

**GCE**

**Chemistry A**

**H432/01:** Periodic table, elements and physical chemistry

Advanced GCE

**Mark Scheme for June 2019**

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





This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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

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

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Annotations available in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

<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

**Subject-specific Marking Instructions****INTRODUCTION**

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

## SECTION A

Question	Answer	Marks	AO element	Guidance
1	D	1	AO1.1	
2	C	1	AO1.2	
3	A	1	AO2.2	
4	B	1	AO2.8	
5	B	1	AO1.2	
6	D	1	AO1.2	
7	A	1	AO1.1	
8	B	1	AO2.6	
9	B	1	AO1.1	
10	A	1	AO2.2	
11	C	1	AO2.6	
12	D	1	AO1.2	
13	B	1	AO2.1	
14	C	1	AO1.1	
15	C	1	AO2.1	
	<b>Total</b>	<b>15</b>		

## SECTION B

Question		Answer	Marks	AO element	Guidance
16	(a)	s-block <b>AND</b> highest energy <b>or</b> outer <b>electron</b> is in a s orbital <b>or</b> s sub-shell ✓	1	1.1	<b>ALLOW</b> 'outer' or 'valence' for 'highest energy' <b>IGNORE</b> electron configurations <b>DO NOT ALLOW</b> s shell / energy level
	(b)	<b>FIRST CHECK THE ANSWER ON ANSWER LINE</b> <b>If answer = 25.982 award 2 marks</b>  $\frac{78.99 \times 23.985 + 10.00 \times 24.986 + 11.01 \times m}{100} = 24.305 \checkmark$ Relative isotopic mass = 25.982 (must be 5 <b>SF</b> ) ✓	2	2.2 ×2	<b>ALLOW</b> any correct rearrangement of this sum for first mark eg 11.01 x m = 2430.5 – 1894.575 – 249.86  <b>ALLOW</b> ecf for transcription errors in first sum but answer must be 5 sf
	(c)	(i)			
		(i)	1	2.8	<b>ALLOW</b> multiples <b>IGNORE</b> state symbols <b>ALLOW</b> $\text{CaO} + 2\text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{H}_2\text{O}$ <b>AND</b> $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$
		(ii)	1	1.2	<b>ALLOW</b> ranges within these values but ranges must not overlap

Question			Answer	Marks	AO element	Guidance
16	(d)	(i)		4	1.2 × 4	<p>Mark each marking point independently</p> <p>Correct species <b>AND</b> state symbols required for each mark</p> <p>For e<sup>-</sup>, <b>ALLOW</b> e</p> <p>For e<sup>-</sup> <b>only</b>, <b>IGNORE</b> any state symbols added</p>
16		(ii)	<p><b>FIRST CHECK THE ANSWER ON ANSWER LINE</b></p> <p>If answer = <math>-2277 \text{ (kJ mol}^{-1}\text{)}</math> award 2 marks</p>	2	2.2 × 2	<p><b>IF</b> there is an alternative answer, check to see if there is any <b>ECF</b> credit possible using</p>



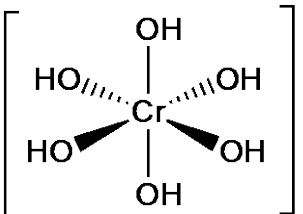
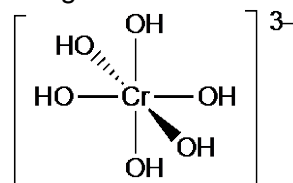
Question			Answer	Marks	AO element	Guidance
			$-363 - (2 \times +89 + 249 + 2 \times 419 - 141 + 790) \checkmark$ $-363 - 1914$ $= -2277 \checkmark \text{ (kJ mol}^{-1}\text{)}$			<p>working below</p> <p><b>See list below for marking of answers from common errors</b></p> <p><b>ALLOW</b> for 1 mark <b>ONE</b> mistake with sign  <b>OR</b> use of 2 ×:  +2277 (wrong sign)  -601 (2 × -419 instead of 2 × +419)  -697 (-790 instead of +790)  -1551 (+363 instead of -363)  -1858 (2 × +419 not used for K)  -1921 (2 × -89 instead of 2 × +89)  -2152.5 or -2153 (+249 ÷ 2)  -2188 (2 × +89 not used for K)  -2280 (rounded to 3SF)  -2559 (+141 instead of -141)</p> <p><b>For other answers</b>, check for a <b>single</b> transcription error or calculator error which could merit 1 mark</p>
16	(e)	(i)	For sodium atomic radius smaller	2	1.1 ×2	<b>ALLOW</b> 'Na/sodium is smaller' <b>IGNORE</b> smaller radius / fewer shells / less

