

GCE

Chemistry A

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

Advanced GCE

Mark Scheme for June 2017

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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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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

Question		Answer	Marks	Guidance
1	(a)	<p>Formation of one mole of a(n ionic) compound ✓ from its gaseous ions ✓</p> <p>IGNORE standard conditions</p>	2	<p>IGNORE 'Energy needed' OR 'energy required'</p> <p>For '<i>compound</i>', ALLOW: lattice, crystal, substance, solid</p> <p>Special case: 1 mark for gaseous ions ONLY 'Formation of 1 mole of compound from 1 mole of gaseous ions.' Duplicate 1 mole is a CON for 1st marking point</p>
1	(b)	<p style="text-align: center;">FULL ANNOTATIONS MUST BE USE</p> <p>For ALL marking points, assume the following:</p> <ul style="list-style-type: none"> • For 'ions', ALLOW 'atoms', e.g. Na has a larger (atomic) radius • For Mg^{2+}, Na^+, Br^- and Cl^-, ALLOW symbols: e.g. Mg, Na, Br and Cl • ALLOW names: e.g. magnesium, sodium, bromine, bromide, chlorine, chloride • DO NOT ALLOW 'composite' particles, e.g. 'magnesium bromide/MgBr_2 has a larger ionic radius' <p>DO NOT ALLOW molecules IGNORE idea of close packing of ions IGNORE electronegative</p>		

Question	Answer	Marks	Guidance
	<p>Comparing cation size AND charge (ORA based on Na⁺) Mg²⁺ is smaller AND Mg²⁺ has a greater charge OR Mg²⁺ has a greater charge density ✓</p> <p>Comparing of anion size (ORA based on Cl⁻) Br⁻ is larger OR Br⁻ has a smaller charge density ✓</p> <p>Comparing cation ↔ anion attraction Mg²⁺ has stronger attraction AND Cl⁻ has stronger attraction ✓</p> <p>IGNORE 'nuclear' attraction</p>	3	<p>ALLOW reverse argument throughout (ORA)</p> <p>-----</p> <p>For 'greater charge' part of mark, ALLOW Mg²⁺ AND Na⁺ seen anywhere ALLOW Mg is 2+ AND Na is 1+</p> <p>IGNORE just Mg²⁺ is small <i>comparison required</i></p> <p>IGNORE just Br⁻ is large <i>comparison required</i></p> <p>ALLOW pull for attraction</p> <p>ALLOW 'attracts with more force' for greater attraction BUT ... IGNORE just 'greater force' (<i>could be repulsion</i>) OR comparison of bond strength/energy to break bonds</p> <p>IGNORE comparisons of numbers of ions</p>

Question	Answer	Marks	Guidance																		
1 (c) (i)	<p>5 marks for species AND state symbols on the dotted lines ✓✓✓✓✓</p> <p>1 mark for ALL 4 correct letters in boxes ✓</p> <p><i>Place tick or cross by top right letter (E when correct)</i></p>	6	<p>Correct species AND state symbols required for marks on dotted lines</p> <p>ALLOW e for e⁻</p> <p>TAKE CARE: e⁻ may be in centre of response and more difficult to see than at end, e.g. Mg⁺(g) + e⁻ + 2Br(g)</p> <p>ONE correct response for each line</p> <p>Mark each marking point independently</p> <hr/> <p>No ECF except for (g) and (s) state symbol of Br₂(l) i.e.:</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; padding: 5px;">Mg(g) + Br₂(g)</td> <td style="text-align: center; padding: 5px;">✓ ECF</td> </tr> <tr> <td style="text-align: center; padding: 5px;">↑</td> <td></td> </tr> <tr> <td style="text-align: center; padding: 5px;">Mg(s) + Br₂(g)</td> <td style="text-align: center; padding: 5px;">✗</td> </tr> </table> <hr/> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; padding: 5px;">Mg(g) + Br₂(s)</td> <td style="text-align: center; padding: 5px;">✓ ECF</td> </tr> <tr> <td style="text-align: center; padding: 5px;">↑</td> <td></td> </tr> <tr> <td style="text-align: center; padding: 5px;">Mg(s) + Br₂(s)</td> <td style="text-align: center; padding: 5px;">✗</td> </tr> </table> <hr/> <p>DO NOT ALLOW ECF for same change with (aq), i.e.</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; padding: 5px;">Mg(g) + Br₂(aq)</td> <td style="text-align: center; padding: 5px;">✗</td> </tr> <tr> <td style="text-align: center; padding: 5px;">↑</td> <td></td> </tr> <tr> <td style="text-align: center; padding: 5px;">Mg(s) + Br₂(aq)</td> <td style="text-align: center; padding: 5px;">✗</td> </tr> </table> <hr/>	Mg(g) + Br ₂ (g)	✓ ECF	↑		Mg(s) + Br ₂ (g)	✗	Mg(g) + Br ₂ (s)	✓ ECF	↑		Mg(s) + Br ₂ (s)	✗	Mg(g) + Br ₂ (aq)	✗	↑		Mg(s) + Br ₂ (aq)	✗
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Question			Answer	Marks	Guidance
1	(c)	(ii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-2433 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks</p> <p>-----</p> <p>Cycle $(-524) = 146 + (2 \times +112) + 738 + 1451 + (2 \times -325) + \text{LE}$ OR $\text{LE} = -524 - (146 + (2 \times +112) + 738 + 1451 + (2 \times -325))$ OR $-524 - 1929 \checkmark$</p> <p>Lattice energy $\text{LE} = -2433 \checkmark \text{ (kJ mol}^{-1}\text{)}$</p>	2	<p>For alternative answers, ALLOW ECF</p> <p>See list below for marking of answers from common errors</p> <p>-----</p> <p>ALLOW for 1 mark:</p> <p>+2433 wrong sign -2321 +112 used instead of 2×112 -2758 -325 used instead of 2×-325 -3733 wrong sign for 2×325 -1385 wrong sign for 524 -2141 wrong sign for 146 -1985 wrong sign for 2×112 -957 wrong sign for 738 +469 wrong sign for 1451</p> <p>Any other number: CHECK for ECF from 1st marking point for expressions with ONE error only e.g. one transcription error: e.g. +461 instead of +416</p>
			Total	13	

