

**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.

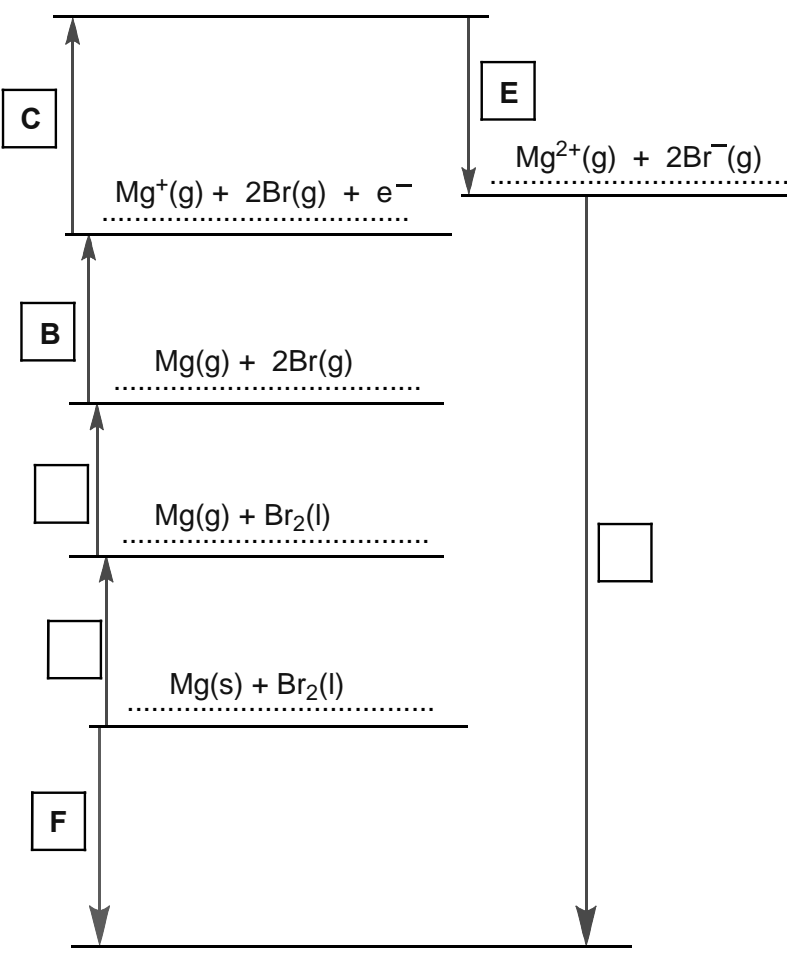
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<b>Annotation</b>	<b>Meaning</b>
<b>DO NOT ALLOW</b>	Answers which are not worthy of credit
<b>IGNORE</b>	Statements which are irrelevant
<b>ALLOW</b>	Answers that can be accepted
( )	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
<b>ECF</b>	Error carried forward
<b>AW</b>	Alternative wording
<b>ORA</b>	Or reverse argument

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

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

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

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



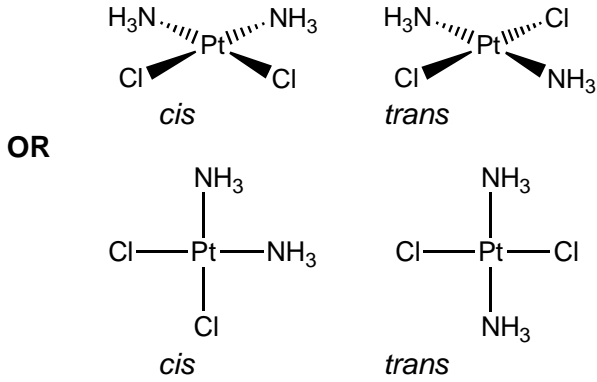
Question	Answer	Marks	Guidance																					
2 (b)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF answer = 185 (J K<sup>-1</sup> mol<sup>-1</sup>) award 2 marks</b></p> <p><i>Conversion of °C to K</i>  <b>AND substitution of values into <math>\Delta G = \Delta H - T\Delta S</math></b>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