Question			Answer	Marks	AO element	Guidance
			<p><b>OR</b> fewer shells ✓</p> <p>nuclear <b>attraction</b> increases <b>OR</b> (outer) electron(s) experience more <b>attraction</b> ✓</p>			<p>shielding if applied to ions but <b>DO NOT ALLOW</b> responses which refer to ions losing electrons <b>DO NOT ALLOW</b> molecules</p> <p><b>ALLOW</b> energy levels for shells <b>IGNORE</b> fewer orbitals <b>OR</b> fewer sub-shells</p> <p><b>ALLOW less</b> (electron) shielding <b>OR</b> electron repulsion between shells <b>IGNORE</b> just 'shielding'</p> <p><b>ALLOW</b> more/stronger/bigger nuclear attraction etc</p> <p><b>IGNORE</b> 'pull' for attraction <b>IGNORE</b> electrons more tightly held <b>IGNORE</b> 'nuclear charge' for 'nuclear attraction' <b>IGNORE</b> more energy (in question)</p> <p><b>ALLOW</b> reverse argument for potassium throughout</p>
16		(ii)	<b>Comparison of size of cations</b> For sodium ions	2	1.2 x2	comparison of <b>IONS</b> is essential

Question			Answer	Marks	AO element	Guidance
			ionic radius of sodium / Na <sup>+</sup> is smaller ✓  <b>Comparison of attraction of cation and anion</b> Na <sup>+</sup> has stronger attraction to O <sup>2-</sup> ✓			<b>ALLOW</b> Na <sup>+</sup> has a larger charge density  <b>IGNORE</b> 'Na has smaller atomic radius' but <b>DO NOT ALLOW</b> contradictory sentences eg 'Na <sup>+</sup> ions have smaller atomic radius'  <b>IGNORE</b> pull for attraction <b>ALLOW</b> 'sodium ion' and 'oxygen ion' <b>IGNORE</b> just 'oxygen' or just 'O' for oxygen ion  <b>ALLOW</b> stronger attraction between oppositely charged ions
			<b>Total</b>	<b>15</b>		

Question		Answer	Marks	AO element	Guidance
17	(a)	<p><i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i></p> <p><b>Level 3 (5–6 mark)</b> Detailed explanation of equilibrium, the action of the buffer and correct calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p><b>Level 2 (3–4 marks)</b> Detailed explanation of equilibrium <b>and</b> the action of the buffer. <b>OR</b> Detailed explanation of equilibrium <b>and</b> correct calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio. <b>OR</b> Detailed explanation of the action of the buffer <b>and</b> correct calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio. <b>OR</b> Partial explanations of equilibrium, <b>and</b> the action of the buffer <b>and</b> attempt calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p><b>Level 1 (1–2 marks)</b> Detailed explanation of equilibrium. <b>OR</b> Correct calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio. <b>OR</b> Detailed explanation of the action of the buffer. <b>OR</b> Partial explanations of equilibrium <b>and</b> the action of the buffer.'</p>	6	1.1 ×2 1.2 ×2 3.1 ×1 3.2 ×1	<p><b>Indicative scientific points may include:</b> (State symbols not required in equations)</p> <p><b>Equilibrium and equilibrium shifts</b></p> <ul style="list-style-type: none"> <li><math>\text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})</math></li> <li>Addition of <math>\text{H}^+</math> causes <math>\rightleftharpoons</math> to shift to left</li> <li>Addition of <math>\text{OH}^-</math> causes <math>\rightleftharpoons</math> to shift to right</li> </ul> <p><b>Action of buffer</b></p> <ul style="list-style-type: none"> <li>Increase in <math>\text{H}^+</math> / addition of acid leads to: <math>\text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq}) \rightarrow \text{H}_2\text{CO}_3(\text{aq})</math> <b>OR</b> <math>\text{HCO}_3^-</math> reacts with added acid</li> <li>Increase in <math>\text{OH}^-</math> / addition of alkali leads to: <math>\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})</math> <b>OR</b> <math>\text{H}_2\text{CO}_3(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{HCO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l})</math> <b>OR</b> <math>\text{H}_2\text{CO}_3</math> reacts with added alkali</li> </ul> <p><b>Calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio</b></p> <ul style="list-style-type: none"> <li><math>K_a = 10^{-6.38}</math> <b>OR</b> <math>4.17 \times 10^{-7}</math> (mol dm<sup>-3</sup>)</li> <li><math>[\text{H}^+] = 10^{-7.40}</math> <b>OR</b> <math>3.98 \times 10^{-8}</math> (mol dm<sup>-3</sup>)</li> <li><math>\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}</math> <b>OR</b> <math>\frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}}</math></li> <li>ratio = 10.47(:1) <b>OR</b> 10.48(:1) <b>ALLOW</b> 10.5 <b>OR</b> 10(:1) (after working shown)</li> </ul> <p><b>ALLOW</b> <math>\frac{4.2 \times 10^{-7}}{4.0 \times 10^{-8}}</math></p> <p><b>And ratio = 10.5 <b>OR</b> 11 (after working shown)</b></p>