Question		Answer	Marks	Guidance
2	(a)	positive OR + AND solid forms liquid OR liquid has more disorder ✓	3	For 'liquid has more disorder': ALLOW liquid has more ways of arranging energy/ more freedom/ more random molecules
		positive OR + AND gas (H ₂) forms OR Mg dissolves/disappears ✓		ASSUME gas is H ₂ unless otherwise stated BUT DO NOT ALLOW an incorrect gas (e.g. CO ₂) IGNORE liquid forms IGNORE equation with state symbols <i>Response should communicate why entropy increases</i>
		negative OR – AND 9 mol gas form 4 mol gas OR forms 5 fewer mol of gas ✓		Numbers and gas are essential IGNORE 'forms fewer moles of gas' For mol, ALLOW molecules IGNORE numbers around equation <i>Treated as rough working</i>

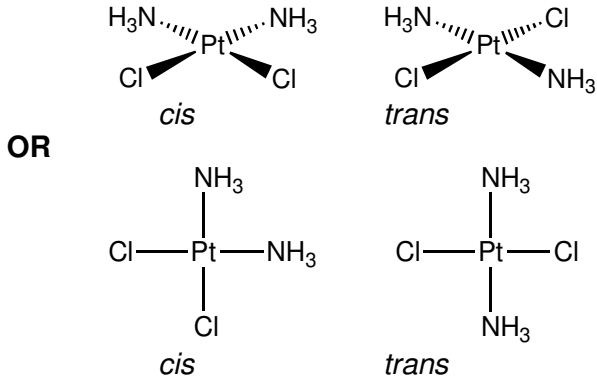
Question	Answer	Marks	Guidance																					
2 (b)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 185 (J K⁻¹ mol⁻¹) award 2 marks</p> <p><i>Conversion of °C to K</i> AND substitution of values into $\Delta G = \Delta H - T\Delta S$</p> $-1041 = -907 - 723 \times \Delta S \checkmark$ <p><i>Calculation of ΔS AND conversion to J K⁻¹ mol⁻¹</i></p> $\Delta S = \frac{1041 - 907}{723} \times 1000 = \frac{134}{723} \times 1000$ $= 185 \text{ OR } 185.3 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ <p>ALLOW 3 SF up to calc value of 185.3388658 correctly rounded</p>	2	<p>Conversion to J may be carried out at start but no mark JUST for this conversion</p> <p>ALLOW ECF ONLY from use of values from question: (-)907 AND (-)1041 AND 450/723</p> <hr/> <p>COMMON ERRORS</p> <table border="0"> <tr> <td>-185</td> <td>wrong sign</td> <td>1 mark</td> </tr> <tr> <td>0.185</td> <td>no conversion from kJ to J</td> <td>1 mark</td> </tr> <tr> <td>1.85 × 10⁻⁴</td> <td>÷ by 1000 instead of ×</td> <td>1 mark</td> </tr> </table> <p>298/297.8 (calc 297.7 recurring)</p> <table border="0"> <tr> <td></td> <td>Use of 450 °C instead of 723 K</td> <td>1 mark</td> </tr> </table> <table border="0"> <tr> <td>-2694</td> <td>wrong sign for 1041</td> <td>1 mark</td> </tr> <tr> <td>2694</td> <td>wrong sign for 907</td> <td>1 mark</td> </tr> </table> <table border="0"> <tr> <td>±4329</td> <td>Wrong sign AND 450°C</td> <td>0 marks</td> </tr> </table>	-185	wrong sign	1 mark	0.185	no conversion from kJ to J	1 mark	1.85 × 10⁻⁴	÷ by 1000 instead of ×	1 mark		Use of 450 °C instead of 723 K	1 mark	-2694	wrong sign for 1041	1 mark	2694	wrong sign for 907	1 mark	±4329	Wrong sign AND 450°C	0 marks
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Question		Answer	Marks	Guidance
2	(c)	<p>Signs of ΔH and ΔS ΔH is positive AND ΔS is positive ✓</p> <p>$T\Delta S$ and temperature 'Value of' $T\Delta S$ increases with temperature ✓</p> <p>Feasibility At high temperatures, ΔG is -ve OR $\Delta G < 0$ AND At low temperatures, ΔG is +ve OR $\Delta G > 0$</p> <p>OR $\Delta H - T\Delta S$ decreases with (increasing) temperature OR $\Delta H - T\Delta S$ from +ve to -ve with (increasing) temperature ✓</p> <p>OR the idea: As temperature increases, $T\Delta S$ outweighs ΔH to make $\Delta G < 0$</p>	3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>ALLOW ΔH is endothermic for ΔH is positive</p> <p>IGNORE sign of $T\Delta S$ (treated as $T\Delta S$) <i>i.e.</i> ALLOW $T\Delta S$ becomes more/less positive OR $T\Delta S$ becomes more/less negative</p> <p>IGNORE ΔS increases with temperature</p> <p>ONLY award feasibility mark if signs of ΔH and ΔS are correct, <i>i.e.</i> ΔH +ve AND ΔS +ve (1st marking point)</p> <p>ALLOW $\Delta H - T\Delta S$ for ΔG, <i>e.g.</i> At high temperatures, $\Delta H - T\Delta S < 0$ OR $\Delta H < T\Delta S$ AND At low temperatures, $\Delta H - T\Delta S > 0$ OR $\Delta H > T\Delta S$</p>
		Total	8	

