OCR
Oxford Cambridge and RSA

GCE

Chemistry A

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

Advanced GCE

Mark Scheme for June 2014

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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.

Annotations available in Scoris

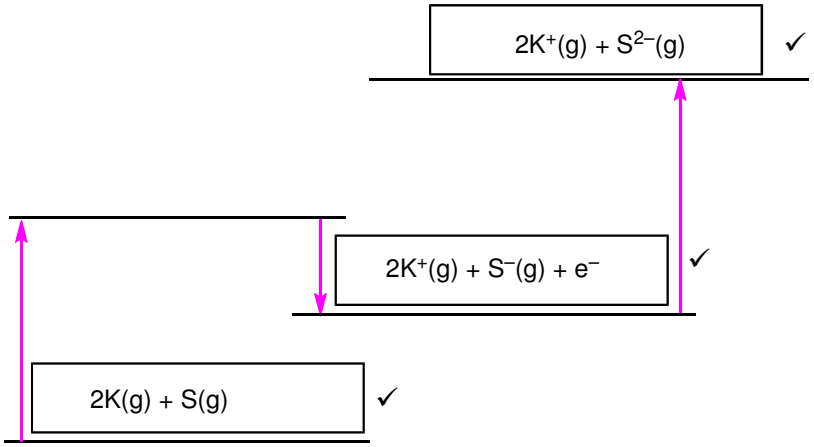
Annotation	Meaning
BP	Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

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

The following questions should be marked using **ALL** appropriate annotations to show where marks have been awarded in the body of the text:

1(b),
2(b),
3(b)(ii),
4(c)(iii),
5(a),
5(b)(iv),
6c(iii),
6(d),
7(b)(ii)
8(d)

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** **RbCl** 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. $1½O_2 \rightarrow O_3$; $O_2 + ½O_2 \rightarrow O_3$ **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** $\mid T\Delta S \mid$ 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** --- $\Delta S = (33 + 3 \times 189) - (76 + 3 \times 131)$ $= (+)131$ (J K^{-1} mol^{-1}) ✓ $\Delta G = 115 - (298 \times 0.131)$ = (+) 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)		$(K_c =) \frac{[C_2H_2]\,[H_2]^3}{[CH_4]^2}$ ✓	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	

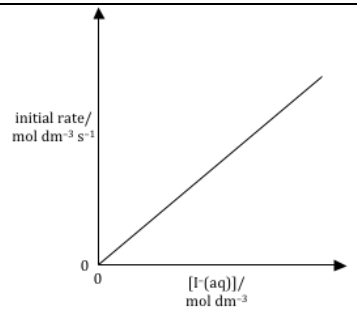
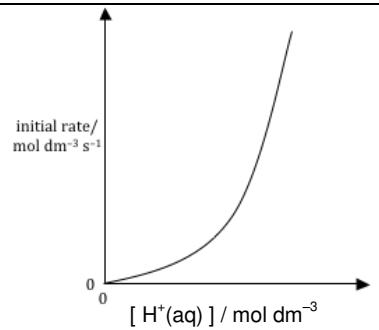
3	(b)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 0.153 $mol^2\ dm^{-6}$, award **3 marks** **IF** answer = 0.153 with incorrect units, award **2 marks** --- **IF answer from 3(b)(i) for $n(H_2) \neq 0.504$, mark by ECF.** **Equilibrium concentrations** (from $n(H_2) = 0.504$ mol 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** $K_c = \frac{4.20\times10^{-2}\times(0.126)^3}{(2.34\times10^{-2})^2} = 0.153$ ✓ $mol^2\ dm^{-6}$ ✓ **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** $[CH_4] = \frac{9.36\times10^{-2}}{4}$ mol dm^{-3} **AND** $[C_2H_2] = \frac{0.168}{4}$ mol dm^{-3} **AND** $[H_2] = \frac{0.504}{4}$ 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)

<table>
<tr>
<td>3 (c)</td>
<td>
<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>
</td>
<td>3</td>
<td>Mark by COLUMN