Question			Answer	Marks	AO element	Guidance
			<p><b>OR</b> Partial explanation of equilibrium <b>and</b> attempt at calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio.'</p> <p><b>OR</b> Partial explanation of the action of the buffer and attempt at calculation of <math>[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]</math> ratio. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b> <i>No response or no response worthy of credit.</i></p>			<p><b>ALLOW</b> <math>\frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}</math> <b>OR</b> <math>\frac{3.98 \times 10^{-7}}{4.17 \times 10^{-7}}</math></p> <p><b>And ratio = 1 : 0.095 ..</b></p>
17	(b)		<p><i>Coordinate bond mark</i> <math>\text{O}_2</math> (coordinately or datively) bonds with <math>\text{Fe}^{2+}/\text{Fe}(\text{II})/\text{Fe}/\text{Iron}</math> ✓</p> <p><i>Ligand substitution mark</i> (When required) <math>\text{O}_2</math> is replaced by <math>\text{H}_2\text{O}</math> <b>OR</b> <math>\text{CO}_2</math> <b>OR</b> <math>\text{O}_2</math> is replaced by <math>\text{CO}</math> <b>OR</b> <math>\text{H}_2\text{O}</math> <b>OR</b> <math>\text{CO}_2</math> is replaced by <math>\text{O}_2</math> ✓</p> <p><i>Ligand strength mark</i> <math>\text{CO}</math> forms strong(er) bonds (than <math>\text{O}_2</math>) ✓</p>	3	<p>1.1 ×2</p> <p>2.1 ×1</p>	<p><b>ALLOW</b> names or symbols of ligands <b>ALLOW</b> <math>\text{H}_2\text{O}/\text{CO}/\text{CO}_2</math> (coordinately or datively) bonds with <math>\text{Fe}^{2+}/\text{Fe}(\text{II})/\text{Fe}/\text{Iron}</math> <b>ALLOW</b> oxygen donates electron pair to <b>OR</b> binds with <math>\text{Fe}^{2+}/\text{Fe}(\text{II})/\text{Fe}/\text{Iron}</math> <b>DO NOT ALLOW</b> <math>\text{Fe}^{3+}</math></p> <p><b>ALLOW</b> other words for replaced</p> <p><b>ALLOW</b> <math>K_{\text{stab}}</math> for <math>\text{CO}</math> (much) higher (than for <math>\text{O}_2</math>) <b>ALLOW</b> <math>\text{CO}</math> bonds irreversibly <b>OR</b> <math>\text{CO}</math> is a strong(er) ligand <b>IGNORE</b> affinity</p>
			<b>Total</b>	<b>9</b>		

Question			Answer	Marks	AO element	Guidance
18	(a)	(i)	$[\text{Cr}(\text{NH}_3)_6]^{3+}(\text{aq})$ ✓	1	1.1	<b>IGNORE</b> state symbols
		(ii)	$\text{CrCl}_3(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{NaCl}(\text{aq})$ or $\text{Cr}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$ ✓ state symbols required	1	2.8	<b>IGNORE</b> square brackets around precipitate formulae <b>ALLOW</b> $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{H}_2\text{O}(\text{l})$ <b>ALLOW</b> 'hybrid' equations, Eg $\text{Cr}^{3+}(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{Na}^{+}(\text{aq})$ $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 6\text{H}_2\text{O}(\text{l})$ $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow$ $\text{Cr}(\text{OH})_3(\text{s}) + 6\text{H}_2\text{O}(\text{l}) + 3\text{Na}^{+}(\text{aq})$
		(iii)	 3-D diagram with all bonds through O in OH ✓ 3- charge ✓	2	1.1 2.3	Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper <b>OR</b> 4 lines, 1 'out wedge' and 1 'in wedge':  <b>ALLOW</b> dotted line <b>OR</b> unfilled wedge as alternatives for dotted wedge <b>IGNORE</b> charges inside brackets
		(iv)	$\text{CrO}_4^{2-}$ ✓	1	3.1	<b>IGNORE</b> compounds e.g. $\text{Na}_2\text{CrO}_4$
		(v)	orange ✓	1	1.1	
	(b)	(i)	$(1s^2)2s^22p^63s^23p^63d^2$ ✓	1	1.1	<b>ALLOW</b> upper case D, etc. and subscripts, e.g. $3D_2$ If included, <b>ALLOW</b> $4s^0$
18	b	(ii)	<i>Explanation of colours</i> $\text{VO}^{2+}$ goes to $\text{V}^{3+}$ (green) <b>AND</b> then $\text{V}^{3+}$ goes to $\text{V}^{2+}$	3	3.1 x2	

