

GCE

Chemistry A

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

Advanced GCE

Mark Scheme for June 2014

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

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

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

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Annotations available in Scoris

Annotation	Meaning
	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.
	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

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)	<p style="text-align: center;"> $2K^+(g) + S^{2-}(g)$ ✓ $2K^+(g) + S^-(g) + e^-$ ✓ $2K(g) + S(g)$ ✓ </p>	3	<p>Mark each marking point independently</p> <p>Correct species AND state symbols required for each mark</p> <p>For S^{2-}, DO NOT ALLOW S^{-2}</p> <p>For e^-, ALLOW e</p> <p>For e^- only, IGNORE any state symbols added</p> <p>ALLOW k and s</p> <p><i>It can be very difficult distinguishing K from k; S from s</i></p>

1	(a)	(ii)	<p>(The enthalpy change that accompanies) the formation of one mole of a(n ionic) compound from its gaseous ions (under standard conditions) ✓✓</p> <p>Award marks as follows. 1st mark: formation of compound from gaseous ions 2nd mark: one mole for compound only</p> <p>DO NOT ALLOW 2nd mark without 1st mark</p> <p>Note: A definition for enthalpy change of formation will receive no marks</p>	2	<p>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</p> <p>IGNORE: $2K^+(g) + S^{2-}(g) \longrightarrow K_2S(s)$ (question asks for words)</p> <p>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) ✓</p>
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1	(a)	(iii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-2116 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks</p> <p>----- $-381 - (2 \times +89 + 279 + 2 \times +419 -200 + 640) \checkmark$ $-381 - 1735$ $= -2116 \checkmark \text{ (kJ mol}^{-1}\text{)}$</p>	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below. See list below for marking of answers from common errors</p> <p>-----</p> <p>2 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 $+2 \times 89$) -439 (-2×419 instead of $+2 \times 419$) -2120 (rounded to 3SF)</p> <p>For other answers, check for a single transcription error or calculator error which could merit 1 mark</p> <p>DO NOT ALLOW any other answers, e.g. -1608 (2 errors: 2×89 and 2×419 not used for K) -846 (3 errors:)</p>
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1	(b)	<p>Lowest melting point KI RbCl Highest melting point NaBr Correct order ✓</p> <p>Mark 2nd and 3rd marking points independently</p> <p>Attraction and ionic size linked: Greater attraction from smaller ions/closer ions/larger charge density ✓ <i>Comparison needed</i></p> <p>Energy AND attraction/breaking bonds linked: More energy/heat to overcome attraction (between ions) OR More energy/heat to break (ionic) bonds ✓</p>	3	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>ORA throughout Response must clearly refer to ions for explanation marks</p> <p>2nd and 3rd marking point must be comparative</p> <p>DO NOT ALLOW incorrect named particles, e.g. ‘atoms’, ‘molecules’, Na, Cl, Cl₂, ‘atomic’, etc DO NOT ALLOW responses using nuclear size or attraction DO NOT ALLOW responses linked with loss of electrons</p> <p>IGNORE larger electron density</p> <p>ALLOW smaller sum of radii gives a greater ionic attraction IGNORE NaBr has greater ionic attraction IGNORE NaBr has smallest ionic radius <i>(not focussing on size of each ion)</i></p> <p>ASSUME bonds broken are ionic unless otherwise stated DO NOT ALLOW incorrect named particles, e.g. ‘atoms’, ‘molecules’, Na, Cl, Cl₂, ‘atomic’, etc</p> <p>Note: Comparison for energy only (<i>i.e. link between more energy and breaking bonds/overcoming attraction</i>)</p>
		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 ✓ <i>Could be from equation with CO₂(g)</i>	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 → 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 → O ₃ ; O ₂ + ½O ₂ → O ₃ ALLOW O ₂ + O → O ₃ Note: DO NOT ALLOW 2 mol gas forms 1 mol gas unless linked to O ₂ + O → O ₃ IGNORE reaction forms fewer moles/molecules

