

GCE

Chemistry A

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

Advanced GCE

Mark Scheme for June 2016

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

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

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1. Annotations available in RM Assessor.

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response

2. 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

3. The following questions should be marked using **ALL** appropriate annotations to show where marks have been awarded in the body of the text:
- 2(a)
 - 4(b)(ii)
 - 4(c)
 - 4(d)
 - 5(c)(i)
 - 5(c)(ii)
 - 5(d)(iv)
 - 6(c)
 - 8(e)

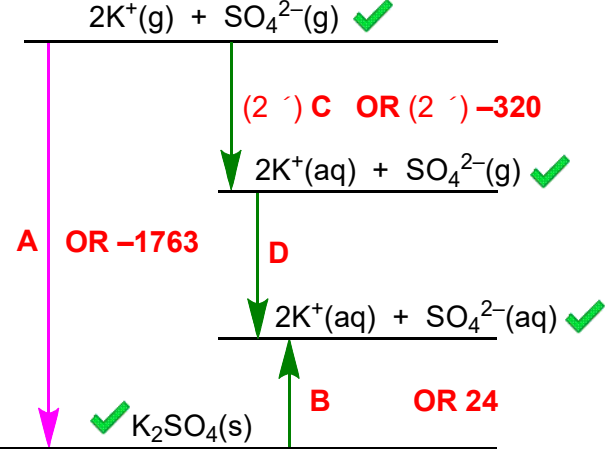
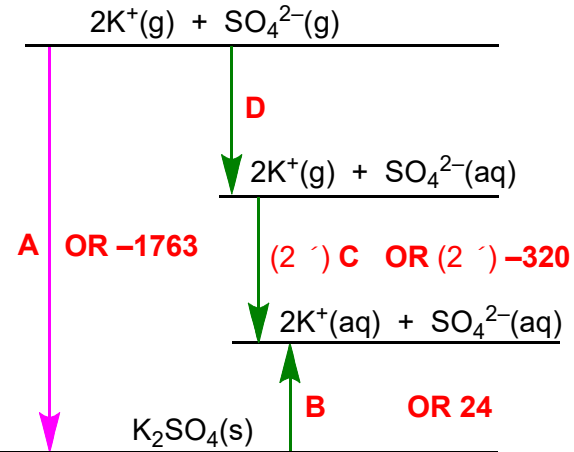
Question		Answer	Marks	Guidance	
1	(a)	<p>IGNORE any charges shown within complexes (treat as rough working)</p> <p>Formulae 2 marks</p> <p style="text-align: center;">$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ ✓</p> <p style="text-align: center;">$[\text{CuCl}_4]^{2-}$ ✓</p> <p>Colours 1 mark</p> <p style="text-align: center;">blue AND yellow ✓</p> <p style="text-align: center;"><i>Mark independently of formulae</i></p>	3	<p>For charges, ALLOW +2 and –2</p> <p>Square brackets required, i.e. DO NOT ALLOW $\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2^{2+}$</p> <p>ALLOW Ligands in any order</p> <p>ALLOW CuCl_4^{2-} i.e. no brackets OR $\text{Cu}(\text{Cl})_4^{2-}$</p> <p>For CuCl_4^{2-}, ALLOW green–yellow OR yellow–green DO NOT ALLOW green</p> <p>For $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ DO NOT ALLOW pale blue, light blue</p> <p>DO NOT ALLOW precipitate with blue OR yellow</p>	
1	(b)	(i)	<p>Donates two electron pairs to a metal ion/metal/Cu^{2+} AND forms two coordinate bonds to a metal ion/metal/Cu^{2+} ✓</p>	1	<p>ALLOW lone pairs for electron pairs ALLOW molecule/atom/ion/substance for 'ligand' ALLOW dative (covalent) bonds for coordinate bonds ALLOW transition element for metal</p> <p>Two is needed once only e.g. Donates two electron pairs to form coordinate bonds to a metal ion/metal/Cu^{2+} Donates electron pairs to form two coordinate bonds to a metal ion/metal/Cu^{2+}</p> <p>DO NOT ALLOW donates two electron pairs to form one/a coordinate bond</p>

Question			Answer	Marks	Guidance						
1	(b)	(ii)		3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>2 marks: one for each correct isomer ✓✓</p> <p>TAKE CARE: structures may be in different orientations and in different order</p> <p>IF BOTH isomers are 'correct', but O connectivity wrong, AWARD 1 mark for both structures Check H₂O ligands carefully for connectivity</p> <p>ALLOW H₂O reversed shown as -O₂H</p> <p>IGNORE charges (anywhere)</p> <p>-----</p> <p>NOTE: For each structure, ALL O atoms must be shown AND For (COO⁻)₂, ALLOW skeletal, structural or displayed formula</p> <p>DO NOT ALLOW structures such as those shown below</p> <p>-----</p> <p>1 mark: for whole of 2nd row for whole of 'Type' row i.e. (cis AND optical) AND trans only</p>						
			<table border="1"> <tbody> <tr> <td><i>cis</i></td> <td>✓</td> </tr> <tr> <td><i>trans</i></td> <td></td> </tr> <tr> <td>optical</td> <td>✓</td> </tr> </tbody> </table>	<i>cis</i>	✓	<i>trans</i>		optical	✓		
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Question			Answer	Marks	Guidance
1	(b)	(iii)	$\text{CuC}_4\text{H}_4\text{O}_{10}^{2-}$ Formula ✓ 2- charge ✓ MARK formula and charge INDEPENDENTLY	2	Empirical formula essential, e.g. DO NOT ALLOW $\text{Cu}(\text{COO})_2(\text{H}_2\text{O})_2$ for formula mark ALLOW any order of elements in formula ALLOW -2 for charge
			Total	9	

