Mark Scheme

Question			Answer	Marks	Guidance
1			***ΔH calculation from experiment***	7	
			q = 100 × 4.18 × 20.5 **OR** 8569 J **OR** 8.569 kJ ✓		
			Amount of butan-1-ol = $\frac{0.259}{74}$ = 3.5×10^{-3} mol ✓		
			ΔH = –2448 kJ mol^{-1} ✓		**ALLOW** Calculator value for ΔH = –2448.285714 correctly rounded to three or more significant figures
			ΔS calculation		
			$\Delta S = S_{products} - S_{reactants}$		
			ΔS = (4 × 214) + (5 × 70) – [(228) + (6 × 205)] **OR** ΔS = 1206 – 1458 ✓		
			ΔS = –252 J K^{-1} mol^{-1} **OR** –0.252 kJ K^{-1} mol^{-1} ✓		
			ΔG calculation		
			$\Delta G = \Delta H - T\Delta S$		
			ΔG = –2448 – (298 × –0.252) ✓		Mark for use of correct expression with ΔS in kJ K^{-1} mol^{-1}
			ΔG = –2373 (kJ mol^{-1}) ✓		**ALLOW** three or more sig figs for ΔG
			Total	7	

Mark Scheme

Question			Answer	Marks	Guidance
2	(a)		$\Delta G = \Delta H - T\Delta S$ linked to $y = mx + c$ (somewhere) ✓ **gradient** = $-\Delta S$ ✓ **P:** ΔH / enthalpy change ✓ **Q**: (temperature) for reaction to be feasible/unfeasible **OR** (temperature) at which feasibility changes ✓	**4**	Could be: $\Delta G = -\Delta S\, T + \Delta H$ – sign required ALLOW ΔS = *–gradient* **ALLOW** 'point of feasibility' For Feasibility: **ALLOW** can take place/happen **OR** is spontaneous **IGNORE** 'minimum/maximum temperature'
	(b)	(i)	(Species have) different states/phases ✓	**1**	
		(ii)	(K_p =) $p(CO(g))^4$ ✓	**1**	Allow species without state symbols and without brackets, e.g. $p_{CO}{}^4$, $pp CO^4$, $P CO^4$, $p(CO^4)$ etc. **DO NOT ALLOW** square brackets
		(iii)	ΔG *at 25 C* $\Delta G = \Delta H - T\Delta S = 676.4 - (298 \times 0.7031)$ = (+) 467 (kJ mol^{-1}) **OR** (+) 466876 (J mol^{-1}) ✓ *Non-feasibility statement* Non-feasible when $\Delta G > 0$ **OR** $\Delta G > 0$ **OR** $\Delta H > T\Delta S$ ✓ *Minimum temperature* minimum temperature = $\frac{\Delta H}{\Delta S} = \frac{676.4}{0.7031}$ = 962(.0) K ✓	**3**	**IGNORE** units **ALLOW** (+) 467 up to calculator value of 466.8762 correctly rounded ECF for any positive value determined in M1 **ALLOW** 962 up to calculator value of 962.0253165 correctly rounded

Mark Scheme

Question	Answer	Marks	Guidance
(iv)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –110.5, Award 3 marks.** --- **Correct expression** $-13.5 = (4 \times -393.5) - (-1118.5 + 4 \times \Delta_f H(CO))$ ✓ **Correct subtraction using ΔH and $\Delta_f H(Fe_3O_4)$** $4 \times \Delta_f H(CO) = (4 \times -393.5) - (-1118.5) + 13.5$ $= -\mathbf{442(.0)}$ (kJ mol^{-1}) ✓ **Calculation of $\Delta_f H$(CO) formation** $\Delta_f H(CO) = -\frac{442}{4} = \mathbf{-110.5}$ (kJ mol^{-1}) ✓	**3**	**For answer,** **ALLOW –111 (kJ mol^{-1})** --- **NOTE:** IF any values are omitted, **DO NOT AWARD** any marks. e.g. –393.5 OR –13.5 may be missing --- **Common errors** **(+)110.5** *wrong/omitted sign* **2 marks** **(+)184.625 / 184.63 / 184.6 / 185** *No $4CO_2$* **2 marks** **(+)738.5 / 739** *No $4CO_2$ and no CO/4* **1 mark** **–117.25 / –117.3 / –117** *Wrong cycle* **2 marks** **–469** *Wrong cycle, no CO/4* **1 mark** **(+)177.875 / 177.88 / 177.9 / 178** *Wrong cycle, no $4CO_2$* **1 mark** **–360.5** *Used 118.5* **2 marks** Any other number: **CHECK** for **ECF** from 1st marking point for expressions using **ALL** values with **ONE** error only e.g. one transcription error:, e.g.395.3 for 393.5
	Total	**12**	