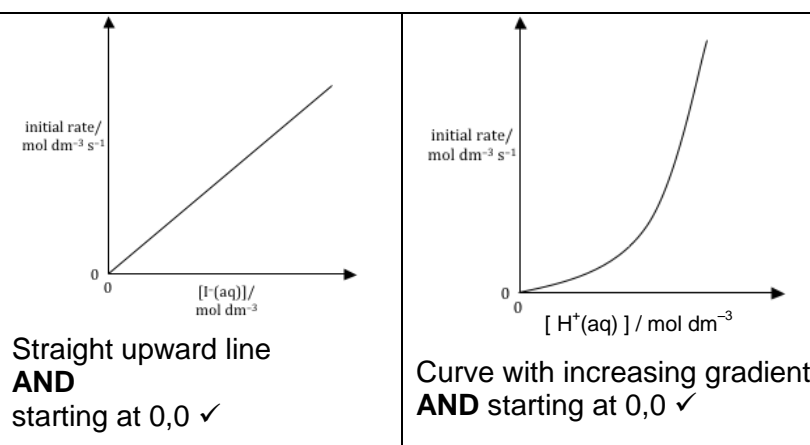
2	(b)	<p>CARE: responses involve changes of negative values</p> <hr/> <p>Feasibility AND ΔG Reaction becomes/is less feasible/not feasible AND ΔG increases OR ΔG becomes/is less negative/more positive OR $\Delta G > 0$ OR $\Delta H - T\Delta S > 0$ OR $\Delta H - T\Delta S$ becomes/is less negative/more positive OR $\Delta H > T\Delta S$ ✓ OR $T\Delta S$ becomes/is more negative than ΔH ✓</p> <hr/> <p>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 $T\Delta S$ increases ✓</p> <hr/>	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>As alternative for 'less feasible' ALLOW 'less spontaneous' OR a comment that implies 'reaction no longer take place'</p> <p>ALLOW for ΔG increases $\Delta G < 0$ only at low T</p> <p>DO NOT ALLOW $T\Delta S > \Delta H$ (<i>comparison wrong way round</i>)</p> <p>NOTE: Last statement automatically scores 2nd mark ALSO</p> <p>IGNORE significance IGNORE magnitude for 1st marking point</p> <hr/> <p>DO NOT ALLOW $T\Delta S$ increases IGNORE significance</p> <hr/> <p>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 ✓</p> <p>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 ✓</p>
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2	(c)	(i)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 75.962 OR 75.96 OR 76.0 OR 76, award 2 marks -----</p> $\Delta S = (33 + 3 \times 189) - (76 + 3 \times 131)$ $= (+)131 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ $\Delta G = 115 - (298 \times 0.131)$ $= (+) 75.962 \text{ OR } 75.96 \text{ OR } 76.0 \text{ OR } 76 \text{ (kJ K}^{-1} \text{ mol}^{-1}) \checkmark$	2	<p>DO NOT ALLOW -131</p> <p>ALLOW ECF from incorrect calculated value of ΔS</p>
2	(c)	(ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 878 OR 877.9 OR 877.86, award 2 marks -----</p> <p>(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 $T = \frac{\Delta H}{\Delta S} \checkmark$</p> $T = \frac{115}{0.131} = 878 \text{ K } \checkmark$	2	<p>ALLOW total entropy statement: $\Delta S(\text{total}) = 0$ OR $\Delta S(\text{total}) > 0$</p> <p>ALLOW ECF from incorrect calculated value of ΔS from 2(c)(i)</p> <p>ALLOW 878 up to calculator value of 877.862595 correctly rounded</p>
			Total	9	

Question			Answer	Marks	Guidance
3	(a)		$(K_c =) \frac{[\text{C}_2\text{H}_2][\text{H}_2]^3}{[\text{CH}_4]^2} \checkmark$	1	Square brackets are essential State symbols not required. IGNORE incorrect state symbols
3	(b)	(i)	amount of $\text{H}_2 = 3 \times 0.168$ $= 0.504 \text{ (mol)} \checkmark$	1	

3	(b)	(ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $0.153 \text{ mol}^2 \text{ dm}^{-6}$, award 3 marks IF answer = 0.153 with incorrect units, award 2 marks</p> <p>----- IF answer from 3(b)(i) for $n(\text{H}_2) \neq 0.504$, mark by ECF. Equilibrium concentrations (from $n(\text{H}_2) = 0.504 \text{ mol dm}^{-3}$)</p> <p>$[\text{CH}_4] = 2.34 \times 10^{-2} \text{ (mol dm}^{-3}\text{)}$</p> <p>AND $[\text{C}_2\text{H}_2] = 4.20 \times 10^{-2} \text{ (mol dm}^{-3}\text{)}$</p> <p>AND $[\text{H}_2] = 0.126 \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Calculation of K_c and units $K_c = \frac{4.20 \times 10^{-2} \times (0.126)^3}{(2.34 \times 10^{-2})^2} = 0.153 \checkmark \text{ mol}^2 \text{ dm}^{-6} \checkmark$</p> <p>3 significant figures are required</p>	<p>FULL ANNOTATIONS MUST BE USED</p> <p>----- IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>-----</p> <p>ALLOW \div by 4 of equilibrium amounts in all expressions, i.e.</p> <p>ALLOW $[\text{CH}_4] = \frac{9.36 \times 10^{-2}}{4} \text{ mol dm}^{-3}$</p> <p>AND $[\text{C}_2\text{H}_2] = \frac{0.168}{4} \text{ mol dm}^{-3}$</p> <p>AND $[\text{H}_2] = \frac{0.504}{4} \text{ mol dm}^{-3} \checkmark$</p> <p>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</p> <p>3 ALLOW $\text{dm}^{-6} \text{ mol}^2$ DO NOT ALLOW mol^2/dm^6</p> <p>ALLOW ECF from incorrect K_c expression for both calculation and units</p> <p>----- 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 \div 4 throughout 1 mark + units</p>
3	(b)	(iii)	<p>Initial amount of CH_4 amount of $\text{CH}_4 = 9.36 \times 10^{-2} + 2 \times 0.168$ = 0.4296 OR 0.43(0) (mol) \checkmark</p>	<p>1 NO ECF possible (all data given in question)</p>

