

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).

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

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	
	Total	15		

SECTION B

Question			Answer	Marks	AO element	Guidance
16	(a)		s-block AND highest energy or outer electron is in a s orbital or s sub-shell ✓	1	1.1	ALLOW 'outer' or 'valence' for 'highest energy' IGNORE electron configurations DO NOT ALLOW s shell / energy level
	(b)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 25.982 award 2 marks $\frac{78.99 \times 23.985 + 10.00 \times 24.986 + 11.01 \times m}{100} = 24.305 \checkmark$ Relative isotopic mass = 25.982 (must be 5 SF) ✓	2	2.2 × 2	ALLOW any correct rearrangement of this sum for first mark eg $11.01 \times m = 2430.5 - 1894.575 - 249.86$ ALLOW ecf for transcription errors in first sum but answer must be 5 sf
	(c)	(i)	$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 \checkmark$	1	2.8	ALLOW multiples IGNORE state symbols ALLOW $\text{CaO} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2\text{O}$ AND $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$
		(ii)	both pH values > 7 AND ≤ 14 AND pH with SrO > pH with CaO ✓	1	1.2	ALLOW ranges within these values but ranges must not overlap

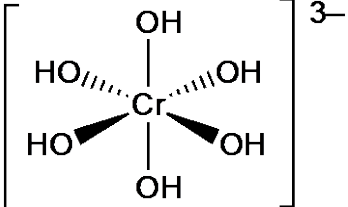
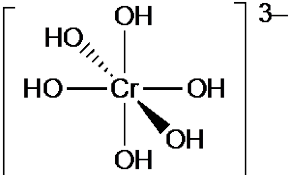
Question			Answer	Marks	AO element	Guidance
16	(d)	(i)	Energy level diagram showing the formation of $2K^+(g) + O^{2-}(g)$ from $2K(s) + \frac{1}{2}O_2(g)$. The diagram includes intermediate states $2K(g) + O(g)$ and $2K^+(g) + O^-(g) + e^-$.	4	1.2 × 4	Mark each marking point independently Correct species AND state symbols required for each mark For e^-, ALLOW e For e^- only, IGNORE any state symbols added
16		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $-2277 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks	2	2.2 × 2	IF there is an alternative answer, check to see if there is any ECF credit possible using

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

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

Question		Answer	Marks	AO element	Guidance
17	(a)	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 mark) Detailed explanation of equilibrium, the action of the buffer and correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Detailed explanation of equilibrium and the action of the buffer. OR Detailed explanation of equilibrium and correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. OR Detailed explanation of the action of the buffer and correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. OR Partial explanations of equilibrium, and the action of the buffer and attempt calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Detailed explanation of equilibrium. OR Correct calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. OR Detailed explanation of the action of the buffer. OR Partial explanations of equilibrium and the action of the buffer.'	6	1.1 ×2 1.2 ×2 3.1 ×1 3.2 ×1	Indicative scientific points may include: (State symbols not required in equations) Equilibrium and equilibrium shifts $\text{H}_2\text{CO}_3(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$ - Addition of H^+ causes $\rightleftharpoons$ to shift to left - Addition of OH^- causes $\rightleftharpoons$ to shift to right Action of buffer - Increase in H^+ / addition of acid leads to: $\text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq}) \rightarrow \text{H}_2\text{CO}_3(\text{aq})$ OR HCO_3^- reacts with added acid - Increase in OH^- / addition of alkali leads to: $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$ OR $\text{H}_2\text{CO}_3(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{HCO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$ OR H_2CO_3 reacts with added alkali Calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio $K_a = 10^{-6.38}$ OR $4.17 \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ $[\text{H}^+] = 10^{-7.40}$ OR $3.98 \times 10^{-8} \text{ (mol dm}^{-3}\text{)}$ $\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$ OR $\frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}}$ - ratio = 10.47(:1) OR 10.48(:1) ALLOW 10.5 OR 10(:1) (after working shown) ALLOW $\frac{4.2 \times 10^{-7}}{4.0 \times 10^{-8}}$ And ratio = 10.5 OR 11 (after working shown)