Question		Expected answers			Marks	Additional guidance									
3	(a)	NO: 2 /Second AND H ₂ : 1 /First AND Overall: 3 /Third ✓			1										
3	(b)	rate × 125 ✓			1	DO NOT ALLOW just 'increases by 5 and then by 25 / 5 ² OR increases by 5 ³									
3	(c)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 7.59×10^4 award 2 marks THEN IF units are $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$, award 1 further mark</p> <p><i>Initial working</i></p> $k = \frac{4.34 \times 10^{-2}}{(3.24 \times 10^{-3})^2 \times 5.45 \times 10^{-2}}$ <p>OR 75858.31764 to 3 SF or more ✓</p> <p><i>3 SF and standard form</i> = 7.59×10^4 ✓</p> <p><i>units:</i> $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$ ✓</p>			3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>NO ECF from incorrectly rearranged <i>k</i> expression</p> <p>ALLOW $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$ OR any order DO NOT ALLOW other units from incorrect <i>k</i> expression (Rate equation supplied on paper – not derived from data)</p>									
3	(d)	<table border="1"> <thead> <tr> <th>Change</th> <th>Effect on rate</th> <th>Effect on <i>k</i></th> </tr> </thead> <tbody> <tr> <td>Increase in pressure</td> <td>increases</td> <td>none</td> </tr> <tr> <td>Increase in temperature</td> <td>increases</td> <td>increases</td> </tr> </tbody> </table> <p>Mark by column: ✓ ✓</p>	Change	Effect on rate	Effect on <i>k</i>	Increase in pressure	increases	none	Increase in temperature	increases	increases			2	ALL boxes are 'increases' EXCEPT top right is 'none'.
Change	Effect on rate	Effect on <i>k</i>													
Increase in pressure	increases	none													
Increase in temperature	increases	increases													

Question		Expected answers	Marks	Additional guidance
3	(e)	<p>Overall equation must be sum of step 1 and step 2</p> <p>step 1: $\text{H}_2(\text{g}) + 2 \text{NO}(\text{g}) \rightarrow \text{N}_2\text{O}(\text{g}) + \text{H}_2\text{O}(\text{g}) \checkmark$</p> <p>overall: $2\text{NO}(\text{g}) + 2\text{H}_2(\text{g}) \rightarrow \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \checkmark$</p> <p>NO ECF for from incorrect step 1 equation</p>	2	<p>IGNORE any state symbols</p> <p><i>For other possible correct responses, contact Team Leader</i></p>
Total			9	

