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.

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**.

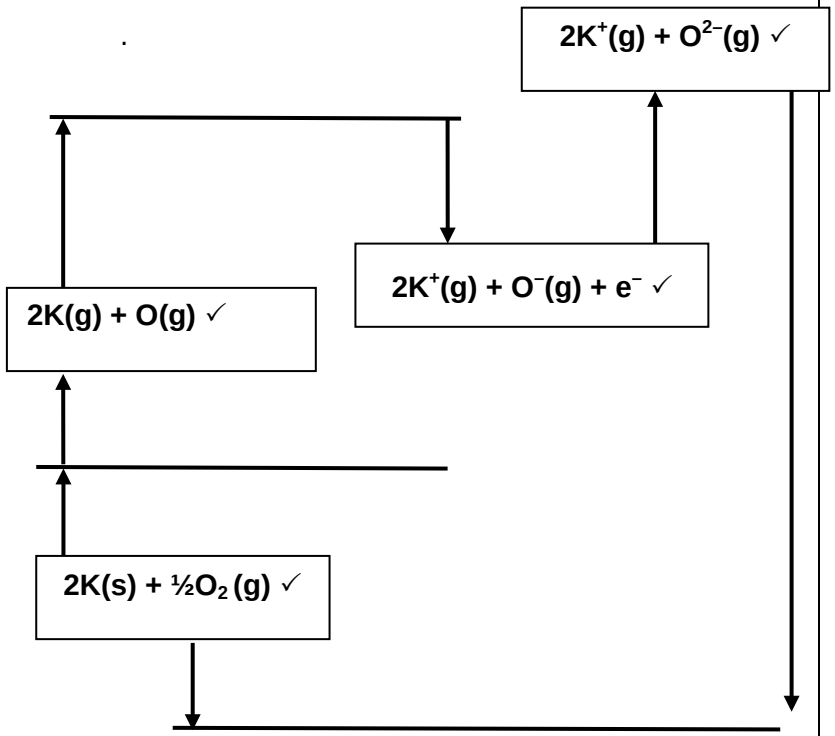
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

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** $\frac{78.99 \times 23.985 + 10.00 \times 24.986 + 11.01 \times m}{100} = 24.305$ ✓ 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 x m = 2430.5 – 1894.575 – 249.86 **ALLOW** ecf for transcription errors in first sum but answer must be 5 sf
	(c)	(i)	$CaO + H_2O \rightarrow Ca(OH)_2$ ✓	1	2.8	**ALLOW** multiples **IGNORE** state symbols **ALLOW** $CaO + 2H_2O \rightarrow Ca(OH)_2 + H_2O$ **AND** $CaO + H_2O \rightarrow Ca^{2+} + 2OH^-$
		(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)		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 (kJ mol^{-1}) award 2 marks**	2	2.2 ×2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using

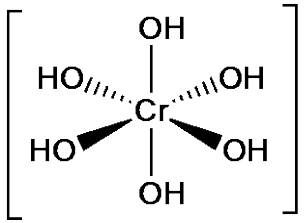
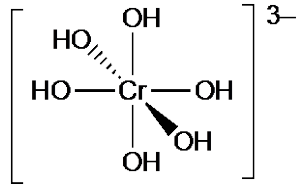
Question			Answer	Marks	AO element	Guidance
			–363 – (2 × +89 +249 + 2 × 419 – 141 + 790) ✓ –363 – 1914 = –2277 ✓ (kJ mol^{-1})			working below **See list below for marking of answers from common errors** **ALLOW** for 1 mark **ONE** mistake with sign **OR** use of 2 ×: +2277 (wrong sign) –601 (2 × –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) **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 ×2**	**ALLOW** 'Na/sodium is smaller' **IGNORE** smaller radius / fewer shells / less

Question			Answer	Marks	AO element	Guidance
			OR fewer shells ✓			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'
			nuclear **attraction** increases **OR** (outer) electron(s) experience more **attraction** ✓			**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 ×2**	comparison of **IONS** is essential