3	(c)				3	Mark by COLUMN ALLOW obvious alternatives for greater/smaller/same, e.g. increases/decreases; more/less	
		Change	K_c	Equilibrium amount of C_2H_2 / mol			Initial rate
		temperature increased	greater	greater			greater
		smaller container	same	smaller			greater
		catalyst added	same	same			greater
		✓	✓	✓			
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>i.e. emphasis on particles</i>) IGNORE more reactants in overall equation If number of species is stated, ALLOW 3–5 only (<i>rate equation contains 5 ions</i>) DO NOT ALLOW negative ions would repel (<i>there is a mixture of positive and negative ions</i>) IGNORE more than two reactants collide (<i>not related to rate equation</i>)
4	(b)		 <p>Straight upward line AND starting at 0,0 ✓</p> <p>Curve with increasing gradient, AND starting at 0,0 ✓</p>	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)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 6.7×10^8 OR 670000000 $\text{dm}^{12} \text{mol}^{-4} \text{s}^{-1}$, award 3 marks IF answer = 6.7×10^8 OR 670000000 with incorrect units, award 2 marks</p> <p><i>k</i> to >2 SF: 666666666.7 ✓ OR <i>k</i> to 2 SF: 6.7×10^8 OR 670000000 ✓✓</p> <p>units: $\text{dm}^{12} \text{mol}^{-4} \text{s}^{-1}$ ✓</p>		<p>ALLOW ECF from incorrect initial rates if 1st experimental results have not been used. (Look to 4(c)(i) to check) <i>i.e.</i> IF other rows have been used, then calculate the rate constant from data chosen.</p> <p>For <i>k</i>, ALLOW 1 mark for the following: 6.6×10^8 recurring 6.6×10^8 2 SF answer for <i>k</i> BUT one power of 10 out <i>i.e.</i> 6.7×10^9 OR 6.7×10^7</p> <p>3 ALLOW units in any order, e.g. $\text{mol}^{-4} \text{dm}^{12} \text{s}^{-1}$</p>
4	(c)	(iii)	<p>(K_a =) $10^{-3.75}$ OR 1.78×10^{-4} (mol dm^{-3}) ✓</p> <p>$[\text{H}^+] = \sqrt{1.78 \times 10^{-4} \times 0.0200}$ = 1.89×10^{-3} (mol dm^{-3}) ✓</p> <p>initial rate = $6.7 \times 10^8 \times 0.01 \times 0.015^2 \times (1.89 \times 10^{-3})^2$ = 5.33×10^{-3} to 5.38×10^{-3} ($\text{mol dm}^{-3} \text{s}^{-1}$) OR 5.3×10^{-3} to 5.4×10^{-3} ($\text{mol dm}^{-3} \text{s}^{-1}$) ✓</p> <p>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.</p>		<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>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})</p> <p>ALLOW ECF from calculated $[\text{H}^+(\text{aq})]$ and calculated answer for <i>k</i> from 4(c)(ii)</p> <p>e.g. If no square root taken, $[\text{H}^+] = 3.56 \times 10^{-6} \text{mol dm}^{-3}$ and <i>rate</i> = 1.91×10^{-8} OR 1.9×10^{-8} by ECF</p> <p>3</p>
			Total	13	