Question			Answer	Marks	Guidance
4	(a)	(i)	<p>Note: Examples must be for V, not other d block elements</p> <p>d block element: (3)d is highest energy sub-shell/orbital ✓</p> <p>Transition element: has an ion with incomplete/partially-filled d sub-shell/orbital ✓</p> <p>V $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ ✓ full electron configuration required</p> <p>V²⁺: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ ✓ full electron configuration required</p>	4	<p>FULL ANNOTATIONS MUST BE USED</p> <p>DO NOT ALLOW highest energy shell</p> <p>ALLOW 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$ ALLOW upper case D, etc and subscripts, e.g. [Ar]4S₂3D₃</p> <p>DO NOT ALLOW USE OF [Ar] for $1s^2 2s^2 2p^6 3s^2 3p^6$ for configuration of V and V²⁺</p> <p>ALLOW electron configuration with 4s⁰</p>
4	(a)	(ii)	<p>$VO_3^- + 6H^+ + 3e^- \longrightarrow V^{2+} + 3H_2O$ ✓</p> <p>$Zn \longrightarrow Zn^{2+} + 2e^-$ ✓</p> <p>$2VO_3^- + 12H^+ + 3Zn \longrightarrow 2V^{2+} + 6H_2O + 3Zn^{2+}$ ✓</p> <p>Multiples of this equation are the ONLY correct answer</p>	3	<p>ALLOW multiples</p> <p>NO ECF from incorrect half equations</p> <p>ALLOW multiples, e.g. $VO_3^- + 6H^+ + 1\frac{1}{2}Zn \longrightarrow V^{2+} + 3H_2O + 1\frac{1}{2}Zn^{2+}$</p>

Question			Answer	Marks	Guidance
4	(b)	(i)	Pt: Pt^{2+} OR +2/2+ AND Cl: $2 \times \text{Cl}^-$ OR 2×-1 OR 2 Cl^-/Cl with oxidation number -1 ✓	1	DO NOT ALLOW response in terms of ' Cl_2 ' or ' Cl molecule', rather than Cl^- DO NOT ALLOW 'charges cancel' without the charges/oxidation numbers involved being stated DO NOT ALLOW if NH_3 shown to have charge
4	(b)	(ii)	 <p>OR</p> <p>✓✓ For each structure AND correct <i>cis</i> and <i>trans</i> labels</p> <p>AWARD 1 mark for TWO correct structures with incorrect <i>cis</i> and <i>trans</i> labels OR no labels.</p> <p>-----</p> <p>Ligands donates electron pairs OR Pt/Pt^{2+}/metal (ion) accepts lone pairs ✓</p>	3	IGNORE any charge, i.e. Pt^{2+} OR Cl^- , even if wrong Bonds MUST go to N of to NH_3 IGNORE labelled bond angles (even if wrong) DO NOT ALLOW any structure that cannot be in one plane If ligands are orientated correctly in <i>cis</i> AND <i>trans</i> , but connectivity to N is poor ALLOW 1 mark for two diagrams ----- ALLOW coordinate bonds shown on diagrams provide that they start from a lone pair on ligands
4	(b)	(iii)	<i>cis</i> -platin binds to DNA (of cancer cells) OR <i>cis</i> -platin stops (cancer) cells dividing/replicating ✓	1	ALLOW <i>cis-isomer</i> : cis is essential IGNORE simply ' <i>cis</i> -platin used in cancer treatment'

Question	Answer	Marks	Guidance
4 (c)	<p>Colour of $\text{Co}^{2+}(\text{aq})$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ 1 mark Pink solution seen at least once AND not contradicted ✓</p> <p>REACTION OF Co^{2+} with $\text{NaOH}(\text{aq})$ 3 marks</p> <p>Correct equation $\text{Co}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow \text{Co}(\text{OH})_2(\text{s})$ ✓ state symbols not required</p> <p>Observation blue precipitate/solid ✓</p> <p>Type of reaction precipitation ✓</p>	7	<p>FULL ANNOTATIONS MUST BE USED ALLOW equilibrium signs in all equations IGNORE state symbols IGNORE an incorrect formula for an observation</p> <p>-----</p> <p>ALLOW '$\text{Co}^{2+}(\text{aq})$ is pink' or similar wording</p> <p>(aq) OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ is equivalent to 'solution' DO NOT ALLOW pink precipitate</p> <p>ALLOW $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^{-} \rightarrow \text{Co}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$</p> <p>ALLOW 'hybrid' equations, e.g. $\text{Co}^{2+} + 2\text{NaOH} \rightarrow \text{Co}(\text{OH})_2 + 2\text{Na}^{+}$ $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^{-} \rightarrow \text{Co}(\text{OH})_2 + 6\text{H}_2\text{O}$</p> <p>ALLOW any shade of blue IGNORE changes in colour over time</p> <p>DO NOT ALLOW 'precipitate reaction'</p> <p>IF equation with $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ has been shown, ALLOW acid–base OR neutralisation</p>
	<p>REACTION OF Co^{2+} WITH $\text{HCl}(\text{aq})$ 3 marks</p> <p>Correct equation $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^{-} \longrightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O}$ ✓</p> <p>Observation blue (solution) ✓</p> <p>Type of reaction ligand substitution ✓</p>		<p>ALLOW CoCl_4^{2-} i.e. no brackets OR $\text{Co}(\text{Cl})_4^{2-}$ ALLOW $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \longrightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O} + 4\text{H}^{+}$ IGNORE $\text{Co}^{2+} + 4\text{Cl}^{-} \longrightarrow \text{CoCl}_4^{2-}$</p> <p>ALLOW any shades of blue DO NOT ALLOW blue precipitate</p> <p>ALLOW ligand exchange</p>