Question	Answer	Marks	Guidance
2 (a)	<p>initial rates data (3 marks) NOTE: Each comparison MUST relate to the actual change in concentration/rate in the experiments</p> <p>H₂O₂: [H₂O₂] × 2 rate × 2 EXPTS AND 1st order ✓ (1 & 2)</p> <p>H⁺: [H⁺] × 2 rate does not change (2 & 3) AND Zero order ✓</p> <p>I⁻: [I⁻] × 2 AND [H₂O₂] × 2 rate × 4 (2 & 4) OR [I⁻] × 2 AND [H₂O₂] × 4 rate × 8 (1 & 4) OR [I⁻] × 2 AND [H₂O₂] × 2 rate × 4 (3 & 4) AND 1st order ✓</p>	3	<p>FULL ANNOTATIONS MUST BE USED -----</p> <p>THROUGHOUT,</p> <ul style="list-style-type: none"> • Square brackets NOT REQUIRED around H₂O₂, H⁺ and I⁻ • ALLOW 'doubles' for × 2; quadruples for × 4 <p>ALLOW direct comparison of concentrations and rate, e.g. [H₂O₂] changes by $\frac{0.0020}{0.0010} = 2$, rate changes by $\frac{1.14 \times 10^{-5}}{5.70 \times 10^{-6}} = 2$</p> <p>AND 1st order (Expts 1 & 2)</p> <p>DO NOT ALLOW I₂ for I⁻</p> <p>IGNORE [H⁺] for Expts 3 & 4</p>
	<p>Calculation of rate constant (3 marks), EITHER $k = \frac{5.70 \times 10^{-6}}{0.0010 \times 0.20}$ OR 2.85×10^{-2} OR 0.0285 OR 0.029 ✓</p> <p>$k = 2.9 \times 10^{-2}$ ✓ (2 SF in standard form) <i>Subsumes previous mark if no working shown</i></p> <p>dm³ mol⁻¹ s⁻¹ ✓</p>	3	<p>IGNORE working</p> <p>DO NOT ALLOW 0.03</p> <p>ALLOW ECF from error in powers of 10 ONLY e.g. 2.9×10^{-3} by use of 0.010 instead of 0.0010</p> <p>DO NOT ALLOW 2.90×10^{-2} (3 SF) OR 29×10^{-3} (Not standard form)</p> <p>ALLOW mol⁻¹, dm³ and s⁻¹ in any order, e.g. mol⁻¹ dm³ s⁻¹</p>

Question		Answer	Marks	Guidance
3	(a)	(enthalpy change for) 1 mole of gaseous ions OR 1 mole of hydrated ions/aqueous ions ✓ gaseous ions forming aqueous/hydrated ions ✓	2	<p>one mole can be stated just once EITHER with gaseous ions OR with aqueous ions, e.g.</p> <ul style="list-style-type: none"> • 1 mole of gaseous ions forms hydrated ions/aqueous ions • Gaseous ions form 1 mole of hydrated ions/aqueous ions <p>ALLOW 1 mol for 1 mole</p> <p>IGNORE 'energy released' OR 'energy required'</p> <p>For 2nd mark IGNORE gaseous ions are hydrated IGNORE gaseous ions dissolve in water Particles formed not stated</p> <p>ALLOW 1 mark for: 1 mole of gaseous <u>IONS</u> forms aqueous/hydrated atoms/ particles/ molecules</p>

Question	Answer	Marks	Guidance
3 (b) (i)	<p>4 marks for species AND state symbols on all 4 energy levels (including added energy level)</p>  <p>1 mark for B, C AND D labels OR enthalpy values AND arrow directions correct ✓</p> <p>ALLOW $K_2SO_4(aq)$ for $2K^+(aq) + SO_4^{2-}(aq)$</p> <p>ALLOW arrows not touching lines.</p> <p>Direction is important:</p> <ul style="list-style-type: none"> • FROM $2K^+(g) + SO_4^{2-}(g)$ line • FROM $K_2SO_4(s)$ line <p>See APPENDIX</p> <p>'2 x' is NOT required – <i>part of calculation mark</i></p>	5	<p>IF extra energy level is above top line OR below bottom line, DO NOT ALLOW mark for species on this line. See APPENDIX</p> <p>ALLOW C and D with associated labels, the other way round:</p>  <p>State symbols are essential</p> <p>IF no extra energy level is shown with C and D combined forming $2K^+(aq) + SO_4^{2-}(aq)$,</p> <ul style="list-style-type: none"> • No mark for the extra energy level with species • No mark for labels as C and D are combined <p>Therefore 3 max for species on energy levels provided</p>
3 (b) (ii)	$\Delta H(\text{hydration}) SO_4^{2-} = -1099 \text{ (kJ mol}^{-1}\text{)} \checkmark$	1	ONLY correct answer