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

Question			Answer	Marks	AO element	Guidance
17	(a)		***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 mark)** Detailed explanation of equilibrium, the action of the buffer and correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Detailed explanation of equilibrium **and** the action of the buffer. **OR** Detailed explanation of equilibrium **and** correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. **OR** Detailed explanation of the action of the buffer **and** correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. **OR** Partial explanations of equilibrium, **and** the action of the buffer **and** attempt calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Detailed explanation of equilibrium. **OR** Correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ 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** • $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ • Addition of H^+ causes ⇌ to shift to left • Addition of OH^- causes ⇌ to shift to right **Action of buffer** • Increase in H^+ / addition of acid leads to: $H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$ **OR** HCO_3^- reacts with added acid • Increase in OH^- / addition of alkali leads to: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ **OR** $H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$ **OR** H_2CO_3 reacts with added alkali **Calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio** • $K_a = 10^{-6.38}$ **OR** 4.17×10^{-7} (mol dm^{-3}) • $[H^+] = 10^{-7.40}$ **OR** 3.98×10^{-8} (mol dm^{-3}) • $\frac{[HCO_3^-]}{[H_2CO_3]}$ **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 $[HCO_3^-]$: $[H_2CO_3]$ ratio.' **OR** Partial explanation of the action of the buffer and attempt at calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant***.** **0 marks** *No response or no response worthy of credit.*			**ALLOW** $\frac{[H_2CO_3]}{[HCO_3^-]}$ **OR** $\frac{3.98 \times 10^{-}}{4.17 \times 10^{-7}}$ **And** ratio = 1 : 0.095 ..
17	**(b)**		*Coordinate bond mark* O_2 (coordinately or datively) bonds with Fe^{2+}/Fe(II)/Fe/Iron ✓ Ligand substitution mark (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 ✓ *Ligand strength mark* CO forms strong(er) bonds (than O_2) ✓	**3**	**1.1 ×2** **2.1 ×1**	**ALLOW** names or symbols of ligands **ALLOW** H_2O/CO/CO_2 (coordinately or datively) bonds with Fe^{2+}/Fe(II)/Fe/Iron **ALLOW** oxygen donates electron pair to **OR** binds with Fe^{2+}/Fe(II)/Fe/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)	$[Cr(NH_3)_6]^{3+}(aq)$ ✓	1	1.1	**IGNORE** state symbols
		(ii)	$CrCl_3(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 3NaCl(aq)$ or $Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$ ✓ state symbols required	1	2.8	**IGNORE** square brackets around precipitate formulae **ALLOW** $[Cr(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(H_2O)_3(s) + 3H_2O(l)$ **ALLOW** 'hybrid' equations, Eg $Cr^{3+}(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 3Na^+(aq)$ $[Cr(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s) + 6H_2O(l)$ $[Cr(H_2O)]_6^{3+}(aq) + 3NaOH(aq) \rightarrow$ $Cr(OH)_3(s) + 6H_2O(l) + 3Na^+(aq)$
		(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)	*Explanation of colours* 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) ✓ *Explanation using $E^{\ominus}$ values* ($E^{\ominus}$ of) system 4 (VO^{2+}/V^{3+}) is more positive / less negative than system 2 (Fe^{2+}/Fe) **OR** ($E^{\ominus}$ of) system 3 (V^{3+}/V^{2+},) is more positive / less negative than system 2 (Fe^{2+}/Fe) ✓ *Equilibrium shift related to $E^{\ominus}$ values* More positive/less negative system 4 (VO^{2+}/V^{3+}) shifts right **AND** More positive/less negative system 3 (V^{3+}/V^{2+}) shifts right		**3.2 ×1**	**IGNORE** 'lower/higher' **ALLOW** reverse argument System 2 more negative than system 4 etc E = (+)0.78 V for system 4 + system 2 reaction **OR** E = (+)0.18 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)	$Fe + 4H^+ + 2VO^{2+} \rightarrow Fe^{2+} + 2H_2O + 2V^{3+}$	**1**	**2.8**	**IGNORE** state symbols **ALLOW** multiples **ALLOW** '⇌'
	(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