Question	Answer	Marks	Guidance
	Total	19	

Question			Answer	Marks	Guidance
5	(a)	(i)	partially dissociates ✓	1	For dissociates, ALLOW ionises
5	(a)	(ii)	$(K_a =) \frac{[H^+(aq)][CH_3COO^-(aq)]}{[CH_3COOH(aq)]}$ ✓ All species MUST have square brackets	1	ALLOW $[H_3O^+]$ for $[H^+]$ IGNORE $\frac{[H^+]^2}{[C_2H_5COOH]}$ OR $\frac{[H^+][A^-]}{[HA]}$ IGNORE state symbols

Question			Answer	Marks	Guidance
5	(a)	(iii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 3.22, award 2 marks</p> <p>-----</p> <p>$[H^+] = \sqrt{(1.30 \times 10^{-5}) \times (2.85 \times 10^{-2})}$</p> <p>OR 6.09×10^{-4} (mol dm⁻³) ✓</p> <p>pH = $-\log 6.09 \times 10^{-4} = 3.22$ ✓ <i>Must be from a calculated [H⁺]</i></p> <p>NOTE: The marks are ONLY available from attempted use of K_a AND [C₂H₅COOH]</p>	2	<p>ALLOW 6.09×10^{-4} to calculator value of $6.086871117 \times 10^{-4}$ correctly rounded</p> <p>ALLOW ECF from incorrect [H⁺] derived from K_a AND [H⁺]</p> <p>ALLOW use of quadratic equation – gives same answer of 3.22</p> <p>-----</p> <p>COMMON ERRORS (MUST be to 2 DP) Mark other errors by ECF</p> <p>pH = 6.43 1 mark $-\log(1.30 \times 10^{-5}) \times (2.85 \times 10^{-2})$ No $\sqrt{\quad}$</p> <p>pH = 3.16 1 mark Wrong acid ($K_a = 1.70 \times 10^{-5}$) but all else correct</p> <p>pH = 4.89 0 marks $-\log(1.30 \times 10^{-5}) = 4.89$ $-\log K_a$</p> <p>pH = 1.55 0 marks $-\log(2.85 \times 10^{-2}) = 4.87$ $-\log [H^+]$</p>

Question			Answer	Marks	Guidance
5	(a)	(iv)	$\text{C}_2\text{H}_5\text{COOH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{C}_2\text{H}_5\text{COOH}_2^+ + \text{CH}_3\text{COO}^- \checkmark$ <p style="text-align: center;"> Base 2 Acid 1 Acid 2 Base 1 ✓ </p> <p><i>1st mark for correct products, C₂H₅COOH₂⁺ AND CH₃COO⁻</i></p> <p><i>2nd mark for correct labels</i></p>	2	<p>ALLOW ECF for 2nd mark if H⁺ transfer shown other way round, i.e.</p> $\text{C}_2\text{H}_5\text{COOH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{C}_2\text{H}_5\text{COO}^- + \text{CH}_3\text{COOH}_2^+ \times$ <p style="text-align: center;"> Acid 1 Base 2 Base 1 Acid 2 ✓ ECF </p> <p>NO OTHER ECF</p> <p>ALLOW A1, B1, etc or any unambiguous labels</p>
5	(b)	(i)	proton/H ⁺ acceptor ✓	1	DO NOT ALLOW OH ⁻ donor
5	(b)	(ii)	<p>FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 5.35 (g) award 3 marks</p> <p>$n(\text{Ba}(\text{OH})_2) = (250/1000) \times 0.1250 = 0.03125 \text{ (mol)} \checkmark$</p> <p>$M(\text{Ba}(\text{OH})_2) = 171.3 \text{ (g mol}^{-1}\text{)} \checkmark$</p> <p>mass = 0.03125 × 171.3 = 5.35 (g) ✓</p> <p>NOTE: Answer to two decimal places</p>	3	ALLOW ECF but answer required to two decimal places