Question			Answer	Marks	Guidance
3	(c)	(i)	<p>Aqueous particles are more disordered than solid (particles) OR Solid particles are more ordered than aqueous (particles) ✓</p>	1	<p>For particles, ALLOW ions DO NOT ALLOW molecules/atoms</p> <p>ALLOW 'When the state changes from solid to aqueous, disorder increases'</p> <p>For more disordered, ALLOW less ordered/ more freedom/ more ways of arranging energy/ more random</p> <p>For aqueous particles, ALLOW particles in solution</p> <p>IGNORE dissolved</p>
3	(c)	(ii)	<p>Calculation (2 marks) $\Delta G = 24 - (298 \times 0.225)$ OR $24 - 67.05$ (in kJ) OR $24000 - (298 \times 225)$ OR $24000 - 67050$ (in J) ✓</p> <p>Calculation of ΔG (IGNORE UNITS) $\Delta G = -43$ (kJ mol⁻¹) OR -43000 (J mol⁻¹) ✓ <i>Subsumes 1st calculation mark</i></p> <p>Reason for solubility Calculated value of ΔG that is negative AND Statement that: ΔG is negative OR $\Delta G < 0$ OR $-43 < 0$ OR $\Delta H - T\Delta S < 0$ OR $T\Delta S > \Delta H$ ✓</p>	3	<p>Contact TL if solely entropy approach rather than ΔG</p> <p>ALLOW -43.1 OR -43.05 (<i>calculator value</i>)</p> <p>ALLOW 1 calculation mark (IGNORE units) for $-67.(026)$ OR -67026 ECF from 225 instead of 0.225 $18.(375)$ OR $+18.375$ ECF from 25 instead of 298</p> <p>ALLOW other ECF from ONE error in 1st step of calc, e.g. incorrect value for ΔH such as -1099 from 3bii $\rightarrow -1166.05$ TAKE CARE that same units used for ΔH and ΔS</p> <p>NO reason mark from a +ve value of ΔG</p>
Total				12	

Question	Answer	Marks	Guidance
4 (a)	Iodine is non-polar OR Iodine does not form H bonds with water ✓	1	IGNORE iodine is slightly polar IGNORE 'cannot bond to water' (too vague) IGNORE 'Lack of a lone pair' IGNORE 'inability to induce a dipole'
4 (b)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF $K_c = 104 \text{ dm}^3 \text{ mol}^{-1}$ award 4 marks: 3 for calculation of 104 from data, 1 for units</p> <p>-----</p> <p>Equilibrium concentrations (mol × 5) (1 mark) $I_2 = 4.00 \times 10^{-5} \times 5 = 2.00 \times 10^{-4} \text{ (mol dm}^{-3}\text{)}$ AND $I^- = 9.404 \times 10^{-2} \times 5 = 0.4702 \text{ (mol dm}^{-3}\text{)}$ ✓ AND $I_3^- = 1.96 \times 10^{-3} \times 5 = 9.80 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$</p> <p>Calculation of K_c and units (3 marks)</p> $K_c = \frac{[I_3^-(aq)]}{[I_2(aq)] \times [I^-(aq)]} \text{ OR } \frac{9.80 \times 10^{-3}}{2.00 \times 10^{-4} \times 0.4702} \checkmark$ <p>= 104 ✓ Must be 3 SF</p> <p>$\text{dm}^3 \text{ mol}^{-1}$ OR $\text{mol}^{-1} \text{ dm}^3$ ✓</p>	4	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>Throughout, at least 3SF but ALLOW absence of trailing zeroes e.g. for 9.80×10^{-3} ALLOW 9.8×10^{-3} FOR I^- 0.4702, ALLOW 0.47(0) (mol dm⁻³) still →104 for calc</p> <p>State symbols not required in K_c expression ALLOW ECF from incorrect concentrations</p> <p>Any ECF value MUST be to 3 SF for K_c value</p> <p>-----</p> <p>COMMON ERRORS</p> <p>104.2 → 104.2109741 (calc) > 3 SF 2 marks + units</p> <p>521 no × 5 for concs 2 marks + units</p> <p>521.1 → 521.0548703 as above and > 3SF 1 mark + units</p> <p>2610 ÷ 5 instead of × 5 for concs 2 marks + units</p> <p>9.60×10^{-3} K_c upside down, correct concs 2 marks + units</p> <p>1.92×10^{-3} K_c upside down, no × 5 for concs 1 mark + units</p> <p>NOTE: With K_c upside down, units become mol dm^{-3} by ECF</p>

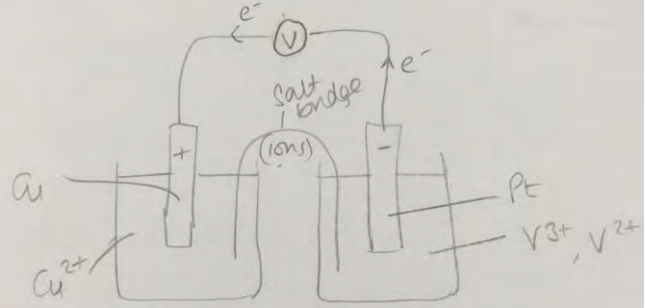
Question		Answer	Marks	Guidance
4	(c)	<p>Ag⁺/silver nitrate reacts with I⁻ to form AgI/silver iodide OR Ag⁺ + I⁻ → AgI ✓</p> <p>yellow precipitate/solid forms ✓</p> <p>Equilibrium 2 shifts to the left ✓</p> <p>Equilibrium 1 shifts to left AND I₂ comes out of solution/less I₂ dissolves/ I₂ precipitates/black solid /grey solid /violet solid ✓</p>	4	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>DO NOT ALLOW cream OR cream–yellow ALLOW just ‘yellow’ if supported by AgI(s) somewhere</p>
4	(d)	<p>in all equations ALLOW equilibrium signs IGNORE state symbols</p> <p>-----</p> <p>Reaction 1: 1 mark 2I₂ + 5O₂ → 2I₂O₅ ✓</p> <p>-----</p> <p>Reaction 2: 2 marks 1st mark: ALL CORRECT species</p> <p>e.g.: I₂ + OH⁻ → I⁻ + IO₃⁻ + H₂O</p> <p>2nd mark for CORRECT balanced equation 3I₂ + 6OH⁻ → 5I⁻ + IO₃⁻ + 3H₂O ✓✓</p>	3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW correct multiples throughout, e.g. I₂ + 2½O₂ → I₂O₅</p> <p>-----</p> <p>For 1st mark, IGNORE e⁻ present</p> <p>ALLOW species/equation with NaOH or KOH, e.g. 3I₂ + 6NaOH → 5I⁻ + IO₃⁻ + 3H₂O + 6Na⁺ 3I₂ + 6NaOH → 5NaI + NaIO₃ + 3H₂O</p> <p>ALLOW</p> <p>Species: I₂ + OH⁻ → I⁻ + IO₂⁺ + H₂O ✓ OR Equation: 3I₂ + 4OH⁻ → 5I⁻ + IO₂⁺ + 2H₂O ✓✓</p> <p>Species: I₂ + OH⁻ → I⁻ + IO³⁺ + H₂O ✓ OR Equation: 3I₂ + 2OH⁻ → 5I⁻ + IO³⁺ + H₂O ✓✓</p>
		Total	12	