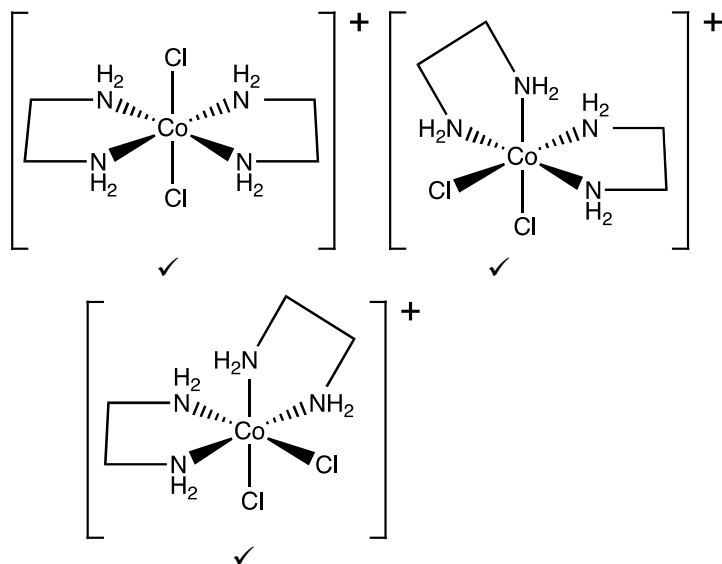
Question		Answer	Marks	Guidance
5	(a)	<p>(Transition element) has an ion with an incomplete/partially-filled d sub-shell/d-orbital ✓</p> <p>Scandium/Sc and zinc/Zn are not transition elements ✓</p> <p><i>Electron configurations of ions</i> Sc^{3+} AND $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓</p> <p>Zn^{2+} AND $1s^2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

5	(b)	(i)	<p>Donates two electron/lone pairs to a metal ion OR Co^{3+} ✓ DO NOT ALLOW metal (complex contains Co^{3+})</p> <p>Electron/lone pair on N OR NH_2 (groups) ✓</p>	2	<p>ALLOW 'forms two coordinate bonds/dative covalent/dative bonds' as an alternative for 'donates two electron/lone pairs' <i>Two is required for 1st marking point</i> <i>Two can be implied using words such as 'both' or 'each'</i></p> <p>For metal ion, ALLOW transition (metal) ion</p> <p>Second mark is for the atom that donates the electron/lone pairs</p> <p>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</p>
5	(b)	(ii)	<p>$[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_2\text{Cl}_2]^+$ ✓</p>	1	<p>Square brackets AND + charge required DO NOT ALLOW any charges included within square brackets</p> <p>ALLOW $[\text{Co}(\text{C}_2\text{H}_8\text{N}_2)_2\text{Cl}_2]^+$ OR $[\text{CoC}_4\text{H}_{16}\text{N}_4\text{Cl}_2]^+$</p> <p>ALLOW structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>IGNORE $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ <i>simplifies question</i></p> <p>Within formula, ALLOW $\dots(\text{Cl})_2$, (Cl_2)</p> <p>ALLOW CO Within the context of the question, CO is Co</p>
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 $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$, **ALLOW** C–C without Hs and NH_2 NH_2

IF NH_2 shown without Hs, e.g. N N , penalise first time **ONLY**

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

AWARD 1 mark

FULL ANNOTATIONS MUST BE USED

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

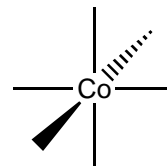
Square brackets **NOT** required

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:



3

TAKE CARE: structures may be in different orientations.

For $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$, **ALLOW** NH_2 H_2N
(connectivity within 'loop' only)

If Cl₂s are shown instead of Cl, penalise 1st time only

5	(c)	(i)	<p>O₂/oxygen bonds to Fe²⁺/Fe(II) ✓ Fe²⁺/Fe(II) essential for 1st marking point</p> <p>(When required,) O₂ substituted OR O₂ released ✓ Fe²⁺ not required for 2nd marking point (e.g. IGNORE Fe)</p>	2	<p>ASSUME that 'it' refers to oxygen ALLOW O₂ binds to Fe²⁺ OR O₂ donates electron pair to Fe²⁺ OR O₂ is a ligand with Fe²⁺</p> <p>IGNORE O₂ reacts with Fe²⁺ OR O₂ is around Fe²⁺</p> <p>ALLOW bond to O₂ breaks when O₂ required OR H₂O replaces O₂ OR vice versa ALLOW CO₂ replaces O₂ OR vice versa ALLOW O₂ bonds/binds reversibly</p>
5	(c)	(ii)	<p>$(K_{\text{stab}} =) \frac{[\text{HbO}_2(\text{aq})]}{[\text{Hb}(\text{aq})][\text{O}_2(\text{aq})]} \checkmark$ ALL Square brackets essential</p>	1	<p>ALLOW expression without state symbols <i>(given in question)</i></p>
5	(c)	(iii)	<p>Both marks require a comparison</p> <p>Stability constant/K_{stab} value with CO is greater (than with complex in O₂) ✓</p> <p>(Coordinate) bond with CO is stronger (than O₂) OR CO binds more strongly ✓</p>	2	<p>IGNORE (complex with) CO is more stable</p> <p>ALLOW bond with CO is less likely to break (than O₂) OR CO is a stronger ligand (than O₂) OR CO has greater affinity for ion/metal/haemoglobin (than O₂)</p> <p>ALLOW CO bond formation is irreversible OR CO is not able to break away</p> <p>IGNORE CO bonds more easily OR CO complex forms more easily</p>
			Total	18	