Question			Answer	Marks	Guidance
5	(b)	(iii)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 13.40 award 3 marks</p> <p>$[\text{OH}^-] = 2 \times 0.1250 = 0.25(0) \text{ (mol dm}^{-3}\text{)} \checkmark$ $[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.25(0)}$ OR $4(.00) \times 10^{-14} \text{ (mol dm}^{-3}\text{)} \checkmark$ <i>Subsumes 1st mark</i></p> <p>$\text{pH} = -\log 4.00 \times 10^{-14} = \mathbf{13.40} \checkmark$ <i>Must be from a calculated $[\text{H}^+]$</i></p> <p>-----</p> <p>pOH variation (also worth 3 marks) $[\text{OH}^-] = 2 \times 0.125 = 0.25(0) \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>$\text{pOH} = -\log 0.25(0) = 0.60 \checkmark$</p> <p>$\text{pH} = 14.00 - 0.60 = 13.40 \checkmark$ <i>Must be from a calculated pOH</i></p>	3	<p>Marks are for correctly calculated values. Working shows how values have been derived.</p> <p>ALLOW by ECF $\frac{1.00 \times 10^{-14}}{\text{calculated value of } [\text{OH}^-]}$</p> <p>DO NOT ALLOW 13.4 <i>not two decimal places</i></p> <p>-----</p> <p>COMMON ERRORS for pH</p> <p>13.4 $\checkmark\checkmark$ <i>not 2 DP</i> 13.10 $\checkmark\checkmark$ <i>no $\times 2$ for $[\text{OH}^-]$</i> 13.1 \checkmark <i>no $\times 2$ for $[\text{OH}^-]$ AND 1 DP only</i> 12.80 $\checkmark\checkmark$ <i>$\div 2$ instead of $\times 2$ for $[\text{OH}^-]$</i> 0.60 \checkmark <i>2×0.1250 expressed as pH</i> 0.90 no marks <i>$-\log 0.125$</i></p>

Question		Answer	Marks	Guidance
5	(c)	<p>Possible conclusion from mixing C₂H₅COOH and Ba(OH)₂ Buffer forms when</p> <ul style="list-style-type: none"> acid / C₂H₅COOH is in excess OR buffer contains C₂H₅COOH AND C₂H₅COO⁻ / (C₂H₅COO)₂Ba ✓ <p>Independent of calculations</p> <p>$n(\text{Ba}(\text{OH})_2)$ $= (100/1000) \times 0.1250 = 0.0125 \text{ (mol) } \checkmark$</p> <p>$n(\text{C}_2\text{H}_5\text{COOH})$ $= (200/1000) \times 0.324 = 0.0648 \text{ (mol) } \checkmark$</p> <p>Correct calculation showing that C₂H₅COOH is in excess Must use 2×0.0125 OR 0.0250 ✓</p> <p>Possible calculations could show:</p> <ul style="list-style-type: none"> C₂H₅COOH is 0.0398 mol in excess ratio $n(\text{C}_2\text{H}_5\text{COOH})/n(\text{Ba}(\text{OH})_2) > 2/1$ $n(\text{C}_2\text{H}_5\text{COOH}) > n(\text{OH}^-)$ 	4	<p>ORA</p> <p>Buffer does not form when</p> <ul style="list-style-type: none"> acid / C₂H₅COOH is not in excess / Ba(OH)₂ is in excess OR buffer does not contains C₂H₅COOH AND C₂H₅COO⁻ / (C₂H₅COO)₂Ba ✓ <p>$n(\text{C}_2\text{H}_5\text{COOH}) = 0.0648 - 0.0250 = 0.0398$</p> <p>ratio $n(\text{C}_2\text{H}_5\text{COOH})/n(\text{Ba}(\text{OH})_2) = 0.0648/0.0125 = 5.184/1$</p> <p>$n(\text{C}_2\text{H}_5\text{COOH}) > n(\text{OH}^-) = 0.0648 > 0.0250$</p>

Question		Answer	Marks	Guidance
5	(d)	<ul style="list-style-type: none"> • 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) • ----- • $H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \checkmark$ • ----- • H_2CO_3 reacts with added alkali / OH^- • OR $H_2CO_3 + OH^- \rightarrow$ • OR added alkali reacts with H^+ • OR $H^+ + OH^- \rightarrow \checkmark$ <p>Equilibrium \rightarrow right OR Equilibrium $\rightarrow HCO_3^- \checkmark$ (QWC)</p> <ul style="list-style-type: none"> • HCO_3^- reacts with added acid / $H^+ \checkmark$ <p>Equilibrium \rightarrow left OR Equilibrium $\rightarrow H_2CO_3 \checkmark$ (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 $HA \rightleftharpoons H^+ + A^-$</p> <p>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</p> <p>DO NOT ALLOW acid reacts with added alkali</p> <p>ALLOW conjugate base reacts with added acid</p> <p>DO NOT ALLOW salt/base reacts with added acid</p>
		Total	22	