Question	Answer	Marks	Guidance
5 (c) (i)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.43, AWARD 4 marks</p> <hr/> <p>Expression: $K_a \times \text{acid/base ratio}$ Use of $K_a \times \frac{[\text{HNO}_2]}{[\text{NO}_2^-]}$ OR $4.69 \times 10^{-4} \times \frac{[\text{HNO}_2]}{[\text{NO}_2^-]}$ ✓</p> <p>Using correct concs/mol in expression $[\text{H}^+] = 4.69 \times 10^{-4} \times \frac{0.0400}{0.0500}$ ✓ Subsumes previous mark</p> <p>Calculation of $[\text{H}^+]$ $[\text{H}^+] = 3.752 \times 10^{-4} \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>pH to 2 DP (From 3.42573717) $\text{pH} = -\log 3.752 \times 10^{-4} = 3.43 \checkmark$</p> <p>NO marks are available using K_a square root approach (weak acid pH) $K_w / 10^{-14}$ approach (strong base pH)</p> <hr/> <p>ALLOW alternative approach based on Henderson–Hasselbalch equation (ALLOW $-\log K_a$ for $\text{p}K_a$) $\text{pH} = \text{p}K_a + \log \frac{[\text{NO}_2^-]}{[\text{HNO}_2]}$ OR $\text{p}K_a - \log \frac{[\text{HNO}_2]}{[\text{NO}_2^-]}$ ✓ $\text{pH} = \text{p}K_a + \log \frac{0.0500}{0.0400}$ OR $\text{p}K_a - \log \frac{0.0400}{0.0500}$ ✓ $\text{pH} = \text{p}K_a + 0.097 \checkmark$ $\text{pH} = 3.329 + 0.097 = 3.43 \checkmark$</p>	4	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>ALLOW just $K_a \times \frac{\text{acid}}{\text{salt}}$ expression</p> <p>Mark by ECF from $4.69 \times 10^{-4} \times \frac{[\text{NO}_2^-]}{[\text{HNO}_2]}$ inverted expression</p> <p>Mark by ECF from incorrect $[\text{HNO}_2]$ and $[\text{NO}_2^-]$ ONLY award marks for a pH calculation via K_a AND using concentrations/mol derived from the question</p> <p>DO NOT ALLOW final pH mark by ECF if $\text{pH} > 7$</p> <hr/> <p>COMMON ERRORS BUT CHECK WORKING pH = 2.82 3 marks initial concs: 0.200 and 0.0625 pH = 3.23 3 marks 0.0400 and 0.0500 acid/base ratio inverted pH = 3.83 2 marks initial concs: 0.200 and 0.0625 and ratio inverted pH = 2.73 3 marks Incorrect $[\text{NO}_2^-] = 0.01$ and correct $[\text{HNO}_2] = 0.04$ pH = 4.03 3 marks correct $[\text{NO}_2^-] = 0.05$ and incorrect $[\text{HNO}_2] = 0.01$</p>

Question			Answer	Marks	Guidance
5	(c)	(ii)	<p>Equilibrium: 1 mark $\text{HNO}_2 \rightleftharpoons \text{H}^+ + \text{NO}_2^-$ ✓ (ignore state symbols)</p> <p>Control of pH: 2 marks (QWC) Added HCl NO_2^- reacts with added acid/HCl/H^+ OR $\text{NO}_2^- + \text{H}^+ \rightarrow$ OR more HNO_2 forms ✓</p> <p>Added NaOH HNO_2 reacts with added alkali/NaOH/OH^- OR $\text{HNO}_2 + \text{OH}^- \rightarrow$ OR more NO_2^- forms OR H^+ reacts with added alkali/NaOH OR $\text{H}^+ + \text{OH}^- \rightarrow$ ✓</p> <p>Equilibrium shift: 1 mark for shifts in $\text{HNO}_2 \rightleftharpoons \text{H}^+ + \text{NO}_2^-$ (See 1st mark) Equilibrium for added acid → left AND Equilibrium for added alkali → right ✓ (QWC)</p>	4	<p>FULL ANNOTATIONS MUST BE USED -----</p> <p>IGNORE $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$</p> <p>Equilibrium sign essential BUT ALLOW small slips in its appearance if it is obviously an attempt to show an equilibrium sign rather than an arrow</p> <p>QWC: Quality of written communication</p> <p>DO NOT ALLOW HA and A^- for HNO_2 and NO_2^-</p> <p>IGNORE just acid reacts with added alkali</p> <p>IGNORE just conjugate base/salt/base reacts with added acid DO NOT ALLOW salt/base reacts with added acid</p> <p>AWARD 'shift mark' ONLY if correct equilibrium equation has been given IGNORE any other equilibria in response</p>