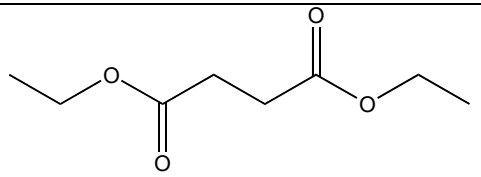
Mark Scheme

Question	Answer	Marks	AO element	Guidance
3	**A**	**1**	AO1.2	

Mark Scheme

Question			Answer	Marks	Guidance
4	(a)		**TAKE CARE: Correct final answer of –52.3 OR –52.25 can be obtained from two cancelling errors:** • Use of 50 for energy released (no ×2 of 50 for two solutions mixed) • No ÷ 2 in final step **–52.3 OR –52.25 would then be awarded 2 marks out of 4** --- ***Correctly calculates n(succinic acid)*** $= 0.400 \times \frac{50.0}{1000} = 0.02(00)$ (mol) ✓ ***Energy released in J OR kJ*** $= 100.00 \times 4.18 \times 5.0 = 2090$ (J) **OR** 2.090 (kJ) ✓ **Energy released, in kJ or J, for formation of 2 mol H_2O** $\pm \frac{2090}{0.0200} = \pm 104500$ (J) **OR** $\pm \frac{2.090}{0.0200} = \pm 104.5$ **OR** ± 105 (kJ) ✓ **$\Delta_{neut}H$ to 3 or more SF AND correct – sign** $= -\frac{104.5}{2} = -52.3$ **OR** – 52.25 kJ mol^{-1} ✓	4	**ALLOW ECF throughout** **DO NOT ALLOW** less than 3 SF **IGNORE** units --- **ALTERNATIVE METHOD** ***n(succinic acid)*** = 0.02(00) (mol) ✓ ***Energy released*** = 2090 (J) **OR** 2.090 (kJ) ✓ ***n*(H_2O) formed** = $2 \times 0.02(00) = 0.04(00)$ (mol) ✓ $\Delta_{neut}H = -\frac{2.090}{0.0400} = -52.3$ **OR** – 52.25 kJ mol^{-1} ✓
	(b)	(i)	Titration ✓	1	**IGNORE** type of titration
		(ii)	$(CH_2COOH)_2 + 2C_2H_5OH \rightleftharpoons (CH_2COOC_2H_5)_2 + 2H_2O$ ✓	1	**ALLOW** → instead of ⇌ sign **ALLOW** molecular formulae or hybrid formulae *Structures provided on QP* e.g. $C_4H_6O_4 + 2C_2H_6O \rightleftharpoons C_8H_{14}O_4 + 2H_2O$