Question			Answer	Marks	AO element	Guidance
			(violet) ✓  <i>Explanation using E° values</i> (E° of) system 4 (VO <sup>2+</sup> /V <sup>3+</sup> ) is more positive / less negative than system 2 (Fe <sup>2+</sup> /Fe) <b>OR</b> (E° of) system 3 (V <sup>3+</sup> /V <sup>2+</sup> ) is more positive / less negative than system 2 (Fe <sup>2+</sup> /Fe) ✓  <i>Equilibrium shift related to E° values</i> More positive/less negative system 4 (VO <sup>2+</sup> /V <sup>3+</sup> ) shifts right <b>AND</b> More positive/less negative system 3 (V <sup>3+</sup> /V <sup>2+</sup> ) shifts right		3.2 × 1	<b>IGNORE</b> 'lower/higher' <b>ALLOW</b> reverse argument System 2 more negative than system 4 etc E = (+)0.78 V for system 4 + system 2 reaction <b>OR</b> E = (+)0.18 V for system 3 + system 2 reaction  For shifts right' <b>ALLOW</b> (VO <sup>2+</sup> ) is reduced <b>OR</b> gains electrons (maybe seen as an equation) <b>AND</b> 'For shifts right' <b>ALLOW</b> (V <sup>3+</sup> ) is reduced <b>OR</b> gains electrons (maybe seen as an equation) <b>IGNORE</b> Fe oxidised
		(iii)	$\text{Fe} + 4\text{H}^+ + 2\text{VO}^{2+} \rightarrow \text{Fe}^{2+} + 2\text{H}_2\text{O} + 2\text{V}^{3+}$	1	2.8	<b>IGNORE</b> state symbols <b>ALLOW</b> multiples <b>ALLOW</b> '⇌'
	(c)	(i)	(0.00200 mol dm <sup>-3</sup> solution gives) a large titre which leads to a small (percentage) error / uncertainty ✓	1	3.4	<b>ALLOW</b> (0.0200 mol dm <sup>-3</sup> solution gives) a small titre which leads to a large (percentage) error / uncertainty  Assume 'it' means dilute solution  <b>ALLOW</b> 13.50 cm <sup>3</sup> gives a lower percentage error than 1.35 cm <sup>3</sup>
18	c	(ii)	<b>FIRST CHECK THE ANSWER ON ANSWER LINE</b> <b>If answer = 301 mg award 5 marks</b>	5	2.8 × 5	<b>ALLOW ECF</b> throughout  <b>ALLOW</b> working to 3SF <b>minimum</b> throughout

Question	Answer	Marks	AO element	Guidance
	$n(\text{MnO}_4^-) = \frac{13.50}{1000} \times 0.00200 = 2.7(0) \times 10^{-5} \text{ (mol)} \checkmark$ $n(\text{Fe}^{2+}) \text{ (in } 25.0 \text{ cm}^3) = 2.7(0) \times 10^{-5} \times 5 = 1.35 \times 10^{-4} \text{ (mol)} \checkmark$ $n(\text{Fe}^{2+}) \text{ (in } 250 \text{ cm}^3) = 1.35 \times 10^{-4} \times 10 = 1.35 \times 10^{-3} \checkmark$ <p>Mass <math>\text{C}_{12}\text{H}_{22}\text{FeO}_{14}</math> in 2 tablets  <math>= 1.35 \times 10^{-3} \times 445.8 = 0.6018 \text{ (g)} \checkmark</math></p> <p>Mass <math>\text{C}_{12}\text{H}_{22}\text{FeO}_{14}</math> in 1 tablet = 301 (mg)  <b>AND to 3 SF</b> <math>\checkmark</math></p>			<p>Common errors  602 (mg) (not dividing by 2) = 4 marks  37.7 (using 55.8 instead of 445.8) = 4 marks</p> <p>Last mark involves dividing by two and converting g to mg. These steps may be seen earlier</p>
(iii)	<p><b>A:</b> Mass Fe = <math>\frac{180 \times 55.8}{151.8} = 66 \text{ mg}</math></p> <p><b>B:</b> Mass Fe = <math>\frac{210 \times 55.8}{169.8} = 69 \text{ mg}</math></p> <p><b>Iron supplement:</b>  <b>B</b> provides more Fe per tablet <math>\checkmark</math></p>	1	3.1 $\times$ 1	<p><b>ALLOW</b> correct working if iron supplement is not named</p> <p><b>ALLOW</b> iron(II) fumarate or <math>\text{C}_4\text{H}_2\text{FeO}_4</math></p>
		18		