Question			Answer	Marks	Guidance
5	(d)	(i)	Endothermic AND K_w increases with temperature OR Endothermic AND dissociation increases with temperature OR Endothermic AND (dissociation) involves breaking bonds ✓	1	Endothermic and reason required for the mark ALLOW Endothermic AND increasing temperature shifts equilibrium/reaction to the right/favours forward reaction DO NOT ALLOW breaking hydrogen bonds OR intermolecular bonds/forces
5	(d)	(ii)	<i>OH⁻ concentration</i> $[\text{OH}^-] = \frac{9.311 \times 10^{-14}}{1.00 \times 10^{-7}} = 9.311 \times 10^{-7} \text{ (mol dm}^{-3}\text{)} \checkmark$ <i>Explanation (dependent on 1st mark)</i> $9.311 \times 10^{-7} > 1.00 \times 10^{-7}$ OR $[\text{OH}^-] > [\text{H}^+]$ OR OH^- in excess AND Alkaline ✓	2	<i>H⁺ OR OH⁻ concentration (neutral pH)</i> $[\text{H}^+] = [\text{OH}^-] = \sqrt{(9.311 \times 10^{-14})} = 3.05 \times 10^{-7} \text{ (mol dm}^{-3}\text{)} \checkmark$ <i>Explanation (dependent on 1st mark)</i> $\text{pH} = -\log(3.05 \times 10^{-7}) = 6.5 \rightarrow 6.515501837$ (calc) AND Alkaline ✓
5	(d)	(iii)	$\text{p}K_w = 13.03 \checkmark$	1	ONLY correct answer

Question	Answer	Marks	Guidance
5 (d) (iv)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 10.76, award 3 marks</p> <p>-----</p> <p>Dilution 1 mark</p> $[\text{OH}^-(\text{aq})] = [\text{NaOH}(\text{aq})] = \frac{0.0270}{5} = 0.00540 \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>[H⁺] 1 mark</p> $[\text{H}^+(\text{aq})] = \frac{9.311 \times 10^{-14}}{0.00540} = 1.72 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p style="text-align: right;">Calculator: $1.724259259 \times 10^{-11}$</p> <p>pH 1 mark</p> $\text{pH} = -\log 1.72 \times 10^{-11} = \mathbf{10.76} \checkmark$ <p>-----</p> <p>ALLOW pOH method for 2nd and 3rd mark:</p> $\text{pOH} = -\log 0.00540 = 2.27 \checkmark \text{ (calculator 2.26760624)}$ $\text{pH} = 13.03 - 2.27 = 10.76 \checkmark$	3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW dilution AFTER calculation of [H⁺(aq)] i.e. original [H⁺] = $\frac{9.311 \times 10^{-14}}{0.0270} = 3.45 \times 10^{-12} \text{ (mol dm}^{-3}\text{)} \checkmark$ After dilution, [H⁺] = $3.45 \times 10^{-12} \times 5 = 1.72 \times 10^{-11} \text{ (mol dm}^{-3}\text{)} \checkmark$ pH = $-\log 1.72 \times 10^{-11} = \mathbf{10.76} \checkmark$ ALLOW ECF from incorrect [H⁺(aq)] provided that pH >7</p> <p>-----</p> <p>COMMON ERRORS (MUST be to 2 DP)</p> <p>pH = 11.73 At 25°C (1.00×10^{-14}): 2 marks pH = $-\log 1.85 \times 10^{-12} = \mathbf{11.73}$</p> <p>pH = 11.46 No dilution at 60°C (9.311×10^{-14}) 2 marks pH = $-\log(3.45 \times 10^{-12}) = \mathbf{11.46}$</p> <p>pH = 12.43 No dilution AND 25°C (1.00×10^{-14}) 1 mark pH = $-\log(3.70 \times 10^{-13}) = \mathbf{12.43}$</p> <p>pH = 12.16 ×5 instead of ÷ 5 at 60°C (9.311×10^{-14}) 2 marks pH = $-\log(6.879 \times 10^{-13}) = \mathbf{12.16}$</p> <p>pH = 13.13 ×5 instead of ÷ 5 at 25°C (1.00×10^{-14}) 1 mark pH = $-\log(7.407 \times 10^{-14}) = \mathbf{13.13}$</p> <p>NOTE: Attempts at dilution → 0.0270 with error in powers of 10 → 12.46 from 0.00270, etc may give 2 marks by ECF</p>
	Total	18	

Question		Answer	Marks	Guidance
6	(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>For e.m.f., ALLOW voltage OR potential difference/p.d. OR electrode/reduction/redox potential ALLOW e.m.f. of a cell</p> <p>ALLOW /(standard) hydrogen cell IGNORE S.H.E. (as abbreviation for standard hydrogen electrode) DO NOT ALLOW hydrogen fuel cell</p> <p>ALLOW 1M OR 1 mol/dm³ DO NOT ALLOW 1 mol OR 1 mole ALLOW 1 atmosphere/1 atm OR 101 kPa OR 101325 Pa</p>
6	(b)	<p>(i)</p> <p>Complete circuit with voltmeter AND labelled salt bridge linking two half-cells ✓</p>  <p>Cu electrode in Cu²⁺ ✓</p> <p>Pt electrode in V²⁺ AND V³⁺ ✓</p> <p>Cu shown as + AND Pt shown as - ✓</p> <p>electrons in wire AND ions in salt bridge ✓ <i>On diagram or stated</i></p>	5	<p>Half cells can be drawn in either order Half cells must show electrodes dipping into solutions ALLOW small gaps in circuit DO NOT ALLOW half-cell with H₂ added</p> <p>IGNORE any stated concentrations IGNORE 'anode' and 'cathode'</p> <p>In salt bridge, ALLOW any stated ion that may be present, e.g. K⁺, NH₄⁺, NO₃⁻, Cu²⁺, V²⁺, V³⁺</p> <p>IGNORE direction of travel of ions and electrons.</p> <p>ALLOW Cu half cell as + AND V half cell as -</p>