Question		Expected answers			Marks	Additional guidance									
3	(a)	NO: 2 /Second AND H <sub>2</sub> : 1 /First AND Overall: 3 /Third ✓			1										
3	(b)	rate × 125 ✓			1	<b>DO NOT ALLOW</b> just 'increases by 5 and then by 25 / 5 <sup>2</sup> <b>OR</b> increases by 5 <sup>3</sup>									
3	(c)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF</b> answer = <math>7.59 \times 10^4</math> award <b>2 marks</b>  <b>THEN IF</b> units are <math>\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}</math>, 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><b>OR</b> 75858.31764 to 3 SF or more ✓</p> <p><i>3 SF and standard form</i>  = <math>7.59 \times 10^4</math> ✓</p> <p><i>units:</i>  <math>\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}</math> ✓</p>			3	<p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p><b>NO ECF</b> from incorrectly rearranged <i>k</i> expression</p> <p><b>ALLOW</b> <math>\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}</math> <b>OR</b> any order  <b>DO NOT ALLOW</b> other units from incorrect <i>k</i> expression  (Rate equation supplied on paper – <b>not</b> 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 <b>column:</b>                      ✓                      ✓</p>	Change	Effect on rate	Effect on <i>k</i>	Increase in pressure	increases	none	Increase in temperature	increases	increases			2	<b>ALL</b> boxes are 'increases' <b>EXCEPT</b> top right is 'none'.
Change	Effect on rate	Effect on <i>k</i>													
Increase in pressure	increases	none													
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Question		Expected answers	Marks	Additional guidance
3	(e)	<p><b>Overall equation must be sum of step 1 and step 2</b></p> <p><b>step 1:</b> <math>\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</math></p> <p><b>overall:</b> <math>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</math></p> <p><b>NO ECF</b> for from <b>incorrect</b> step 1 equation</p>	2	<p><b>IGNORE</b> any state symbols</p> <p><i>For other possible correct responses, contact Team Leader</i></p>
		<b>Total</b>	<b>9</b>	

Question			Answer	Marks	Guidance
4	(a)	(i)	<p><b>Note:</b> Examples must be for V, not other d block elements</p> <p><b>d block element:</b> (3)d is <b>highest energy</b> sub-shell/orbital ✓</p> <p><b>Transition element:</b> has an <b>ion</b> with incomplete/partially-filled <b>d sub-shell/orbital</b> ✓</p> <p><b>V</b> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2</math> ✓ <i>full electron configuration required</i></p> <p><b>V<sup>2+</sup>:</b> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^3</math> ✓ <i>full electron configuration required</i></p>	4	<p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p><b>DO NOT ALLOW</b> highest energy shell</p> <p><b>ALLOW</b> 4s before 3d, ie <math>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3</math> <b>ALLOW</b> upper case D, etc and subscripts, e.g. [Ar]4S<sub>2</sub>3D<sub>3</sub></p> <p><b>DO NOT ALLOW USE OF [Ar]</b> for <math>1s^2 2s^2 2p^6 3s^2 3p^6</math> for configuration of V and V<sup>2+</sup></p> <p><b>ALLOW</b> electron configuration with 4s<sup>0</sup></p>
4	(a)	(ii)	<p><math>VO_3^- + 6H^+ + 3e^- \longrightarrow V^{2+} + 3H_2O</math> ✓</p> <p><math>Zn \longrightarrow Zn^{2+} + 2e^-</math> ✓</p> <p><math>2VO_3^- + 12H^+ + 3Zn \longrightarrow 2V^{2+} + 6H_2O + 3Zn^{2+}</math> ✓</p> <p><b>Multiples of this equation are the ONLY correct answer</b></p>	3	<p><b>ALLOW</b> multiples</p> <p><b>NO ECF</b> from incorrect half equations</p> <p><b>ALLOW</b> multiples, e.g. <math>VO_3^- + 6H^+ + 1\frac{1}{2}Zn \longrightarrow V^{2+} + 3H_2O + 1\frac{1}{2}Zn^{2+}</math></p>