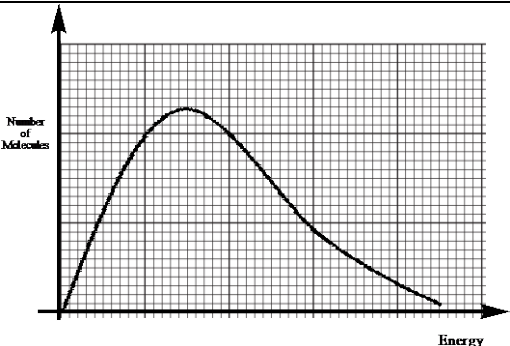


Question			Answer	Marks	AO element	Guidance
19	(a)	(i)	<p><b>More energy is released by forming bonds than energy required when breaking bonds</b>  <b>OR</b>  bond enthalpy of bonds being made is higher than bond enthalpy of bonds being broken ✓</p>	1	1.2	<p>Response needs link between <b>energy, breaking and making bonds</b>  Eg 'bond breaking is endothermic' <b>AND</b> 'bond making is exothermic' <b>AND</b> 'exothermic change outweighs endothermic change'  <b>IGNORE</b> more bonds made than broken</p>
		(ii)	<p><b>FIRST CHECK <math>\Delta G</math></b>  <b>If <math>\Delta G = -1010</math> (<math>\text{kJ mol}^{-1}</math>) award first 3 marks</b></p> $\Delta S = (2 \times 248 + 2 \times 70) - (2 \times 206 + 3 \times 205)$ $= -391 \text{ (J K}^{-1} \text{ mol}^{-1} \text{) OR } -0.391 \text{ (kJ K}^{-1} \text{ mol}^{-1} \text{) } \checkmark$ $\Delta G = \Delta H - T\Delta S = -1125 - (293 \times -0.391) \checkmark$ $= -1010 \text{ (kJ mol}^{-1} \text{) } \checkmark$ <p>Feasible <b>AND</b> <math>\Delta G &lt; 0</math> <b>OR</b> <math>\Delta G</math> is negative ✓</p>	4	<p>2.2 x3</p> <p>3.2 x1</p>	<p><b>ALLOW</b> ecf</p> <p><b>ALLOW</b> <math>-1010000</math> (<math>\text{J mol}^{-1}</math>)  <b>ALLOW</b> 3 SF up to calculator value <math>-1010.437</math></p> <p><b>Common errors</b>  <b>ALLOW:</b>  <b>Two calculation marks for:</b>  <math>-1117</math> to 3 SF up to calculator value of <math>-1117.179865</math>  (use of 20 instead of 293)  <math>(+)</math><math>113438</math> (<math>\text{kJ mol}^{-1}</math>) or 113000, 113400, 113440  (mix of J and kJ)  <math>-1008</math> up to calculator value of <math>-1008.482</math>  (use of <math>T = 298</math>)  <math>-1018</math> up to calculator value of <math>-1018.257</math>  (use of <math>T = 273</math>)</p> <p><b>ALLOW ECF</b> for from incorrect <math>\Delta G</math>,  eg Non feasible <b>AND</b> <math>\Delta G &gt; 0</math> <b>OR</b> <math>\Delta G</math> is +ve</p>
19	a	(iii)	<p><b>FIRST CHECK THE ANSWER ON ANSWER LINE</b>  <b>If answer = <math>-20</math> (<math>\text{kJ mol}^{-1}</math>) award 3 marks</b></p>	3	2.2 x3	

Question		Answer	Marks	AO element	Guidance
		<p>Using Both <math>\Delta_c H^\ominus</math> values multiplied by 2  <math>2 \times (-296.8)</math> or <math>-593.6</math>  <b>AND</b>  <math>2 \times (-285.8)</math> or <math>-571.6</math> (<math>= -1165.2</math>) ✓</p> <p>Use of <math>-1125</math> and correctly processed:  <math>2\Delta_f H(\text{H}_2\text{S}) = [2 \times (-296.8) + 2 \times (-285.8)] - (-1125)</math>  <math>= -40.2</math> (<math>\text{kJ mol}^{-1}</math>) ✓</p> <p>Division by 2  <math>\Delta_f H(\text{H}_2\text{S}) = -20</math> (<math>\text{kJ mol}^{-1}</math>) ✓</p>			<p>First mark may be awarded from data on a cycle</p> <p><b>ALLOW</b> <math>-20.1(0)</math></p> <p><b>ALLOW ECF:</b> third mark is for dividing by 2  <b>and</b> use of all three values</p> <p>Common errors  <b>Two</b> marks for <math>(+20(.1))</math></p> <p><b>ALLOW</b> ecf if <b>no</b> multiplication by two occurred  <math>[(-296.8) + (-285.8)] - (-1125) = (+)542.4</math> for 2<sup>nd</sup> mark</p> <p>Leading to <math>\Delta_f H(\text{H}_2\text{S}) = (+) 271(.2)</math> for 3<sup>rd</sup> mark</p> <p><b>ALLOW</b> <math>-296.8 - 285.8 = -582.6</math> for 1<sup>st</sup> mark if <math>-1125/2</math> <b>OR</b> <math>-562.5</math> is seen in 2<sup>nd</sup> mark</p>
	(b)	(i)			
		$(K_p) = \frac{p(\text{SO}_3)^2(\text{g})}{p(\text{SO}_2(\text{g}))^2 \times p(\text{O}_2(\text{g}))} \checkmark$ <p>atm<sup>-1</sup> ✓</p>	2	1.2 x2	<p><b>ALLOW</b> species without state symbols and without brackets.  e.g., <math>p\text{SO}_3^2</math>, <math>pp\text{SO}_3^2</math>, <math>PSO_3^2</math>, <math>p(\text{SO}_3)^2</math> (<math>p\text{SO}_3</math>)<sup>2</sup> etc.  <b>DO NOT ALLOW</b> square brackets</p> <p><b>ALLOW</b> atm as <b>ECF</b> if <math>K_p</math> is upside down  <b>ALLOW</b> use of any pressure unit  eg Pa<sup>-1</sup> or kPa<sup>-1</sup></p>

