H_2O + 4H^+ \rightarrow 1\frac{1}{2}O_2 + 2Fe(OH)_3$ ✓	**3**	**DO NOT ALLOW** names **IGNORE** a balancing number shown before a formula **ALLOW** $Fe(OH)_3(H_2O)_3$ **ALLOW** multiples **ALLOW** $2FeO_4^{2-} + 11H_2O \rightarrow 1\frac{1}{2}O_2 + 2Fe(OH)_3(H_2O)_3 + 4OH^-$
			Total	**12**	