Question		Answer	Marks	Guidance
6	(a)	$(K_c =) \frac{[\text{NH}_3]^2}{[\text{N}_2] [\text{H}_2]^3} \checkmark$	1	Must be square brackets IGNORE state symbols

Question	Answer	Marks	Guidance
6 (b)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $0.0368 \text{ dm}^6 \text{ mol}^{-2}$, award 6 marks IF answer = 0.0368 with incorrect units, award 5 mark</p> <hr/> <p>Equilibrium amounts in mol 2 MARKS $n(\text{N}_2) = 10.40 - 5.60/2 = 7.6(0) \text{ (mol)} \checkmark$ $n(\text{H}_2) = 22.50 - 1.5 \times 5.60 = 14.1(0) \text{ (mol)} \checkmark$</p> <p>Equilibrium concentrations (moles \div 5) 1 MARK $\text{N}_2 = 7.60/5 = 1.52 \text{ (mol dm}^{-3}\text{)}$ AND $\text{H}_2 = 14.1/5 = 2.82 \text{ (mol dm}^{-3}\text{)}$ AND $\text{NH}_3 = 5.60/5 = 1.12 \text{ (mol dm}^{-3}\text{)} \checkmark$</p> <p>Calculation of K_c and units 3 MARKS $K_c = \frac{1.12^2}{1.52 \times 2.82^3} \checkmark$</p> <p>$K_c = 0.0368 \checkmark$ $\text{dm}^6 \text{ mol}^{-2} \checkmark$ 3SF required</p> <hr/> <p>NOTE: If inverted K_c expression used, look back to Q6(a) Then apply ECF with ALL marks being available in 16(b). Expected answer = 27.2 Expected units = $\text{mol}^2 \text{ dm}^{-6}$</p> <p>See also Common errors</p>	6	<p>FULL ANNOTATIONS NEEDED</p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <hr/> <p>ALLOW ECF from incorrect moles of SO_2, O_2 AND SO_2 ALL three concentrations required for this mark</p> <p>ALLOW ECF from incorrect concentrations or moles (if concentration stage is omitted)</p> <p>ALLOW ECF from wrong K_c expression for K_c value and units For units, ALLOW $\text{mol}^{-2} \text{ dm}^6$ DO NOT ALLOW dm^6/mol^2</p> <p>Common errors for K_c</p> <p>1.47×10^{-3} <i>missing $\div 5$ to calculate concentrations</i> 4 marks + units mark (i.e. just one mark dropped)</p> <p>0.0338 <i>Subtracting 5.60 from initial moles of N_2 and H_2</i> 3 marks + units mark</p> <p>6.62×10^{-3} <i>Use of initial concentrations of N_2 and H_2</i> (3 marks + units mark)</p> <p>2.65×10^{-4} <i>Use of initial moles of N_2 and H_2 and no $\div 5$ for concs</i> (2 marks + units mark)</p> <p>27.2 <i>Calculated value from inverted K_c</i> 4 marks + units mark for $\text{mol}^2 \text{ dm}^{-6}$</p>

Question			Answer	Marks	Guidance
6	(c)	(i)	K_c is smaller AND (forward) reaction is exothermic OR ΔH is negative ✓	1	Link to ΔH /exothermic essential ALLOW reverse reaction is endothermic DO NOT ALLOW equilibrium shifts to the right (CON)
6	(c)	(ii)	K_c is the same AND K_c is temperature dependent/only changed by temperature OR K_c is not changed by pressure ✓	1	ALLOW K_c is only changed by temperature IGNORE same number of moles on both side
			Total	9	