Question			Answer	Marks	AO element	Guidance
19	b	(ii)	<p><b>FIRST CHECK THE ANSWER ON ANSWER LINE if answer = 27.2 award 5 marks</b></p> <p>-----</p> <p><b>Initial amounts</b>  <math>n(\text{SO}_2) = \left(\frac{10.2}{24.0}\right) = 0.425 \text{ (mol) AND}</math>  <math>n(\text{O}_2) = \left(\frac{12}{32.0}\right) = 0.375 \text{ (mol) } \checkmark</math></p> <p><b>Equilibrium amounts in moles</b>  <math>n(\text{SO}_2) = (0.425 - 0.350) = 0.075 \text{ (mol) AND}</math>  <math>n(\text{O}_2) = (0.375 - 0.350/2) = 0.200 \text{ (mol) } \checkmark</math></p> <p><b>Total moles</b>  <math>n_{\text{tot}} = 0.625 \text{ (mol) } \checkmark</math></p> <p><b>Partial pressures</b>  <math>p_{\text{SO}_2} = \left(\frac{0.075}{0.625}\right) \times 2.50 = 0.3 \text{ (atm) AND}</math>  <math>p_{\text{O}_2} = \left(\frac{0.2}{0.625}\right) \times 2.50 = 0.8 \text{ (atm) AND}</math>  <math>p_{\text{SO}_3} = \left(\frac{0.350}{0.625}\right) \times 2.50 = 1.4 \text{ (atm) } \checkmark</math></p> <p><b><math>K_p</math> to 3 SF</b>  <math>(K_p = \frac{1.4^2}{0.3^2 \times 0.8}) = 27.2 \text{ (atm}^{-1}\text{) } \checkmark</math></p>	5	2.6 x5	<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> <p><i>Common errors</i>  Allow 4 marks for 1.45/1.46 (depending upon rounding)  <i>Initial amounts</i>  <math>n(\text{SO}_2) = 2 \times n(\text{O}_2)</math>  <math>n(\text{O}_2) = 0.375</math> and <math>n(\text{SO}_2) = 0.75(0)</math>  <i>Equilibrium moles</i>  <math>n(\text{SO}_2) 0.75 - 0.350 = 0.4(0)</math>  <math>n(\text{O}_2) = 0.2(0)</math>  <i>total moles</i>  <math>n_{\text{tot}} = 0.95</math>  <i>partial pressures</i>  <math>p_{\text{SO}_2} = 1.05</math>  <math>p_{\text{O}_2} = 0.526</math>  <math>p_{\text{SO}_3} = 0.921</math></p> <p>Allow 4 marks for <b>15.1/15.0</b>  <i>Initial amounts</i>  <math>n(\text{O}_2) = 12/16 = 0.75</math>  <i>Equilibrium moles</i>  <math>n(\text{O}_2) = 0.575</math>  <i>total moles</i>  <math>n_{\text{tot}} = 1.00</math>  <i>partial pressures</i>  <math>p_{\text{SO}_2} = 0.188</math>  <math>p_{\text{O}_2} = 1.438</math>  <math>p_{\text{SO}_3} = 0.88</math></p> <p><b>IGNORE</b> units</p>

Question			Answer	Marks	AO element	Guidance
19	b	(iii)	(greater $K_p$ value means) equilibrium position shifted to right/RHS ✓  Lower temperature because (forward) reaction is exothermic ✓	2	3.2 ×2	<b>ALLOW</b> greater/higher amount of $\text{SO}_3$ /product <b>ALLOW</b> greater $K_p$ means larger numerator
		(iv)	equilibrium position (far) to the right ✓	1	3.2	<b>ALLOW</b> (very) high yield of products or of $\text{SO}_3$ <b>ALLOW</b> reaction is nearly complete / irreversible <b>ALLOW</b> Forward reaction is (greatly) favored <b>ALLOW</b> (far) more product(s) than reactant(s) or <b>ALLOW</b> equilibrium (greatly) favours product

Question			Answer	Marks	AO element	Guidance
19	(c)	(i)	 <p><b>Correct drawing of Boltzmann distribution</b> Curve starts within one small square of origin <b>AND</b> not touching the x axis at high energy ✓</p> <p><b>Axes labels:</b> y: (number of) molecules/particles <b>AND</b> x: (kinetic) energy ✓</p> <p><b>Catalyst and activation energy</b> Catalyst provides a lower activation energy <b>OR</b> <math>E_c</math> shown to the left of <math>E_a</math> on Boltzmann distribution ✓</p> <p><b>Particles with <math>E &gt; E_a</math></b> more or a greater proportion of molecules / particles / collisions have (energy above) activation energy (with catalyst) <b>OR</b> more molecules have enough energy to react <b>OR</b> greater area under curve above activation energy ✓</p>	4	1.1 ×4	<p><b>DO NOT ALLOW</b> two curves <i>Confusion with effect of temperature</i></p> <p><b>DO NOT ALLOW</b> 'enthalpy' for x-axis label <b>DO NOT ALLOW</b> 'atoms' as y-axis label</p> <p><b>ALLOW ECF</b> for atoms (instead of molecules/particles) if y axis labelled as 'atoms'</p> <p><b>IGNORE</b> (more) successful collisions <b>IGNORE</b> response implying 'more collisions' <i>(confusion with effect of greater temperature)</i></p>
		(ii)	heterogeneous (catalyst) <b>AND</b> catalyst in a different phase/state (from other substances) ✓	1	1.2	<b>ALLOW</b> catalyst is a solid <b>AND</b> not a gas / everything else is a gas
			<b>Total</b>	<b>23</b>		