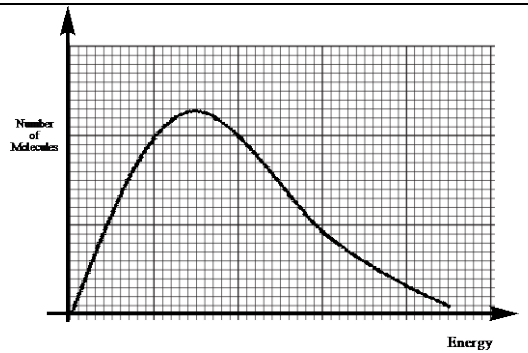
Question			Answer	Marks	AO element	Guidance
			$n(MnO_4^-) = \frac{13.50}{1000} \times 0.00200 = 2.7(0) \times 10^{-5}$ (mol) ✓ $n(Fe^{2+})$ (in.25.0 cm^3) = $2.7(0) \times 10^{-5} \times 5 = 1.35 \times 10^{-4}$ (mol) ✓ $n(Fe^{2+})$ (in 250 cm^3) = $1.35 \times 10^{-4} \times 10 = 1.35 \times 10^{-3}$ ✓ Mass $C_{12}H_{22}FeO_{14}$ in 2 tablets $= 1.35 \times 10^{-3} \times 445.8 = 0.6018$ (g) ✓ Mass $C_{12}H_{22}FeO_{14}$ in 1 tablet = 301 (mg) **AND** to **3 SF** ✓			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 mg **B**: Mass Fe = $\frac{210 \times 55.8}{169.8}$ = 69 mg **Iron supplement:** **B** provides more Fe per tablet ✓	**1**	**3.1 ×1**	**ALLOW** correct working if iron supplement is not named **ALLOW** iron(II) fumarate or $C_4H_2FeO_4$
				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 Δ*G*** **If Δ*G* = –1010 (kJ mol^{-1}) award first 3 marks** ΔS = (2 × 248 + 2 × 70) – (2 × 206 + 3 × 205) = –391 (J K^{-1} mol^{-1}) **OR** –0.391 (kJ K^{-1} mol^{-1}) ✓ $\Delta G = \Delta H - T\Delta S$ = –1125 – (293 × –0.391) ✓ = –1010 (kJ mol^{-1}) ✓ Feasible **AND** $\Delta G < 0$ **OR** ΔG is negative ✓	4	2.2 ×3 3.2 ×1	**ALLOW** ecf **ALLOW** –1010000 (J mol^{-1}) **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 (kJ mol^{-1}) 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 (kJ mol^{-1}) award 3 marks**	3	2.2 ×3	