Question			Answer	Marks	Guidance
6	(b)	(ii)	0.60 OR 0.6 (V) ✓	1	IGNORE any sign
6	(c)		<p>Definitions: 1 mark Oxidising agent removes/accepts/gains electrons OR increases oxidation number (of another species) AND Reducing agent adds/donates/loses electrons OR decreases oxidation number (of another species) ✓</p> <p>Oxidising agent: 2 marks Cr³⁺ oxidises Al OR Cr³⁺ acts as oxidising agent AND 3Cr³⁺ + Al → 3Cr²⁺ + Al³⁺ ✓ Explanation (dependent on Cr³⁺ oxidising Al above) E of redox system 2 (Cr³⁺/Cr²⁺) is more positive /less negative (than E of system 1 (Al³⁺/Al)) ORA, i.e. in terms of 1 being more negative (than 2) ✓</p> <p>Reducing agent: 3 marks Cr³⁺ reduces FeO₄²⁻/(H⁺) ✓ 2Cr³⁺ + 2FeO₄²⁻ + 2H⁺ → Cr₂O₇²⁻ + 2Fe³⁺ + H₂O ✓ Explanation (dependent on Cr³⁺ reducing FeO₄²⁻ above) E of redox system 5 (Cr₂O₇²⁻/Cr³⁺) is less positive/ more negative (than E of system 6 (FeO₄²⁻/Fe³⁺)) ORA, i.e. in terms of 6 being more positive (than 5) ✓</p>	6	<p>FULL ANNOTATIONS MUST BE USED ----- ALLOW oxidising agent decreases its oxidation number AND reducing agent increases its oxidation number</p> <p>IGNORE oxidising agent oxidises/is reduced OR reducing agent reduces/is oxidised In equations,</p> <ul style="list-style-type: none"> IGNORE state symbols (even if incorrect) ALLOW ⇌ in equation <p>IF more than one equation shown for Cr³⁺ as oxidising agent, CON and zero marks for 2 oxidising agent marks IGNORE equations with Cr²⁺ as reactant</p> <p>Explanations MUST be in terms of positive/negative: IGNORE 'higher' E OR 'greater'</p> <p>ALLOW E_{cell} = +1.25 V (+ sign required)</p> <p>IF more than one equation shown for Cr³⁺ as a reducing agent, CON and zero marks for 3 reducing agent marks IGNORE equations with Cr²⁺ as reactant</p> <p>Explanations MUST be in terms of positive/negative: IGNORE 'higher' E OR 'greater'</p> <p>ALLOW E_{cell} = +0.87 V (+ sign required)</p>
Total				14	

Question			Answer	Marks	Guidance
7	(a)	(i)	<p>IGNORE any charges shown within complexes (treat as rough working)</p> <p>Complex ion C: $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ ✓</p> <p>Solid D: $\text{Ni}(\text{OH})_2$ ✓</p> <p>Complex ion E: $[\text{Ni}(\text{CN})_4]^{2-}$ ✓</p>	3	<p>ALLOW +2 and -2 for charges</p> <p>Square brackets required</p> <p>ALLOW $\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2$ $(\text{H}_2\text{O})_4$ and $(\text{OH})_2$ in any order</p> <p>IGNORE any square brackets</p> <p>Square brackets required</p> <p>TAKE CARE for round brackets within complex ion, i.e. (H_2O), (OH) and (CN)</p>

Question			Answer	Marks	Guidance
7	(a)	(ii)	<p>Mark independently of 7(a)(i) ALLOW +2 and –2 for charges IGNORE any charges shown within complexes (treat as rough working)</p> $\text{Ni}^{2+} + 2\text{OH}^- \rightarrow \text{Ni}(\text{OH})_2 \checkmark$ <p>Type of reaction: precipitation ✓ INDEPENDENT of equation</p> $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 4\text{CN}^- \rightarrow [\text{Ni}(\text{CN})_4]^{2-} + 6\text{H}_2\text{O}(\text{l}) \checkmark$ <p>Type of reaction: ligand substitution ✓ INDEPENDENT of equation</p>	4	<p>For equations: IGNORE state symbol (even if wrong) Square brackets not required for $\text{Ni}(\text{OH})_2$</p> <p>ALLOW $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$ ALLOW $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Ni}(\text{OH})_2 + 6\text{H}_2\text{O}$ ALLOW $\text{NiSO}_4(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Ni}(\text{OH})_2(\text{s}) + \text{SO}_4^{2-}(\text{aq})$ ALLOW $\text{NiSO}_4(\text{aq}) + 2\text{KOH}(\text{aq}) \rightarrow \text{Ni}(\text{OH})_2(\text{s}) + \text{K}_2\text{SO}_4(\text{aq})$</p> <p>ALLOW acid/base OR neutralisation OR deprotonation ONLY IF $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ AND $[\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2]$ used</p> <p>ALLOW precipitate</p> <p>ALLOW $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 4\text{KCN} \rightarrow [\text{Ni}(\text{CN})_4]^{2-} + 6\text{H}_2\text{O} + 4\text{K}^+$</p> <p>LOOK at formulae for E from 7(a)(i) (copied at bottom) ALLOW ECF in 7a(ii) Equation for no round brackets around CN, i.e. $[\text{NiCN}_4]^{2-}$ in 7a(i) This is the only ECF allowed from 7a(i) structures.</p> <p>ALLOW ligand exchange</p>
7	(b)	(i)	linear ✓	1	IGNORE planar