Question			Answer	Marks	Guidance
6	(a)		$\begin{array}{ccccccc} \text{CH}_3\text{COOH} & + & \text{H}_2\text{O} & \rightleftharpoons & \text{H}_3\text{O}^+ & + & \text{CH}_3\text{COO}^- \checkmark \\ \text{Acid 1} & & \text{Base 2} & & \text{Acid 2} & & \text{Base 1} \checkmark \end{array}$	2	<p>IGNORE state symbols (even if incorrect)</p> <p>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'</p> <p>IF proton transfer is wrong way around ALLOW 2nd mark for idea of acid–base pairs, <i>i.e.</i></p> $\begin{array}{ccccccc} \text{CH}_3\text{COOH} & + & \text{H}_2\text{O} & \rightleftharpoons & \text{CH}_3\text{COOH}_2^+ & + & \text{OH}^- \times \\ \text{Base 2} & & \text{Acid 1} & & \text{Acid 2} & & \text{Base 1} \checkmark \end{array}$ <p>NOTE For the 2nd marking point (acid–base pairs), this is the ONLY acceptable ECF <i>i.e.</i>, NO ECF from impossible chemistry</p>
6	(b)	(i)	<p>Water dissociates/ionises</p> <p>OR</p> $\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$ <p>OR</p> $2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^- \checkmark$	1	<p>ALLOW $K_w = [\text{H}^+][\text{OH}^-]$ OR $[\text{H}^+][\text{OH}^-] = 10^{-14} \text{ (mol}^2 \text{ dm}^{-6}\text{)}$ IGNORE breaking for dissociation</p> <p>IGNORE water contains H^+ and OH^-</p> <p>IGNORE $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$ <i>i.e.</i> no equilibrium sign IGNORE $2\text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{OH}^-$ <i>i.e.</i> no equilibrium sign</p>

6	(b)	(ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 1.15×10^{-11}, award 2 marks</p> <p>-----</p> <p>$[H^+] = 10^{-3.06} = 8.71 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$[OH^-] = \frac{1.00 \times 10^{-14}}{8.71 \times 10^{-4}} = 1.15 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>ALLOW answer to two or more significant figures 2SF: 1.1×10^{-11}; 4SF: 1.148×10^{-11}; calculator $1.148153621 \times 10^{-11}$</p>	2	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below.</p> <p>-----</p> <p>ALLOW 2 SF: 8.7×10^{-4} up to calculator value of 8.7096359×10^{-4} correctly rounded</p> <p>ALLOW alternative approach using pOH:</p> <p>pOH = $14 - 3.06 = 10.94 \checkmark$ $[OH^-] = 10^{-10.94} = 1.15 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$</p>
6	(c)	(i)	$2\text{CH}_3\text{COOH} + \text{CaCO}_3 \rightarrow (\text{CH}_3\text{COO})_2\text{Ca} + \text{CO}_2 + \text{H}_2\text{O} \checkmark$	1	<p>IGNORE state symbols</p> <p>ALLOW \rightleftharpoons provided that reactants on LHS For $\text{CO}_2 + \text{H}_2\text{O}$, ALLOW H_2CO_3</p> <p>ALLOW $\text{Ca}(\text{CH}_3\text{COO})_2$</p> <p>ALLOW $(\text{CH}_3\text{COO}^-)_2\text{Ca}^{2+}$ BUT DO NOT ALLOW if either charge is missing or incorrect</p>