ALLOW obvious alternatives for greater/smaller/same,
e.g.
increases/decreases;
more/less</td>
</tr>
<tr>
<td>3 (d)</td>
<td>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</td>
<td>1</td>
<td>IGNORE just ‘fuel’
IGNORE hydrogenation of margarine
ALLOW hydrogenation of fats/oils

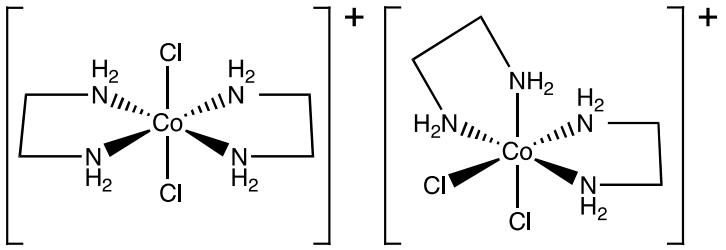
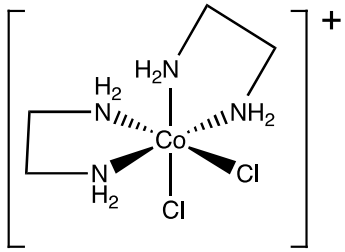
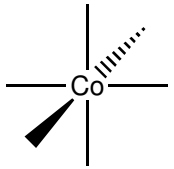
DO NOT ALLOW explosives OR fertilisers</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>10</td>
<td></td>
</tr>
</table>

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}) ✓ $[H^+]$ = $\sqrt{1.78\times10^{-4}\times0.0200}$ = 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** $\sqrt{10^{-3.75}\times0.0200}$ 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 x 10^{-6} mol dm^{-3} and *rate* = 1.91 x 10^{-8} **OR** 1.9 x 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**	

5	(b)	(iv)	 ✓ ✓  ✓ 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  --- **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	**3**	***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**

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)	$(K_{stab} =) \frac{[HbO_2(aq)]}{[Hb(aq)]\,[O_2(aq)]}$ ✓ **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}) ✓ $[OH^-] = \frac{1.00 \times 10^{-14}}{8.71 \times 10^{-4}} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓ **ALLOW** answer to two or more significant figures 2SF: 1.1 × 10^{-11}; 4SF: 1.148 × 10^{-11}; calculator 1.148153621 × 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** ⇌ 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}) ✓ --- **$[CH_3COO^-]$** = $\frac{1.75\times10^{-5}}{10^{-5}}$ ✓ × 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*(CH_3COONa/CH_3COO^-) 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^-**) = $\frac{1.75\times10^{-5}}{10^{-5}}$ ✓ × 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. $pK_a = -\log(1.75 \times 10^{-5}) = 4.757$ ✓ *Calc: 4.75696…..* $\log \frac{[CH_3COO^-]}{[CH_3COOH]} = pH - pK_a = 5 - 4.757 = 0.243$ $\frac{[CH_3COO^-]}{[CH_3COOH]} = 10^{0.243} = 1.75$ ✓ $[CH_3COO^-] = 1.75 \times 0.200 = 0.350$ mol dm^{-3} ✓ *n*(**CH_3COONa**/**CH_3COO^-**) in 400 cm^3 $= 0.350 \times \frac{400}{1000} = 0.14(0)$ (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** ⇌ 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** $E^{\ominus}$ 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) ✓ $n(FeO_4^{2-}) = ½ \times 2/3 \times 2.64 \times 10^{-3} = 8.8(0) \times 10^{-4}$ (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**: $2FeO_4^{2-} + 5H_2O \rightarrow 1½O_2 + 2Fe(OH)_3 + 4OH^-$ **OR** $2FeO_4^{2-} + H_2O + 4H^+ \rightarrow 1½O_2 + 2Fe(OH)_3$ ✓	**3**	**DO NOT ALLOW** names **IGNORE** a balancing number shown before a formula **ALLOW** $Fe(OH)_3(H_2O)_3$ **ALLOW** multiples **ALLOW** $2FeO_4^{2-} + 11H_2O \rightarrow 1½O_2 + 2Fe(OH)_3(H_2O)_3 + 4OH^-$
			Total	**12**	

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