Question			Answer	Marks	AO element	Guidance
20	(a)		<p><b>FIRST CHECK THE ANSWER ON ANSWER LINE</b>  <b>If answer = 2.98 award 2 marks</b></p> <p>-----</p> $[H^+] = \sqrt{K_a \times [C_2H_5COOH]} = 1.039 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark$ $pH = -\log 1.039 \times 10^{-3} = 2.98 \text{ (Must be to 2 DP)} \checkmark$	2	2.2 x2	<p><b>ALLOW ECF</b> throughout</p> <p><b>ONLY ALLOW</b> pH mark by <b>ECF</b> if <math>K_a</math> <b>AND</b> 0.080 used and <b>AND</b> pH &lt;7</p> <p><b>Common errors (Must be to 2 DP)</b>            One mark for pH = 5.97 (<i>No square root</i>):</p> <p>One mark for pH = 0.92 <b>OR</b> pH = 5.15 (<i>Using incorrect <math>K_a</math> values</i>)</p>
	(b)	(i)	$n(C_2H_5COOH) = (0.0800 \times \frac{25.0}{1000}) = 0.002 \text{ (mol)}$ <p><b>AND</b></p> $V(NaOH) = \frac{0.002}{0.100} \times 1000 = 20.0 \text{ (cm}^3\text{)} \checkmark$	1	2.5	<p><b>ALLOW</b> 0.02 dm<sup>3</sup> if unit given</p> <p>Mark is for <b>WORKING</b> which could all be shown as 1 step</p> <p><b>ALLOW</b> method showing 20cm<sup>3</sup> NaOH contains the same moles as acid  <math>n(C_2H_5COOH) = 0.08(00) \times 0.025(0) = 0.002 \text{ (mol)}</math>            and  <math>n(NaOH) = 0.02(00) \times 0.1 = 0.002(00) \text{ (mol)}</math></p>
20	b	(ii)	<b>FIRST CHECK THE ANSWER ON ANSWER LINE</b>	4		<b>ALLOW ECF</b> throughout

Question			Answer	Marks	AO element	Guidance
			<p>If answer = 12.55 award 4 marks</p> <p>-----</p> <p><b>Excess mol of NaOH:</b></p> $n(\text{OH}^-)_{\text{excess}} = n(\text{OH}^-) - n(\text{C}_2\text{H}_5\text{COOH})$ $= (0.100 \times \frac{45.0}{1000}) - (0.0800 \times \frac{25.0}{1000})$ $= 0.0045 - 0.002 = 0.0025 \text{ (mol)} \checkmark$ <p><b>Concentration of OH<sup>-</sup>:</b></p> $[\text{OH}^-] = (\frac{0.0025}{70.0 \times 10^{-3}}) = 0.0357 \text{ (mol dm}^{-3}\text{)} \checkmark$ <p><b>Concentration of H<sup>+</sup>:</b></p> $[\text{H}^+] = (\frac{1.00 \times 10^{-14}}{0.0357}) = 2.8 \times 10^{-13} \text{ (mol dm}^{-3}\text{)} \checkmark$ <p><b>Conversion to pH:</b></p> $\text{pH} = (-\log 2.8 \times 10^{-13}) = 12.55 \checkmark$			<p>For first mark <b>ALLOW</b> (Excess volume of NaOH = 25(.0) cm<sup>3</sup>)  <math>n(\text{OH}^-)_{\text{excess}} = 0.100 \times \frac{25.0}{1000} = 0.0025 \text{ (mol)}</math></p> <p>Common errors            If initial V(NaOH) = 45 cm<sup>3</sup>  <math>[\text{OH}^-] = 0.0643 \text{ (mol)}</math>  <math>[\text{H}^+] = 1.56 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}</math>            pH = 12.81 award three marks (no 1<sup>st</sup> mark)</p> <p>If <math>n(\text{OH}^-)_{\text{excess}}</math> is used in <math>[\text{H}^+]</math> calculation  <math>n(\text{OH}^-)_{\text{excess}} = 0.0025 \text{ (mol)}</math>  <math>[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.(00) \times 10^{-12} \text{ (mol dm}^{-3}\text{)}</math>            pH = 11.40 award three marks (no 2<sup>nd</sup> mark)</p> <p><b>ALLOW</b> pOH method for last two marks  <math>\text{pOH} = -\log[\text{OH}^-] = 1.447</math>  <math>\text{pH} = 14 - 1.447 = 12.55</math></p> <p><b>ALLOW</b> ECF for conversion from <math>[\text{H}^+]</math> to pH provided value calculated is above 7 and from derived <math>[\text{H}^+]</math></p>
20	b	(iii)	Shape	3	2.3 x1	If pH curves wrong way round (i.e. adding acid to