Question			Answer	Marks	AO element	Guidance
			OR Partial explanation of equilibrium and attempt at calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio.' OR Partial explanation of the action of the buffer and attempt at calculation of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ ratio. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>			ALLOW $\frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}$ OR $\frac{3.98 \times 10^{-7}}{4.17 \times 10^{-7}}$ And ratio = 1 : 0.095 ..
17	(b)		<i>Coordinate bond mark</i> O_2 (coordinately or datively) bonds with $\text{Fe}^{2+}/\text{Fe(II)}/\text{Fe}/\text{Iron}$ ✓ <i>Ligand substitution mark</i> (When required) O_2 is replaced by H_2O OR CO_2 OR O_2 is replaced by CO OR H_2O OR CO_2 is replaced by O_2 ✓ <i>Ligand strength mark</i> CO forms strong(er) bonds (than O_2) ✓	3	1.1 ×2 2.1 ×1	ALLOW names or symbols of ligands ALLOW $\text{H}_2\text{O}/\text{CO}/\text{CO}_2$ (coordinately or datively) bonds with $\text{Fe}^{2+}/\text{Fe(II)}/\text{Fe}/\text{Iron}$ ALLOW oxygen donates electron pair to OR binds with $\text{Fe}^{2+}/\text{Fe(II)}/\text{Fe}/\text{Iron}$ DO NOT ALLOW Fe^{3+} ALLOW other words for replaced ALLOW K_{stab} for CO (much) higher (than for O_2) ALLOW CO bonds irreversibly OR CO is a strong(er) ligand IGNORE affinity
			Total	9		

Question			Answer	Marks	AO element	Guidance
18	(a)	(i)	$[\text{Cr}(\text{NH}_3)_6]^{3+}(\text{aq})$ ✓	1	1.1	IGNORE 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	IGNORE square brackets around precipitate formulae ALLOW $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{H}_2\text{O}(\text{l})$ ALLOW '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 OR 4 lines, 1 'out wedge' and 1 'in wedge':  ALLOW dotted line OR unfilled wedge as alternatives for dotted wedge IGNORE charges inside brackets
		(iv)	CrO_4^{2-} ✓	1	3.1	IGNORE compounds e.g. Na_2CrO_4
		(v)	orange ✓	1	1.1	
	(b)	(i)	$(1s^2)2s^22p^63s^23p^63d^2$ ✓	1	1.1	ALLOW upper case D, etc. and subscripts, e.g. 3D_2 If included, ALLOW $4s^0$
18	b	(ii)	<i>Explanation of colours</i> VO^{2+} goes to V^{3+} (green) AND then V^{3+} goes to V^{2+}	3	3.1 × 2	

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

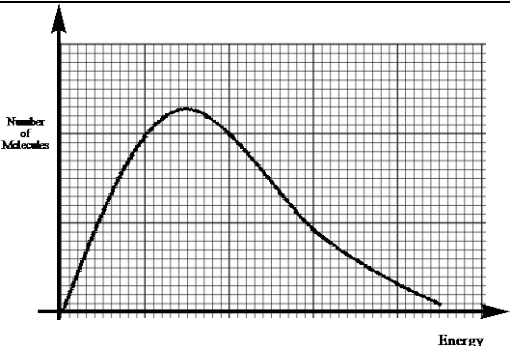
Question			Answer	Marks	AO element	Guidance
			$n(\text{MnO}_4^-) = \frac{13.50}{1000} \times 0.00200 = 2.7(0) \times 10^{-5} \text{ (mol)} \checkmark$ $n(\text{Fe}^{2+}) \text{ (in } 25.0 \text{ cm}^3) = 2.7(0) \times 10^{-5} \times 5 = 1.35 \times 10^{-4} \text{ (mol)} \checkmark$ $n(\text{Fe}^{2+})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

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

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

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

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	ALLOW greater/higher amount of SO_3 /product ALLOW greater K_p means larger numerator
		(iv)	equilibrium position (far) to the right ✓	1	3.2	ALLOW (very) high yield of products or of SO_3 ALLOW reaction is nearly complete / irreversible ALLOW Forward reaction is (greatly) favored ALLOW (far) more product(s) than reactant(s) or ALLOW equilibrium (greatly) favours product