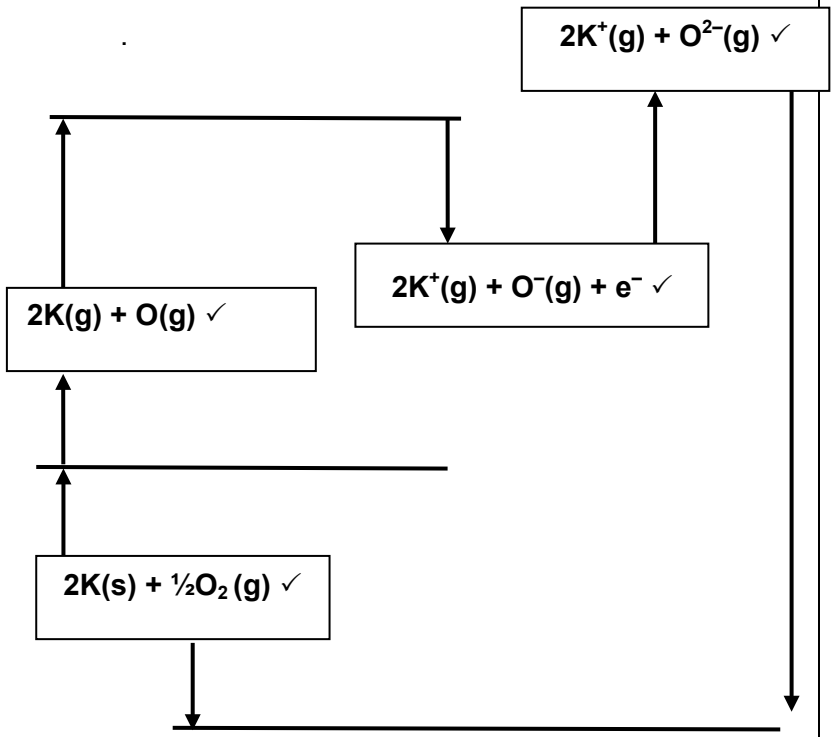
Mark Scheme

Question			Answer	Marks	Guidance
		(iii)	 ✓	**1**	**IGNORE** displayed formulae
		(iv)	Volume cancels **OR** Same number of moles on each side of equation ✓	**1**	**ALLOW** units cancel **ALLOW** (sum of) balancing numbers/coefficients on each side of equation are the same **OR** same number of (moles of) reactants and products **IGNORE** volume is the same; K_c has no units
		(v)	**Moles of equilibrium products** ***1 mark*** $n((CH_2COOC_2H_5)_2)$ = 0.0300 (mol) **AND** $n(H_2O)$ = 0.0600 (mol) ✓ **Moles of C_2H_5OH** ***1 mark*** $n(\mathbf{C_2H_5OH})$ = 0.150 – 0.060 = 0.0900 (mol) ✓ ***K_c* calculated** ***1 mark*** $= \frac{0.03 \times 0.06^2}{0.02 \times 0.09^2} = 0.667$ **OR** 0.67 ✓ **NOTE:** 0.02 must be used for *n*(succinic acid)	**3**	**ALLOW ECF** **ALLOW** 0.66, 0.666, etc. (**2 SF** and more) *Treated as meaning 0.6 recurring* **ALLOW** 2/3 **IGNORE** any units
			Total	**11**	

Mark Schemes

Question			Answer	Marks	AO element	Guidance
5	(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

Mark Schemes

Question			Answer	Marks	AO element	Guidance
	(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
		(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

Mark Schemes

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
	(e)	**(i)**	*For sodium* **atomic** radius smaller	**2**	**1.1 ×2**	**ALLOW** 'Na/sodium is smaller' **IGNORE** smaller radius / fewer shells / less

Mark Schemes

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
		(ii)	***Comparison of size of cations*** For sodium ions	**2**	**1.2 ×2**	comparison of **IONS** is essential

Mark Schemes

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**		

Mark Schemes

Question			Answer	Marks	AO element	Guidance
6	(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 ΔG = –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** ΔG < 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** ΔG > 0 **OR** ΔG is +ve
	a	(iii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = –20 (kJ mol^{-1}) award 3 marks**	3	2.2 ×3	

Mark Schemes

Question			Answer	Marks	AO element	Guidance
			Using Both $\Delta cH^{\ominus}$ values multiplied by 2 $2 \times (-296.8)$ **or** -593.6 **AND** $2 \times (-285.8)$ 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}

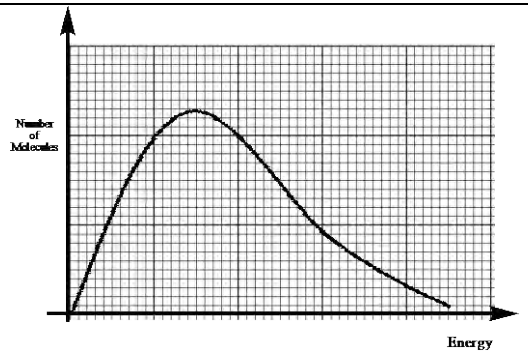
Mark Schemes

Question			Answer	Marks	AO element	Guidance
	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* $n(SO_2) = 2$ x $n(O_2)$ $n(O_2) = 0.375$ 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* $pSO_2 = 1.05$ $pO_2 = 0.526$ pSO3 = 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* $pSO_2 = 0.188$ $pO_2 = 1.438$ pSO3 = 0.88 **IGNORE** units

Mark Schemes

Question			Answer	Marks	AO element	Guidance
	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

Mark Schemes

Question			Answer	Marks	AO element	Guidance
	(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**		