Question			Answer	Marks	Guidance
7	(a)	(i)	<p>complete circuit with voltmeter AND salt bridge linking two half-cells ✓</p> <p>Cr electrode in Cr³⁺ solution ✓</p> <p>Pt electrode in solution containing Fe²⁺ AND Fe³⁺ ✓</p> <p>Conditions <i>Units essential</i> (Temperature of) 298 K / 25°C AND (solution concentrations of) 1 mol dm⁻³ ✓ (may be on diagram)</p>	4	<p>FULL ANNOTATIONS MUST BE USED circuit shown must be complete, <i>ie</i> must be capable of working salt bridge must be labelled and must dip into both solutions</p> <p>Half cells can be drawn in either order Half cells must show electrodes dipping into solutions ALLOW small gaps in circuit</p> <p>ALLOW 1M and 1 mol/dm³ DO NOT ALLOW 1 mol</p> <p>IGNORE pressure (<i>No gases in this cell</i>)</p>
7	(a)	(ii)	<p>Cr(s) + 3Fe³⁺(aq) → Cr³⁺(aq) + 3Fe²⁺(aq) ✓ <i>State symbols not required</i></p>	1	<p>IGNORE state symbols</p> <p>ALLOW equilibrium sign providing reactants and products are on correct sides of equation</p>
7	(a)	(iii)	<p>$E = 1.51$ (V) AND Sign of Cr electrode: – /negative ✓</p>	1	<p>IGNORE sign for E</p>
7	(b)		<p>Assume Cr³⁺ Cr OR Cr half-cell unless otherwise stated.</p> <p>[Cr³⁺] increases OR > 1 mol dm⁻³ ✓</p> <p>Equilibrium (shown in table) shifts to right OR towards Cr ✓</p> <p>Electrons are removed/used up/fewer electrons released OR</p>	3	<p>FULL ANNOTATIONS MUST BE USED</p> <p>----- ALLOW [Cr³⁺] more than standard concentration/1 mol dm⁻³ IGNORE CrCl₃ reacts</p> <p>Take care: Response may refer to a reverse half equation written by candidate. The equilibrium then shifts to left.</p> <p>IGNORE comments about E^{\ominus} changing</p>

Question			Answer	Marks	Guidance
			E (for $\text{Cr}^{3+} \text{Cr}$) is less negative / more positive OR The cell has a smaller difference in E ✓		IGNORE just 'cell potential decreases' (in the question)
7	(c)	(i)	$\text{HCOOH}(\text{l}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^-$	1	ALLOW multiples e.g. $2\text{HCOOH}(\text{l}) \rightarrow 2\text{CO}_2(\text{g}) + 4\text{H}^+ + 4\text{e}^-$
7	(c)	(ii)	HCOOH is a liquid OR is less volatile AND HCOOH is easier to store/transport/stored more safely OR H_2 is more explosive/more flammable ✓	1	Assume that 'it' refers to HCOOH ALLOW ORA throughout IGNORE comments about efficiency IGNORE comments about biomass and renewable
7	(d)	(i)	amount MnO_4^- used = $0.01500 \times \frac{25.40}{1000}$ = 3.81×10^{-4} (mol) ✓ amount SO_3^{2-} = $3.81 \times 10^{-4} \times 2.5$ = 9.525×10^{-4} (mol) ✓ amount SO_3^{2-} in original 250 cm^3 = $10 \times 9.525 \times 10^{-4}$ = 9.525×10^{-3} mol ✓ Mass of Na_2SO_3 in sample = $126.1 \times 9.525 \times 10^{-3}$ g = 1.20 g ✓ $n(\text{H}_2\text{O}) = \frac{2.40 - 1.20}{18.0} = 6.67 \times 10^{-2}$ (mol) ✓	6	FULL ANNOTATIONS MUST BE USED IF a step is omitted but subsequent step subsumes previous, then award mark for any missed step Working: at least 3 SF throughout until final % mark BUT ignore trailing zeroes, ie for 0.01500 allow 0.015/0.0150 ----- ALLOW ECF at all stages ALLOW $M(\text{hydrated sodium sulfite}) = \frac{2.40}{9.525 \times 10^{-3}} = 252$ ✓ Molar mass of $\text{H}_2\text{O} = 252 - 126.1 = 125.9$ ✓

Question		Answer	Marks	Guidance
		$n(\text{Na}_2\text{SO}_3) : n(\text{H}_2\text{O}) = 9.525 \times 10^{-3} : 6.67 \times 10^{-2} = 1 : 7$ Formula = Na₂SO₃•7H₂O ✓ <i>Formula is required. 1:7 ratio is insufficient</i>		Number of H ₂ O of crystallisation = $\frac{125.9}{18.0} = 7$ Formula = Na₂SO₃•7H₂O ✓
(d)	(ii)	MARK INDEPENDENTLY Except for multiples, equations are only correct answers Overall: $2\text{MnO}_4^- + 6\text{H}^+ + 5\text{SO}_3^{2-} \rightarrow 2\text{Mn}^{2+} + 5\text{SO}_4^{2-} + 3\text{H}_2\text{O}$ ✓ Half equations: $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$ ✓ $\text{SO}_3^{2-} + \text{H}_2\text{O} \rightarrow \text{SO}_4^{2-} + 2\text{H}^+ + 2\text{e}^-$ ✓	3	ALLOW multiples and equilibrium signs throughout IGNORE state symbols throughout e.g. $\text{MnO}_4^- + 3\text{H}^+ + 2\frac{1}{2}\text{SO}_3^{2-} \rightarrow \text{Mn}^{2+} + 2\frac{1}{2}\text{SO}_4^{2-} + 1\frac{1}{2}\text{H}_2\text{O}$
Total			20	

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