Question			Answer	Marks	Guidance
7	(b)	(ii)	<p>Au/Gold has been oxidised from 0 to +1 ✓</p> <p>O/Oxygen/O₂ has been reduced from 0 to -2 ✓</p>	2	<p>IF Ag referred to, rather than Au, treat as a slip and apply BOD ALLOW 0 to 1 (i.e. no + sign for +1)</p> <p>ALLOW 1 mark for ALL oxidation numbers correct with no oxidised or reduced OR oxidation and reduction wrong way round, e.g. Au goes from 0 to +1 and O goes from 0 to -2 ✓ Au is reduced from 0 to +1 and O is oxidised from 0 to -2 ✓</p>
7	(b)	(iii)	<p>IGNORE any charges shown within complexes (treat as rough working)</p> <p>$4\text{Au} + 8\text{CN}^- + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4[\text{Au}(\text{CN})_2]^- + 4\text{OH}^-$ ✓✓</p> <p>First mark for all 6 species</p> <p>Second mark for balancing</p>	2	<p>IF Ag referred to, rather than Au, treat as a slip and apply BOD</p> <p>IGNORE state symbols</p> <p>CARE: In $[\text{Au}(\text{CN})_2]^-$, - sign is OUTSIDE square brackets</p> <p>For 1st mark, IGNORE e⁻ present</p> <p>ALLOW 1 mark for balanced equation with CN⁻ missing, i.e. $4\text{Au} + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{Au}^+ + 4\text{OH}^-$</p> <p>ALLOW 1 mark rogue e⁻ on either side</p> <p>ALLOW multiples, e.g. $2\text{Au} + 4\text{CN}^- + \text{H}_2\text{O} + \frac{1}{2}\text{O}_2 \rightarrow 2[\text{Au}(\text{CN})_2]^- + 2\text{OH}^-$ $\text{Au} + 2\text{CN}^- + \frac{1}{2}\text{H}_2\text{O} + \frac{1}{4}\text{O}_2 \rightarrow [\text{Au}(\text{CN})_2]^- + \text{OH}^-$</p>
7	(b)	(iv)	<p>$\text{ClO}^- + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{Cl}^- + \text{H}_2\text{O}$ ✓</p>	1	<p>IGNORE state symbols</p> <p>ALLOW e for electron</p> <p>ALLOW multiples</p>
Total				13	

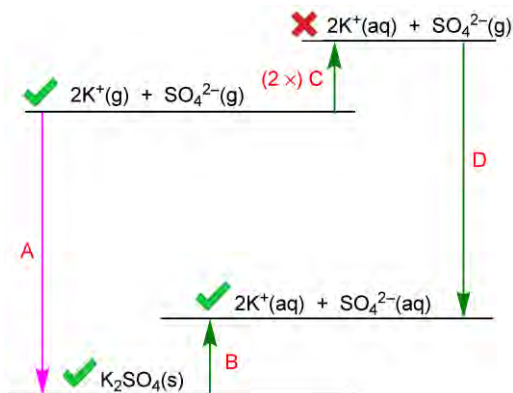
Question		Answer	Marks	Guidance
8	(a)	$\text{Cu}^{2+}: (1s^2)2s^22p^63s^23p^63d^9 \checkmark$ $\text{Cu}^+: (1s^2)2s^22p^63s^23p^63d^{10} \checkmark$	2	<p>IGNORE repeated $1s^2$ after $1s^2$ prompt on answer line ALLOW $4s^0$, either before or after $3d$</p> <p>ALLOW upper case D, etc and subscripts, e.g.$3S_23P^6$ DO NOT ALLOW [Ar] as shorthand for $1s^22s^22p^63s^23p^6$</p>
8	(b)	<p>IGNORE any charges shown within formulae (treat as rough working)</p> $\text{CuCO}_3 + 2\text{HCOOH} \rightarrow \text{Cu}(\text{HCOO})_2 + \text{H}_2\text{O} + \text{CO}_2$ <p>OR $\text{CuO} + 2\text{HCOOH} \rightarrow \text{Cu}(\text{HCOO})_2 + \text{H}_2\text{O}$</p> <p>OR $\text{Cu}(\text{OH})_2 + 2\text{HCOOH} \rightarrow \text{Cu}(\text{HCOO})_2 + 2\text{H}_2\text{O} \checkmark$</p>	1	<p>IGNORE state symbols In formula of HCOOH/HCOO, ALLOW H, C and O in ANY order ALLOW H_2CO_3 for H_2O and CO_2 in carbonate equation</p> <p>ALLOW $(\text{HCOO})_2\text{Cu}$ for $\text{Cu}(\text{HCOO})_2$</p> <p>DO NOT ALLOW equation with CuSO_4</p>
8	(c)	$2\text{Cu}^{2+} + 4\text{I}^- \rightarrow 2\text{CuI}(\text{s}) + \text{I}_2 \checkmark$ State symbol for $\text{CuI}(\text{s})$ ONLY required	1	<p>ALLOW multiples, e.g. $\text{Cu}^{2+} + 2\text{I}^- \rightarrow \text{CuI}(\text{s}) + \frac{1}{2}\text{I}_2$</p> <p>IGNORE other state symbols, even if incorrect</p>
8	(d)	Starch \checkmark Blue/black to colourless/white \checkmark MARK INDEPENDENTLY	2	<p>IGNORE 'brown' in composite colour with blue or black, i.e. ALLOW blue/brown to colourless ALLOW black/brown to colourless</p> <p>DO NOT ALLOW just 'it turns colourless/is decoloured' <i>Initial colour required</i></p> <p>IGNORE clear for colourless</p>