Question			Answer	Marks	Guidance
4	(b)	(i)	Pt: $\text{Pt}^{2+}$ OR +2/2+ <b>AND</b> Cl: $2 \times \text{Cl}^-$ OR $2 \times -1$ OR 2 $\text{Cl}^-/\text{Cl}$ with oxidation number $-1$ ✓	1	<b>DO NOT ALLOW</b> response in terms of ' $\text{Cl}_2$ ' or ' $\text{Cl}$ molecule', rather than $\text{Cl}^-$  <b>DO NOT ALLOW</b> 'charges cancel' without the charges/oxidation numbers involved being stated  <b>DO NOT ALLOW</b> if $\text{NH}_3$ shown to have charge
4	(b)	(ii)	 <p>OR</p> <p>✓✓ For each structure <b>AND</b> correct <i>cis</i> and <i>trans</i> labels</p> <p><b>AWARD</b> 1 mark for <b>TWO</b> correct structures with incorrect <i>cis</i> and <i>trans</i> labels <b>OR</b> no labels.</p> <p>-----</p> <p>Ligands <b>donates</b> electron pairs  <b>OR</b> <math>\text{Pt}/\text{Pt}^{2+}/\text{metal}</math> (ion) <b>accepts</b> lone pairs ✓</p>	3	<b>IGNORE</b> any charge, i.e. $\text{Pt}^{2+}$ OR $\text{Cl}^-$ , even if wrong  Bonds <b>MUST</b> go to <b>N</b> of to $\text{NH}_3$  <b>IGNORE</b> labelled bond angles (even if wrong)  <b>DO NOT ALLOW</b> any structure that cannot be in one plane  If ligands are orientated correctly in <i>cis</i> <b>AND</b> <i>trans</i> , but connectivity to N is poor <b>ALLOW</b> 1 mark for two diagrams  ----- <b>ALLOW</b> 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) <b>OR</b> <i>cis</i> -platin stops (cancer) cells dividing/replicating ✓	1	<b>ALLOW</b> <i>cis</i> -isomer: <i>cis</i> is essential  <b>IGNORE</b> simply ' <i>cis</i> -platin used in cancer treatment'

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

Question	Answer	Marks	Guidance
	<b>Total</b>	<b>19</b>	



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

Question			Answer	Marks	Guidance
5	(a)	(iii)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF answer = 3.22, award 2 marks</b></p> <p>-----</p> <p><math>[H^+] = \sqrt{(1.30 \times 10^{-5}) \times (2.85 \times 10^{-2})}</math></p> <p><b>OR</b> <math>6.09 \times 10^{-4}</math> (mol dm<sup>-3</sup>) ✓</p> <p>pH = <math>-\log 6.09 \times 10^{-4} = 3.22</math> ✓  <i>Must be from a calculated [H<sup>+</sup>]</i></p> <p><b>NOTE:</b> The marks are <b>ONLY</b> available from attempted use of <math>K_a</math> <b>AND</b> [C<sub>2</sub>H<sub>5</sub>COOH]</p>	2	<p><b>ALLOW</b> <math>6.09 \times 10^{-4}</math> to calculator value of <math>6.086871117 \times 10^{-4}</math> correctly rounded</p> <p><b>ALLOW ECF</b> from incorrect [H<sup>+</sup>] derived from <math>K_a</math> <b>AND</b> [H<sup>+</sup>]</p> <p><b>ALLOW</b> use of quadratic equation – gives same answer of 3.22</p> <p>-----</p> <p><b>COMMON ERRORS (MUST be to 2 DP)</b>  Mark other errors by <b>ECF</b></p> <p><b>pH = 6.43 1 mark</b>  <math>-\log(1.30 \times 10^{-5}) \times (2.85 \times 10^{-2})</math>    No <math>\sqrt{\phantom{x}}</math></p> <p><b>pH = 3.16 1 mark</b>  Wrong acid (<math>K_a = 1.70 \times 10^{-5}</math>) but all else correct</p> <p><b>pH = 4.89 0 marks</b>  <math>-\log(1.30 \times 10^{-5}) = 4.89</math>    <math>-\log K_a</math></p> <p><b>pH = 1.55 0 marks</b>  <math>-\log(2.85 \times 10^{-2}) = 4.87</math>    <math>-\log [H^+]</math></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;"> <b>Base 2          Acid 1          Acid 2          Base 1          ✓</b> </p> <p><i>1st mark for correct products, C<sub>2</sub>H<sub>5</sub>COOH<sub>2</sub><sup>+</sup> AND CH<sub>3</sub>COO<sup>-</sup></i></p> <p><i>2nd mark for correct labels</i></p>	2	<p><b>ALLOW ECF</b> for 2nd mark if H<sup>+</sup> 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;"> <b>Acid 1          Base 2          Base 1          Acid 2          ✓ ECF</b> </p> <p><b>NO OTHER ECF</b></p> <p><b>ALLOW</b> A1, B1, etc or any unambiguous labels</p>
5	(b)	(i)	proton/H <sup>+</sup> acceptor ✓	1	<b>DO NOT ALLOW</b> OH <sup>-</sup> donor
5	(b)	(ii)	<p><b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b></p> <p><b>IF</b> answer = 5.35 (g) award <b>3</b> marks</p> <p><math>n(\text{Ba}(\text{OH})_2) = (250/1000) \times 0.1250 = 0.03125 \text{ (mol)} \checkmark</math></p> <p><math>M(\text{Ba}(\text{OH})_2) = 171.3 \text{ (g mol}^{-1}\text{)} \checkmark</math></p> <p>mass = 0.03125 × 171.3 = 5.35 (g) ✓</p> <p><b>NOTE:</b> Answer to <b>two</b> decimal places</p>	3	<b>ALLOW ECF</b> but answer required to <b>two</b> decimal places