6	(c)	(ii)	solution contains CH_3COOH AND CH_3COO^- ✓	1	<p>ALLOW names: ethanoic acid for CH_3COOH ethanoate for CH_3COO^-</p> <p>ALLOW calcium ethanoate OR $(\text{CH}_3\text{COO})_2\text{Ca}$ for CH_3COO^-</p> <p>IGNORE 'acid, salt, conjugate base; responses must identify the acid and conjugate base as ethanoic acid and ethanoate</p> <p>IGNORE ethanoic acid is in excess (<i>in question</i>) BUT DO ALLOW some ethanoic acid is left over/present/some ethanoic acid has reacted</p> <p>IGNORE equilibrium: $\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$ <i>Dissociation of ethanoic acid only</i></p>
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6	(c)	(iii)	<p>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)</p> <p>-----</p> <p>$\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^- \checkmark$</p> <p>-----</p> <p>CH₃COOH reacts with added alkali OR CH₃COOH + OH⁻ → OR added alkali reacts with H⁺ OR H⁺ + OH⁻ → ✓</p> <p>Equilibrium → right OR Equilibrium → CH₃COO⁻ ✓ (QWC)</p> <p>CH₃COO⁻ reacts with added acid ✓</p> <p>Equilibrium → left OR Equilibrium → CH₃COOH ✓ (QWC)</p>	5	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2</p> <p>DO NOT ALLOW HA ⇌ H⁺ + A⁻ DO NOT ALLOW more than one equilibrium equation.</p> <p>-----</p> <p>ALLOW response in terms of H⁺, A⁻ and HA</p> <p>IF more than one equilibrium shown, it must be clear which one is being referred to by labeling the equilibria.</p> <p>ALLOW weak acid reacts with added alkali DO NOT ALLOW acid reacts with added alkali</p> <p>ALLOW conjugate base reacts with added acid DO NOT ALLOW salt/base reacts with added acid</p>
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6	(d)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = 11.48 OR 11.5 (g), award 5 marks</p> <p>-----</p> <p>$[H^+] = 10^{-5} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>-----</p> <p>$[CH_3COO^-] = \frac{1.75 \times 10^{-5}}{10^{-5}} \checkmark \times 0.200 = 0.350 \text{ mol dm}^{-3} \checkmark$</p> <p>$n(CH_3COONa/CH_3COO^-) \text{ in } 400 \text{ cm}^3$ $= 0.350 \times \frac{400}{1000} = 0.14(0) \text{ (mol)} \checkmark$</p> <p>-----</p> <p>mass $CH_3COONa = 0.140 \times 82.0 = 11.48 \text{ OR } 11.5 \text{ (g)} \checkmark$</p> <p>For ECF, $n(CH_3COONa/CH_3COO^-)$ must have been calculated in step before</p>	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible.</p> <p>Incorrect use of $[H^+] = \sqrt{[CH_3COOH] \times K_a}$ scores zero BUT IGNORE if an alternative successful method is present</p> <p>Incorrect use of K_w, 1 max for $[H^+] = 10^{-5} \text{ (mol dm}^{-3}\text{)}$ BUT IGNORE if an alternative successful method is present</p> <p>-----</p> <p>ALLOW $n(CH_3COONa/CH_3COO^-)$ $= \frac{1.75 \times 10^{-5}}{10^{-5}} \checkmark \times 0.08 = 0.14(0) \text{ (mol)} \checkmark \checkmark$</p> <p>Note: There is no mark just for $n(CH_3COOH) \text{ in } 400 \text{ cm}^3 = 0.200 \times \frac{400}{1000} = 0.08 \text{ (mol)}$</p> <p>-----</p> <p>5 As alternative for the 4th and 5th marks, ALLOW: mass of CH_3COONa in $1 \text{ dm}^3 = 0.350 \times 82.0 = 28.7 \text{ g} \checkmark$ mass of CH_3COONa in $400 \text{ cm}^3 = 28.7 \times \frac{400}{1000} = 11.48 \text{ g} \checkmark$</p> <p>-----</p> <p>COMMON ECF 4.592 OR 4.6 g AWARD 4 marks <i>use of 400/1000 twice</i></p>
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					<p>ALLOW variants of Henderson–Hasselbalch equation.</p> <p>$pK_a = -\log(1.75 \times 10^{-5}) = 4.757 \checkmark$ <i>Calc: 4.75696.....</i></p> <p>$\log \frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = \text{pH} - pK_a = 5 - 4.757 = 0.243$</p> <p>$\frac{[\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = 10^{0.243} = 1.75 \checkmark$</p> <p>$[\text{CH}_3\text{COO}^-] = 1.75 \times 0.200 = 0.350 \text{ mol dm}^{-3} \checkmark$</p> <p>$n(\text{CH}_3\text{COONa}/\text{CH}_3\text{COO}^-)$ in 400 cm^3</p> <p>$= 0.350 \times \frac{400}{1000} = 0.14(0) \text{ (mol)} \checkmark$</p> <p>-----</p> <p>mass CH₃COONa = $0.140 \times 82.0 = 11.48$ OR $11.5 \text{ (g)} \checkmark$</p>
			Total	17	