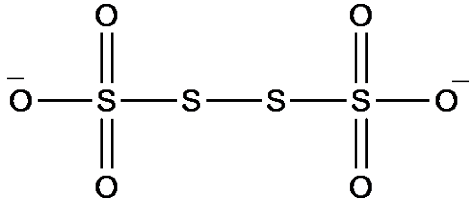
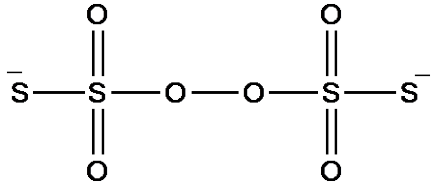
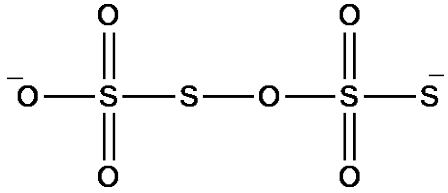
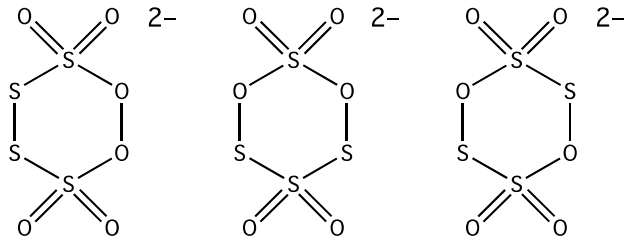
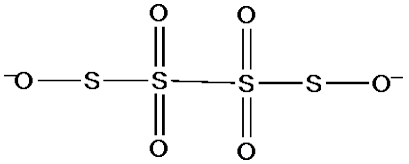
Mark Scheme

Question			Answer	Marks	AO element	Guidance
7	(a)	(i)*	*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)** Calculates **CORRECT** enthalpy change with correct – signs for $\Delta_{sol}H$ ($CuSO_4$(s)) for **reaction 5.2** **AND** Δ_rH, for **reaction 5.1**. *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)** Calculates a value of $\Delta_{sol}H$ ($CuSO_4$(s)) for **reaction 5.2** from the: Energy change **AND** Amount in mol of $CuSO_4$. *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)** Processes experimental data to obtain the: Energy change from $mc\Delta T$ **OR** Amount in mol of $CuSO_4$. *There is an attempt at a logical structure with a line of reasoning.* *The information is in the most part relevant.*	**6**	AO3.1 ×4 AO3.2 ×2	*Indicative scientific points may include:* **1. Processing experimental data** **Energy change from $mc\Delta T$** • Energy in J **OR** kJ *Using 50.70 g, 50.0 g* = **50.70** × 4.18 × 13.5 = **2861** (J) **OR** 2.861 (kJ) *3SF or more (2.861001 unrounded)* **OR** **50.0** × 4.18 × 13.5 = **2821.5** (J) **OR** 2.8215 (kJ) **Amount in mol of $CuSO_4$** • $n(CuSO_4) = \frac{7.98}{159.6}$ = 0.0500 (mol) --- **2. ± value of $\Delta_{sol}H(CuSO_4(s))$ for reaction 5.2** From m = 50.70 g = $\pm\frac{2.861}{0.0500}$ = **±57.22** (kJ mol^{-1}) *(–57.22002 unrounded)* From m = 50.0 g = $\pm\frac{2.8215}{0.0500}$ = **±56.43** (kJ mol^{-1}) --- **3. CORRECT enthalpy changes for reactions 5.2 and 5.1 with signs (using 50.70 g ONLY)** **Reaction 5.2** = **–57.22** (kJ mol^{-1}) *3SF or more with correct – sign* **Reaction 5.1** $\Delta_rH = \Delta_{sol}H(CuSO_4(s)) - \Delta_{sol}H(CuSO_4 \cdot 5H_2O(s))$ = –57.22 – 8.43 = **–65.65** (kJ mol^{-1}) *3SF or more with correct – sign* **NOTE:** *A clear and logically structured response would include an energy cycle* **ALLOW** omission of trailing zeroes **ALLOW** minor slips