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

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

Question		Answer	Marks	Guidance
5	(d)	<ul style="list-style-type: none"> <li>• <b>Quality of written communication, QWC</b></li> <li>• 2 marks are available for explaining how the equilibrium system allows the buffer solution to control the pH on addition of <math>H^+</math> and <math>OH^-</math> (see below)</li> <li>• -----</li> <li>• <math>H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \checkmark</math></li> <li>• -----</li> <li>• <math>H_2CO_3</math> reacts with added alkali / <math>OH^-</math></li> <li>• <b>OR</b> <math>H_2CO_3 + OH^- \rightarrow</math></li> <li>• <b>OR</b> added alkali reacts with <math>H^+</math></li> <li>• <b>OR</b> <math>H^+ + OH^- \rightarrow \checkmark</math></li> </ul> <p>Equilibrium <math>\rightarrow</math> right <b>OR</b> Equilibrium <math>\rightarrow HCO_3^- \checkmark</math> (QWC)</p> <ul style="list-style-type: none"> <li>• <math>HCO_3^-</math> reacts with added acid / <math>H^+ \checkmark</math></li> </ul> <p>Equilibrium <math>\rightarrow</math> left <b>OR</b> Equilibrium <math>\rightarrow H_2CO_3 \checkmark</math> (QWC)</p>	5	<p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p>-----</p> <p><b>Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2</b></p> <p><b>DO NOT ALLOW</b> <math>HA \rightleftharpoons H^+ + A^-</math></p> <p><b>DO NOT ALLOW</b> more than one equilibrium equation.</p> <p>-----</p> <p><b>ALLOW</b> response in terms of <math>H^+</math>, <math>A^-</math> and HA</p> <p><b>IF</b> more than one equilibrium shown, it <b>must</b> be clear which one is being referred to by labeling the equilibria.</p> <p><b>ALLOW</b> weak acid reacts with added alkali</p> <p><b>DO NOT ALLOW</b> acid reacts with added alkali</p> <p><b>ALLOW</b> conjugate base reacts with added acid</p> <p><b>DO NOT ALLOW</b> salt/base reacts with added acid</p>
		<b>Total</b>	<b>22</b>	

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 <b>IGNORE</b> state symbols

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



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

Question			Answer	Marks	Guidance
7	(a)	(i)	<p>complete circuit with voltmeter  <b>AND</b> salt bridge linking two half-cells ✓</p> <p>Cr electrode in Cr<sup>3+</sup> solution ✓</p> <p>Pt electrode in solution containing Fe<sup>2+</sup> <b>AND</b> Fe<sup>3+</sup> ✓</p> <p><b>Conditions</b>      <i>Units essential</i>            (Temperature of) 298 K / 25°C  <b>AND</b> (solution concentrations of) 1 mol dm<sup>-3</sup> ✓            (may be on diagram)</p>	4	<p><b>FULL ANNOTATIONS MUST BE USED</b>            circuit shown <b>must</b> be complete, ie must be capable of working            salt bridge <b>must</b> 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  <b>ALLOW</b> small gaps in circuit</p> <p><b>ALLOW</b> 1M and 1 mol/dm<sup>3</sup>  <b>DO NOT ALLOW</b> 1 mol</p> <p><b>IGNORE</b> pressure      (<i>No gases in this cell</i>)</p>
7	(a)	(ii)	<p>Cr(s) + 3Fe<sup>3+</sup>(aq) → Cr<sup>3+</sup>(aq) + 3Fe<sup>2+</sup>(aq) ✓  <i>State symbols not required</i></p>	1	<p><b>IGNORE</b> state symbols</p> <p><b>ALLOW</b> equilibrium sign providing reactants and products are            on correct sides of equation</p>
7	(a)	(iii)	<p><math>E = 1.51</math> (V)  <b>AND</b>            Sign of Cr electrode: – /negative ✓</p>	1	<p><b>IGNORE</b> sign for <math>E</math></p>
7	(b)		<p><b>Assume Cr<sup>3+</sup> Cr OR Cr half-cell unless otherwise stated.</b></p> <p>[Cr<sup>3+</sup>] increases <b>OR</b> &gt; 1 mol dm<sup>-3</sup> ✓</p> <p>Equilibrium (shown in table) shifts to right <b>OR</b> towards Cr ✓</p> <p>Electrons are removed/used up/fewer electrons released  <b>OR</b></p>	3	<p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p>-----  <b>ALLOW</b> [Cr<sup>3+</sup>] more than standard concentration/1 mol dm<sup>-3</sup>  <b>IGNORE</b> CrCl<sub>3</sub> reacts</p> <p><b>Take care:</b> Response may refer to a <b>reverse</b> half equation            written by candidate. The equilibrium then shifts to left.</p> <p><b>IGNORE</b> comments about <math>E^\ominus</math> changing</p>