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

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

Question			Answer	Marks	AO element	Guidance
			If answer = 12.55 award 4 marks ----- Excess mol of NaOH: $n(\text{OH}^-)_{\text{excess}} = n(\text{OH}^-) - n(\text{C}_2\text{H}_5\text{COOH})$ $= (0.100 \times \frac{45.0}{1000}) - (0.0800 \times \frac{25.0}{1000})$ $= 0.0045 - 0.002 = 0.0025 \text{ (mol)} \checkmark$ Concentration of OH⁻: $[\text{OH}^-] = (\frac{0.0025}{70.0 \times 10^{-3}}) = 0.0357 \text{ (mol dm}^{-3}\text{)} \checkmark$ Concentration of H⁺: $[\text{H}^+] = (\frac{1.00 \times 10^{-14}}{0.0357}) = 2.8 \times 10^{-13} \text{ (mol dm}^{-3}\text{)} \checkmark$ Conversion to pH: $\text{pH} = (-\log 2.8 \times 10^{-13}) = 12.55 \checkmark$			For first mark ALLOW (Excess volume of NaOH = 25(.0) cm³) $n(\text{OH}^-)_{\text{excess}} = 0.100 \times \frac{25.0}{1000} = 0.0025 \text{ (mol)}$ Common errors If initial V(NaOH) = 45 cm³ $[\text{OH}^-] = 0.0643 \text{ (mol)}$ $[\text{H}^+] = 1.56 \times 10^{-13} \text{ (mol dm}^{-3}\text{)}$ pH = 12.81 award three marks (no 1st mark) If $n(\text{OH}^-)_{\text{excess}}$ is used in $[\text{H}^+]$ calculation $n(\text{OH}^-)_{\text{excess}} = 0.0025 \text{ (mol)}$ $[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.(00) \times 10^{-12} \text{ (mol dm}^{-3}\text{)}$ pH = 11.40 award three marks (no 2nd mark) ALLOW pOH method for last two marks $\text{pOH} = -\log[\text{OH}^-] = 1.447$ $\text{pH} = 14 - 1.447 = 12.55$ ALLOW ECF for conversion from $[\text{H}^+]$ to pH provided value calculated is above 7 and from derived $[\text{H}^+]$
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
			Slight rise/flat, AND (near) vertical, AND then slight rise/flat ✓ pH Vertical section within the extremes of pH 5 to 12 and a minimum range of three pH units AND middle of vertical section (equivalence point) needs to be above pH 7 ✓ End point Vertical section at ~ 20 cm³ NaOH ✓		2.4 × 2	alkali), ONLY award mark for End point (~ 20 cm ³)
		(iv)	cresol purple AND pH range matches vertical section/rapid pH change OR end point/colour change matches vertical section/rapid pH change ✓	1	3.3	ALLOW pH range (of the indicator) matches equivalence point ALLOW end point/colour change matches equivalence point IGNORE colour change matches end point <i>Colour change is the same as end point</i>
		(v)	similarity: end point / volume (20 cm³) of NaOH needed to neutralise OR final pH / shape of curve after end point ✓ difference: HCN higher starting pH OR HCN shorter vertical section ✓	2	3.2 × 2	End point must not refer to same pH ALLOW different equivalence point IGNORE different starting pH

Question			Answer	Marks	AO element	Guidance
20	(c)		HIO_3 dissociation is not negligible / dissociates to a significant extent OR Large K_a and HIO_3 is 'stronger' (weak) acid OR $[\text{HIO}_3]_{\text{eqm}}$ is significantly lower than $[\text{HIO}_3]_{\text{initial/undissociated}}$ ✓	1	3.3	ALLOW use of HA Ignore $[\text{HIO}_3]_{\text{equilibrium}} < [\text{HIO}_3]_{\text{initial/undissociated}}$ ALLOW $[\text{HIO}_3]_{\text{equilibrium}} \sim [\text{HIO}_3]_{\text{undissociated}}$ is no longer a valid assumption ALLOW $[\text{HIO}_3]$ has a larger K_a so the assumption that $[\text{HIO}_3]_{\text{at equilibrium}} = [\text{HIO}_3]_{\text{initially}}$ so assumption is not valid
			Total	15		

Question	Answer	Marks	AO element	Guidance
21	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) Most evidence used to determine the correct orders AND rate equation AND 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> Level 2 (3–4 marks) Some evidence used to determine two orders correctly AND rate equation AND rate constant consistent with orders. OR Little evidence used to determine all three orders correctly AND rate equation AND 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> Level 1 (1–2 marks) Little evidence used to determine two orders correctly OR One order correct, with attempt to determine the rate equation AND 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> 0 marks <i>No response or no response worthy of credit.</i>	6	3.1 ×4 3.2 ×2	Indicative scientific points may include: Orders Student 1 • zero order wrt Br₂ Student 2 • 1st order wrt CH₃COCH₃ Student 3 • 1st order wrt H⁺ Explanations Student 1 • constant gradient OR linear negative gradient OR constant rate OR rate independent of concentration OR decreasing half-life Student 2 • straight line through 0,0 • OR rate directly proportional to [CH₃COCH₃] OR [CH₃COCH₃] × 2, rate × 2 Student 3 • [H⁺] × 2, rate × 2 Rate equation, rate constant and units • rate = k [CH₃COCH₃] [H⁺] ALLOW rate = k [Br₂]⁰ [CH₃COCH₃]¹ [H⁺]¹ • $k = \frac{\text{rate}}{[\text{CH}_3\text{COCH}_3][\text{H}^+]}$ OR $\frac{1.25 \times 10^{-5}}{1.6 \times 0.2}$ • $k = 3.9... \times 10^{-5}$ • units: dm³ mol⁻¹ s⁻¹ (Any order, e.g. mol⁻¹ dm³ s⁻¹)
	Total	6		

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