Question			Answer	Marks	AO element	Guidance
			Using Both $\Delta cH^{\ominus}$ values multiplied by 2 2 × (–296.8) **or** –593.6 **AND** 2 × (–285.8) or –571.6 (= –1165.2) ✓ *Use of –1125 and correctly processed:* $2\Delta_f H(H_2S) = [2 \times (-296.8) + 2 \times (-285.8)] - (-1125)$ = –40.2 (kJ mol^{-1}) ✓ *Division by 2* $\Delta_f H(H_2S)$ = –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 $\Delta_f H(H_2S)$ = (+) 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)**	$(K_p) = \dfrac{p(SO_3)^2(g)}{p(SO_2(g))^2 \times p(O_2(g))}$ ✓ atm^{-1} ✓	**2**	**1.2 ×2**	**ALLOW** species without state symbols and without brackets. e.g., pSO_3^2, $ppSO_3^2$, PSO_3^2, $p(SO_3)^2$ $(pSO_3)^2$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** $n(SO_2) = (\frac{10.2}{24.0} =) 0.425$ (mol) **AND** $n(O_2) = (\frac{12}{32.0} =) 0.375$ (mol) ✓ **Equilibrium amounts in moles** $n(SO_2) = (0.425 - 0.350 =) 0.075$ (mol) **AND** $n(O_2) = (0.375 - 0.350/2 =) 0.200$ (mol) ✓ **Total moles** $n_{tot} = 0.625$ (mol) ✓ **Partial pressures** $pSO_2 = (\frac{0.075}{0.625} \times 2.50 =) 0.3$ (atm) **AND** $pO_2 = (\frac{0.2}{0.625} \times 2.50 =) 0.8$ (atm) **AND** $pSO_3 = (\frac{0.350}{0.625} \times 2.50 =) 1.4$ (atm) ✓ **K_p to 3 SF** $(K_p = \frac{1.4^2}{0.3^2 \times 0.8} =) 27.2$ (atm^{-1}) ✓	5	2.6 ×5	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. *Common errors* Allow 4 marks for 1.45/1.46 (depending upon rounding) *Initial amounts* $n(SO_2) = 2 \times n(O_2)$ $n(O_2) = 0.375$ and $n(SO_2) = 0.75(0)$ *Equilibrium moles* $n(SO_2)$ 0.75 – 0.350 = 0.4(0) $n(O_2) = 0.2(0)$ *total moles* $n_{tot} = 0.95$ *partial pressures* $pSO_2 = 1.05$ $pO_2 = 0.526$ *p*SO3 = 0.921 Allow 4 marks for **15.1/15.0** *Initial amounts* $n(O_2) = 12/16 = 0.75$ *Equilibrium moles* $n(O_2) = 0.575$ *total moles* $n_{tot} = 1.00$ *partial pressures* $pSO_2 = 0.188$ $pO_2 = 1.438$ *p*SO3 = 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 *Confusion with effect of temperature* **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' *(confusion with effect of greater temperature)*
		(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** **----------** $[H^+] = \sqrt{(Ka \times [C_2H_5COOH])} = 1.039 \times 10^{-3}$ (mol dm^{-3}) ✓ pH = –log 1.039×10^{-3} = 2.98 (**Must be to 2 DP**) ✓	**2**	**2.2 ×2**	**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 (*No square root):* One mark for pH = 0.92 **OR** pH = 5.15 (*Using incorrect K_a values*)
	(b)	**(i)**	$n(C_2H_5COOH) = (0.0800 \times \frac{25.0}{1000}) =) 0.002$ (mol) **AND** $V(NaOH) = \frac{0.002}{0.100} \times 1000 =$ (= 20(.0) cm^3) ✓	**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) x 0.025(0) = 0.002 (mol) and n(NaOH) = 0.02(00) x 0.1 = 0.002(00) (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:*** $n(OH^-)_{excess} = n(OH^-) - n(C_2H_5COOH)$ $= (0.100 \times \frac{45.0}{1000}) - (0.0800 \times \frac{25.0}{1000})$ = 0.0045 – 0.002 = 0.0025 (mol) ✓ ***Concentration of OH^-:*** $[OH^-] = (\frac{0.0025}{70.0 \times 10^{-3}}) = 0.0357$ (mol dm^{-3}) ✓ ***Concentration of H^+:*** $[H^+] = (\frac{1.00 \times 10^{-14}}{0.0357}) = 2.8 \times 10^{-13}$ (mol dm^{-3}) ✓ ***Conversion to pH:*** pH = ($-\log 2.8 \times 10^{-13}$) = 12.55 ✓		**1.2 ×1** **2.6 ×3**	For first mark **ALLOW** *(*Excess volume of NaOH **=** 25(.0) cm^3) $n(OH^-)_{excess} = 0.100 \times \frac{25.0}{1000} = 0.0025$ (mol) Common errors If initial *V(*NaOH) = 45 cm^3 $[OH^-] = 0.0643$ (mol) $[H^+] = 1.56 \times 10^{-13}$ (mol dm^{-3}) pH = 12.81 award three marks (no 1st mark) If $n(OH^-)_{excess}$ is used in $[H^+]$ calculation $n(OH^-)_{excess} = 0.0025$ (mol) $[H^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.(00) \times 10^{-12}$ (mol dm^{-3}) pH = 11.40 award three marks (no 2nd mark) **ALLOW** pOH method for last two marks pOH = $-\log[OH^-]$ =1.447 pH = 14 – 1.447 = 12.55 **ALLOW** ECF for conversion from $[H^+]$ to pH provided value calculated is above 7 and from derived $[H^+]$
20	**b**	**(iii)**	**Shape**	**3**	**2.3 ×1**	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 cm^3 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 *Colour change is the same as end point*
		(v)	**similarity**: end point / volume (20 cm^3) 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** $[HIO_3]_{eqm}$ is significantly lower than $[HIO_3]_{initial/undissociated}$ ✓	1	3.3	**ALLOW** use of HA **Ignore** $[HIO_3]_{equilibrium} < [HIO_3]_{initial/undissociated}$ **ALLOW** $[HIO_3]_{equilibrium} \sim [HIO_3]_{undissociated}$ is no longer a valid assumption **ALLOW** $[HIO_3]$ has a larger K_a so the assumption that $[HIO_3]$ at equilibrium = $[HIO_3]$ 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. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **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. *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **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. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	**3.1 ×4** **3.2 ×2**	**Indicative scientific points may include:** **Orders** **Student 1** • zero order wrt Br_2 **Student 2** • 1st order wrt CH_3COCH_3 **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 $[CH_3COCH_3]$ **OR** $[CH_3COCH_3] \times 2$, rate $\times 2$ **Student 3** • $[H^+] \times 2$, rate $\times 2$ **Rate equation, rate constant and units** • rate = $k\,[CH_3COCH_3]\,[H^+]$ **ALLOW** rate = $k\,[Br_2]^0\,[CH_3COCH_3]^1\,[H^+]^1$ • $k = \frac{\text{rate}}{[CH_3COCH_3]\,[H^+]}$ **OR** $\frac{1.25 \times 10^{-5}}{1.6 \times 0.2}$ • $k = 3.9\ldots \times 10^{-5}$ • units: $dm^3\ mol^{-1}\ s^{-1}$ (Any order, e.g. $mol^{-1}\ dm^3\ s^{-1}$)
			Total	**6**		

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