Question			Answer	Marks	Guidance
			$E$ (for $\text{Cr}^{3+} \text{Cr}$ ) is less negative / more positive <b>OR</b> The cell has a smaller <b>difference</b> in $E$ ✓		<b>IGNORE</b> 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	<b>ALLOW</b> multiples e.g. $2\text{HCOOH}(\text{l}) \rightarrow 2\text{CO}_2(\text{g}) + 4\text{H}^+ + 4\text{e}^-$
7	(c)	(ii)	$\text{HCOOH}$ is a <b>liquid</b> <b>OR</b> is <b>less</b> volatile <b>AND</b> $\text{HCOOH}$ is easier to store/transport/stored more safely <b>OR</b> $\text{H}_2$ is more explosive/more flammable ✓	1	Assume that 'it' refers to $\text{HCOOH}$ <b>ALLOW ORA</b> throughout <b>IGNORE</b> comments about efficiency <b>IGNORE</b> comments about biomass and renewable
7	(d)	(i)	amount $\text{MnO}_4^-$ used = $0.01500 \times \frac{25.40}{1000}$ = $3.81 \times 10^{-4}$ (mol) ✓ amount $\text{SO}_3^{2-}$ = $3.81 \times 10^{-4} \times 2.5$ = $9.525 \times 10^{-4}$ (mol) ✓ amount $\text{SO}_3^{2-}$ in original $250 \text{ cm}^3$ = $10 \times 9.525 \times 10^{-4}$ = $9.525 \times 10^{-3}$ mol ✓ Mass of $\text{Na}_2\text{SO}_3$ in sample = $126.1 \times 9.525 \times 10^{-3}$ g = <b>1.20 g</b> ✓ $n(\text{H}_2\text{O}) = \frac{2.40 - 1.20}{18.0} = 6.67 \times 10^{-2}$ (mol) ✓	6	<b>FULL ANNOTATIONS MUST BE USED</b> <b>IF</b> a step is omitted but subsequent step subsumes previous, then award mark for any missed step <b>Working: at least 3 SF throughout until final % mark</b> <b>BUT</b> ignore trailing zeroes, ie for 0.01500 allow 0.015/0.0150 ----- <b>ALLOW ECF at all stages</b>  <b>ALLOW</b> $M(\text{hydrated sodium sulfite}) = \frac{2.40}{9.525 \times 10^{-3}} = 252$ ✓  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 = <b><math>\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}</math></b> ✓ <i>Formula is required. 1:7 ratio is insufficient</i>		Number of $\text{H}_2\text{O}$ of crystallisation = $\frac{125.9}{18.0} = 7$ Formula = <b><math>\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}</math></b> ✓
(d)	(ii)	<b>MARK INDEPENDENTLY</b> <b>Except for multiples, equations are only correct answers</b>  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	<b>ALLOW multiples and equilibrium signs throughout</b> <b>IGNORE</b> state symbols throughout  e.g. $\text{MnO}_4^- + 3\text{H}^+ + 2\frac{1}{2}\text{SO}_3^{2-} \rightarrow \text{Mn}^{2+} + 2\frac{1}{2}\text{SO}_4^{2-} + 1\frac{1}{2}\text{H}_2\text{O}$
<b>Total</b>			<b>20</b>	

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