Question		Answer	Marks	Guidance	
7	(a)	<p>Definition The e.m.f. (of a half-cell) compared with/connected to a (standard) hydrogen half-cell/(standard) hydrogen electrode ✓</p> <p>Standard conditions <i>Units essential</i> Temperature of 298 K / 25°C AND (solution) concentrations of 1 mol dm⁻³ AND pressure of 100 kPa OR 10⁵ Pa OR 1 bar ✓</p>	2	<p>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)</p> <p>ALLOW 1M DO NOT ALLOW 1 mol ALLOW 1 atmosphere/1 atm OR 101 kPa OR 101325 Pa</p>	
7	(b)	(i)	$2\text{Ag}^+(\text{aq}) + \text{Cu}(\text{s}) \rightarrow 2\text{Ag}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \checkmark$	1	<p>State symbols not required ALLOW = provided that reactants on LHS</p>
7	(b)	(ii)	<p>Assume Cu²⁺ Cu OR Cu half cell unless otherwise stated.</p> <p>[Cu²⁺] decreases OR < 1 mol dm⁻³ AND Equilibrium (shown in table) shifts to left ✓</p> <p>more electrons are released by Cu ✓</p> <p>The cell has a bigger difference in <i>E</i> ✓</p>	3	<p>FULL ANNOTATIONS MUST BE USED ----- ALLOW [Cu²⁺] less than standard concentration/1 mol dm⁻³ DO NOT ALLOW water reacts with Cu²⁺ OR Cu</p> <p>ALLOW <i>E</i> (for Cu²⁺ Cu) is less positive / more negative /decreases IGNORE standard electrode potential (<i>Cell no longer standard</i>) IGNORE <i>E</i>^o decreases CARE DO NOT ALLOW statements about silver <i>E</i> changing (CON)</p> <p>IGNORE just 'cell potential increases' (in the question) <i>The final mark is more subtle and is a consequence of the less positive E value of the copper half cell</i></p>

7	(c)	(i)	no/less CO ₂ OR H ₂ O 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 ₂ O 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 <i>processes are described in the question</i>
7	(d)	(i)	$E = -2.31$ (V) ✓	1	– sign AND 2.31 required for the mark
7	(d)	(ii)	$4\text{Al(s)} + 4\text{OH}^{\text{-}}(\text{aq}) + 3\text{O}_2(\text{g}) + 6\text{H}_2\text{O(l)} \rightarrow 4\text{Al(OH)}_4^{\text{-}}(\text{aq})$ 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. $4\text{Al(s)} + 16\text{OH}^{\text{-}}(\text{aq}) + 3\text{O}_2(\text{g}) + 6\text{H}_2\text{O(l)} \rightarrow 4\text{Al(OH)}_4^{\text{-}}(\text{aq}) + 12\text{OH}^{\text{-}}(\text{aq})$ ALLOW 1 mark if charge on Al(OH) ₄ is omitted, i.e. $4\text{Al(s)} + 4\text{OH}^{\text{-}}(\text{aq}) + 3\text{O}_2(\text{g}) + 6\text{H}_2\text{O(l)} \rightarrow 4\text{Al(OH)}_4(\text{aq})$ ALLOW 1 mark for an ‘correct equation’ reversed, i.e. $4\text{Al(OH)}_4^{\text{-}}(\text{aq}) \rightarrow 4\text{Al(s)} + 4\text{OH}^{\text{-}}(\text{aq}) + 3\text{O}_2(\text{g}) + 6\text{H}_2\text{O(l)}$
Total				11	