Question		Answer	Marks	AO element	Guidance
		<p>Slight rise/flat, <b>AND</b> (near) vertical, <b>AND</b> then slight rise/flat ✓</p> <p><b>pH</b> Vertical section within the extremes of pH 5 to 12 and a minimum range of three pH units <b>AND</b> middle of vertical section (equivalence point) needs to be above pH 7 ✓</p> <p><b>End point</b> Vertical section at ~ 20 cm<sup>3</sup> NaOH ✓</p>		2.4 × 2	alkali), <b>ONLY</b> award mark for End point (~ 20 cm <sup>3</sup> )
	(iv)	<p>cresol purple</p> <p><b>AND</b> pH range matches vertical section/rapid pH change <b>OR</b> end point/colour change matches vertical section/rapid pH change ✓</p>	1	3.3	<p><b>ALLOW</b> pH range (of the indicator) matches equivalence point <b>ALLOW</b> end point/colour change matches equivalence point <b>IGNORE</b> colour change matches end point <i>Colour change is the same as end point</i></p>
	(v)	<p><b>similarity:</b> end point / volume (20 cm<sup>3</sup>) of NaOH needed to neutralise <b>OR</b> final pH / shape of curve after end point ✓</p> <p><b>difference:</b> HCN higher <b>starting</b> pH <b>OR</b> HCN shorter vertical section ✓</p>	2	3.2 × 2	<p>End point must not refer to same pH</p> <p><b>ALLOW</b> different equivalence point <b>IGNORE</b> different starting pH</p>



Question		Answer	Marks	AO element	Guidance
20	(c)	<p>HIO<sub>3</sub> dissociation is not negligible / dissociates to a significant extent</p> <p><b>OR</b></p> <p>Large <math>K_a</math> and HIO<sub>3</sub> is 'stronger' (weak) acid</p> <p><b>OR</b></p> <p><math>[HIO_3]_{eqm}</math> is significantly lower than <math>[HIO_3]_{initial/undissociated}</math> ✓</p>	1	3.3	<p><b>ALLOW</b> use of HA</p> <p><b>Ignore</b> <math>[HIO_3]_{equilibrium} &lt; [HIO_3]_{initial/undissociated}</math></p> <p><b>ALLOW</b></p> <p><math>[HIO_3]_{equilibrium} \sim [HIO_3]_{undissociated}</math> is no longer a valid assumption</p> <p><b>ALLOW</b></p> <p><math>[HIO_3]</math> has a larger <math>K_a</math> so the assumption that <math>[HIO_3]</math> at equilibrium = <math>[HIO_3]</math> initially so assumption is not valid</p>
<b>Total</b>			<b>15</b>		

Question	Answer	Marks	AO element	Guidance
21	<p><b>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</b></p> <p><b>Level 3 (5–6 marks)</b> Most evidence used to determine the correct orders <b>AND</b> rate equation <b>AND</b> rate constant. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p><b>Level 2 (3–4 marks)</b> Some evidence used to determine two orders correctly <b>AND</b> rate equation <b>AND</b> rate constant consistent with orders. <b>OR</b> Little evidence used to determine all three orders correctly <b>AND</b> rate equation <b>AND</b> rate constant. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i></p> <p><b>Level 1 (1–2 marks)</b> Little evidence used to determine two orders correctly <b>OR</b> One order correct, with attempt to determine the rate equation <b>AND</b> rate constant. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p><b>0 marks</b> <i>No response or no response worthy of credit.</i></p>	6	3.1 ×4 3.2 ×2	<p>Indicative scientific points may include:</p> <p><b>Orders</b></p> <p><b>Student 1</b></p> <ul style="list-style-type: none"> <li>• zero order wrt Br<sub>2</sub></li> </ul> <p><b>Student 2</b></p> <ul style="list-style-type: none"> <li>• 1st order wrt CH<sub>3</sub>COCH<sub>3</sub></li> </ul> <p><b>Student 3</b></p> <ul style="list-style-type: none"> <li>• 1st order wrt H<sup>+</sup></li> </ul> <p><b>Explanations</b></p> <p><b>Student 1</b></p> <ul style="list-style-type: none"> <li>• constant gradient <b>OR</b> linear negative gradient <b>OR</b> constant rate <b>OR</b> rate independent of concentration <b>OR</b> decreasing half-life</li> </ul> <p><b>Student 2</b></p> <ul style="list-style-type: none"> <li>• straight line through 0,0</li> <li>• <b>OR</b> rate directly proportional to [CH<sub>3</sub>COCH<sub>3</sub>] <b>OR</b> [CH<sub>3</sub>COCH<sub>3</sub>] × 2, rate × 2</li> </ul> <p><b>Student 3</b></p> <ul style="list-style-type: none"> <li>• [H<sup>+</sup>] × 2, rate × 2</li> </ul> <p><b>Rate equation, rate constant and units</b></p> <ul style="list-style-type: none"> <li>• rate = k[CH<sub>3</sub>COCH<sub>3</sub>][H<sup>+</sup>] <b>ALLOW</b> rate = k[Br<sub>2</sub>]<sup>0</sup>[CH<sub>3</sub>COCH<sub>3</sub>]<sup>1</sup>[H<sup>+</sup>]<sup>1</sup></li> <li>• <math>k = \frac{\text{rate}}{[\text{CH}_3\text{COCH}_3][\text{H}^+]}</math> <b>OR</b> <math>\frac{1.25 \times 10^{-5}}{1.6 \times 0.2}</math></li> <li>• <math>k = 3.9... \times 10^{-5}</math></li> <li>• units: dm<sup>3</sup> mol<sup>-1</sup> s<sup>-1</sup> (Any order, e.g. mol<sup>-1</sup> dm<sup>3</sup> s<sup>-1</sup>)</li> </ul>
	<b>Total</b>	<b>6</b>		

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