Question	Answer	Marks	Guidance
8 (e)	<p>WORKING REQUIRED Correct answer: $x = 4$ required evidence of working ----- $n(\text{S}_2\text{O}_3^{2-})$ OR $n(\text{Cu}^{2+}) = \frac{0.0420 \times 23.5}{1000} = 9.87 \times 10^{-4}$ (mol) ✓ In 250.0 cm³ solution, $n(\text{Cu}^{2+}) = 9.87 \times 10^{-3}$ (mol) ✓ $M(\text{Cu}(\text{HCOO})_2 \cdot 4\text{H}_2\text{O}) = \frac{2.226}{9.87 \times 10^{-3}} = 225.5$ (g mol⁻¹) ✓ $x(\text{H}_2\text{O})$ has mass of $225.5 - M(\text{Cu}(\text{HCOO})_2)$ $= 225.5 - 153.5$ $= 72(.0)$ ✓ $x = \frac{72(.0)}{18(.0)} = 4$ WHOLE NUMBER needed AND evidence of working ✓</p>	5	<p>FULL ANNOTATIONS MUST BE USED ----- At least 3 SF required throughout <i>Alternative approach for final 3 marks based on mass:</i> mass $\text{Cu}(\text{HCOO})_2 = 9.87 \times 10^{-3} \times 153.5 = 1.515$ g ✓ $n(\text{H}_2\text{O}) = \frac{2.226 - 1.515}{18(.0)} = \frac{0.711}{18(.0)} = 0.0395$ (mol) ✓ $x = \frac{0.0395}{9.87 \times 10^{-3}} = 4$ ✓ ALLOW $\text{Cu}(\text{HCOO})_2 \cdot 4\text{H}_2\text{O}$ ----- COMMON ERRORS for 4 marks $x = 117$ (calc 116.78) Use of 9.87×10^{-4} (no scaling $\times 10$) $\rightarrow M = 2255.319$ $x = 17$ (calc 16.53) 4 marks Use of 4.935×10^{-4} (Use of $0.5 \times 9.87 \times 10^{-3}$) Check $n(\text{Cu}^{2+})$ for other ECFs Check for ECFs from incorrect $M(\text{anhydr salt})$ Actual = 153.5</p>
	Total	11	

APPENDIX Q3(b)

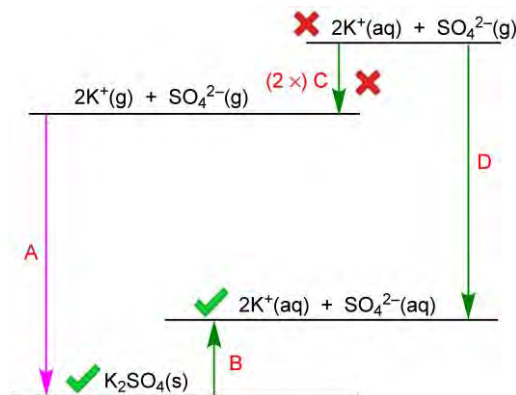
Extra energy line placed **ABOVE** top line
3 out of 4 marks awarded for energy lines and species.

Top arrow is shown **FROM** $2\text{K}^+(\text{g}) + \text{SO}_4^{2-}(\text{g})$ and arrow directions correct. Letter labels correct so last mark is awarded. **4/5 marks**



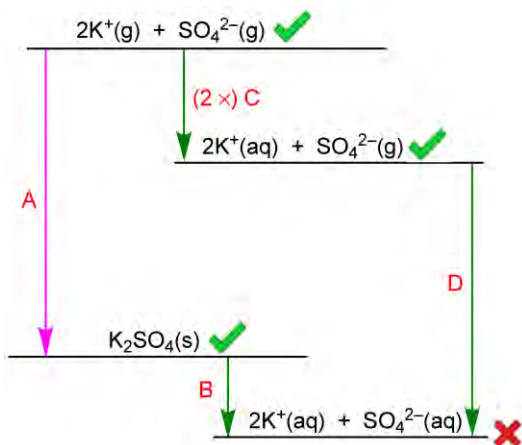
Same as left-hand response

BUT top arrow shown **TO** $2\text{K}^+(\text{g}) + \text{SO}_4^{2-}(\text{g})$ so last mark not awarded
3/5 marks



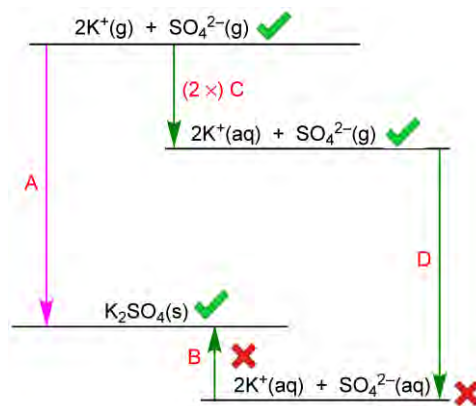
Extra energy line placed **BELOW** bottom line
3 out of 4 marks awarded for energy lines and species.

Top arrow is shown **FROM** $\text{K}_2\text{SO}_4(\text{s})$ and arrow directions correct. Letter labels correct so last mark is awarded. **4/5 marks**



Same as left-hand response

BUT bottom arrow shown **TO** $\text{K}_2\text{SO}_4(\text{s})$ so last mark not awarded
3/5 marks



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