Question		Answer	Marks	Guidance
8	(a)	$\text{Fe}_2\text{O}_3 + 3\text{Cl}_2 + 10\text{OH}^- \rightarrow 2\text{FeO}_4^{2-} + 6\text{Cl}^- + 5\text{H}_2\text{O} \checkmark\checkmark$ <p>First mark for all 6 species Second mark for balancing</p>	2	<p>ALLOW multiples ALLOW oxidation half equation for two marks $\text{Fe}_2\text{O}_3 + 10\text{OH}^- \rightarrow 2\text{FeO}_4^{2-} + 5\text{H}_2\text{O} + 6\text{e}^-$ Correct species would obtain 1 mark – <i>question: equation for oxidation</i></p> <p>ALLOW variants forming H⁺ for 1 mark, e.g: $\text{Fe}_2\text{O}_3 + 3\text{Cl}_2 + 5\text{OH}^- \rightarrow 2\text{FeO}_4^{2-} + 6\text{Cl}^- + 5\text{H}^+$ $\text{Fe}_2\text{O}_3 + 3\text{Cl}_2 + 5\text{OH}^- \rightarrow 2\text{FeO}_4^{2-} + 5\text{HCl} + \text{Cl}^-$</p>
8	(b)	$\text{Ba}^{2+}(\text{aq}) + \text{FeO}_4^{2-}(\text{aq}) \rightarrow \text{BaFeO}_4(\text{s}) \checkmark$	1	Balanced ionic equation AND state symbols required DO NOT ALLOW +2 or –2 for ionic charges
8	(c)	<p>Reason can ONLY be correct from correct reducing agent ----- <i>reducing agent.</i> I⁻ OR KI ✓</p> <p>I⁻ adds/donates/loses electrons AND to FeO₄²⁻ OR to BaFeO₄ OR to Fe(VI) or to Fe(+6) ✓ ALLOW Fe(6+) OR Fe⁶⁺</p>	2	<p>IGNORE H⁺ OR acidified ALLOW iodide/potassium iodide but DO NOT ALLOW iodine</p> <p>ALLOW I⁻ loses electrons AND to form I₂</p> <p>ALLOW Fe(6+) OR Fe⁶⁺</p>

8	(d)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 51.8%, award 4 marks.</p> <p>-----</p> $n(\text{S}_2\text{O}_3^{2-}) \text{ used} = 0.1000 \times \frac{26.4}{1000} = 2.64 \times 10^{-3} \text{ (mol)} \checkmark$ $n(\text{FeO}_4^{2-}) = \frac{1}{2} \times \frac{2}{3} \times 2.64 \times 10^{-3} = 8.8(0) \times 10^{-4} \text{ (mol)} \checkmark$ <p>Mass BaFeO₄ in sample = $8.8 \times 10^{-4} \times 257.1 \text{ g} = 0.226248 \text{ g} \checkmark$</p> $\% \text{ purity} = \frac{0.226248}{0.437} \times 100 = 51.8\% \checkmark$ <p>MUST be to one decimal place (in the question)</p> <p>-----</p> <p>As an alternative for the final two marks, ALLOW:</p> $\text{Theoretical amount of BaFeO}_4 = \frac{0.437}{257.1} = 0.00170 \text{ (mol)} \checkmark$ $\% \text{ purity} = \frac{8.8 \times 10^{-4}}{1.70 \times 10^{-3}} \times 100 = 51.8\% \checkmark$	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>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</p> <p>-----</p> <p>Working must be to at least 3 SF throughout until final % mark BUT ignore trailing zeroes, ie for 0.880 allow 0.88</p> <p>ECF answer above $\times \frac{1}{2} \times \frac{2}{3}$ This mark may be seen in 2 steps via I₂ but the mark is for both steps combined</p> <p>ECF 257.1 \times answer above</p> <p>ECF $\frac{\text{answer above}}{0.437} \times 100$</p> <p>ALLOW 51.7% FROM 0.226 g BaFeO₄ (earlier rounding)</p> <p>-----</p> <p>Common ECFs:</p> <p>No $\times \frac{2}{3}$ for $n(\text{FeO}_4^{2-})$: % purity = 77.7%/77.6% 3 marks</p> <p>No $\div 2$ for $n(\text{FeO}_4^{2-})$: % purity = 25.9% 3 marks</p> <p>24.6 used instead of 26.4: % purity = 48.2% 3 marks</p>
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4

8	(e)	<p>gas: O₂ ✓</p> <p>precipitate: Fe(OH)₃ ✓</p> <p>equation: 2FeO₄²⁻ + 5H₂O → 1½O₂ + 2Fe(OH)₃ + 4OH⁻</p> <p>OR 2FeO₄²⁻ + H₂O + 4H⁺ → 1½O₂ + 2Fe(OH)₃ ✓</p>	3	<p>DO NOT ALLOW names</p> <p>IGNORE a balancing number shown before a formula</p> <p>ALLOW Fe(OH)₃(H₂O)₃</p> <p>ALLOW multiples</p> <p>ALLOW 2FeO₄²⁻ + 11H₂O → 1½O₂ + 2Fe(OH)₃(H₂O)₃ + 4OH⁻</p>
		Total	12	

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

Education and Learning

Telephone: 01223 553998

Facsimile: 01223 552627

Email: general.qualifications@ocr.org.uk

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Head office
Telephone: 01223 552552
Facsimile: 01223 552553

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