Mark Scheme

Question			Answer	Marks	AO element	Guidance
			0 marks – No response or no response worthy of credit.			
	(a)	**(ii)**	Temperature change = $0.2 \times \frac{100}{20}$ = **1(.0)°C** ✓	**1**	AO2.8	**IGNORE** direction of temperature change Working **NOT** required
	(b)		**FIRST CHECK THE ANSWER IN ON ANSWER LINE** **If answer = (+)156 (J K^{-1} mol^{-1}) award 4 marks** --- **Part 1: Calc of $\Delta_r S$** **Use of 298 K** (seen anywhere) **1 mark** ✓ • e.g. –16.1 = –55.8 – 298 × ΔS --- **CORRECT** use of Gibbs' equation **1 mark** • using candidate's temperature (e.g. 298) • with –16.1 **AND** –55.8 • to calculate ΔS *in kJ* ***OR*** *J* ✓ --- **Part 2: Calc of $S(Na_2S_2O_3)$** **1 mark** **CORRECT** use of standard *S* data in question ✓ Seen anywhere (could be within an expression) e.g. • 372.4 – [$S(Na_2S_2O_3)$ + (5 × 69.9)] • **OR** 372.4 – (5 × 69.9) • **OR** 372.4 – 349.5 • **OR** 22.9 **IGNORE** sign, i.e. **ALLOW** –22.9, etc --- **CORRECT** calculation of $S(Na_2S_2O_3)$ using candidate's calculated ΔS in Part 1 **to 3 SF** **1 mark** ✓	**4**	AO2.4 ×4	Using 298 K, $\Delta S = \frac{-55.8 - (-16.1)}{298} = \frac{-39.7}{298}$ = –0.133…(kJ K^{-1}mol^{-1}) **OR –133**… (J K^{-1}mol^{-1}) ***Sign required*** ***IGNORE*** *units* Calculator: –0.133221 (kJ K^{-1} mol^{-1}) –133.221 (J K^{-1} mol^{-1}) **ALLOW ECF** from incorrect temperature. --- Using –133: $S(Na_2S_2O_3)$ = 372.4– 349.5 – (–133) = 22.9 + 133 = (+)**156** (J K^{-1} mol^{-1}) **3 SF** required **ALLOW ECF** from incorrect $\Delta_r S$ (Part 1)

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(c)	(i)	109.5(°) **AND** tetrahedral ✓	1	AO1.2	**ALLOW** 109–110(°)
		(ii)	 **OR**  **OR**  ✓ **IGNORE** absence of charges **OR** incorrect charges	1	AO3.1	**IGNORE** charges **ALLOW** cyclic structures. Three 6-ring structures possible, e.g.  **NOTE**: There **MUST** be 2 atoms in centre between 6-bonded S atoms. e.g. **DO NOT ALLOW**  **For other structures, contact TL**
			Total	13		

Mark Scheme

Question			Answer	Marks	AO element	Guidance
8	(a)		High pressure **AND** low temperature ✓ Right-hand side has fewer (gaseous) moles/molecules **OR** left-hand side has more (gaseous) moles/molecules ✓ (Forward) reaction is exothermic/gives out heat **OR** reverse reaction is endothermic/takes in heat ✓	**3**	1.2×1 1.1×2	Marks are independent **ORA** throughout **ALLOW** RHS **ALLOW** suitable alternatives for RHS e.g. product side
	(b)		(Reaction can be carried out at) lower temperatures / lower energy demand ✓ Less (fossil) fuels burnt / less CO_2 emissions ✓	**2**	1.1×2	**ALLOW** lower pressures as alternative to lower temperature **ALLOW** reduced carbon footprint as alternative to less fuels burnt **ALLOW** different reactions can be used with greater atom economy / less waste **ALLOW** can reduce use of toxic substances

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(c)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 25.55 kJ mol^{-1} **OR** 25550 J mol^{-1} **award first 4 marks** --- ΔS = 238 – (198 **+** 2 × 131) ✓ = –222 (J K^{-1} mol^{-1}) **OR** –0.222 (kJ K^{-1} mol^{-1}) ✓ $\Delta G = \Delta H - T\Delta S$ **OR** ΔG = –91 – (525 × –0.222) **OR** ΔG = –91000 – (525 × –222) ✓ = 25.55 kJ mol^{-1} **OR** 25550 J mol^{-1} ✓ (Reaction is) not feasible **AND** $\Delta G > 0$ ✓	**5**	2.2×4 3.2×1	**ALLOW ECF** **IGNORE** units at this stage Units for ΔG required **ALLOW** 26 kJ mol^{-1} **OR** 26000 J mol^{-1} up to calculator value.

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(d)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 2.22 $\times$ 10^4 **award first 2 marks** --- ln $K_p = -\Delta G/RT = \frac{2.48 \times 10^4}{8.314 \times 298}$ = 10.01 ✓ K_p = 2.22 $\times$ 10^4 (**3SF required**) ✓ Units = atm^{-2} ✓	**3**	3.1×2 1.2×1	**ALLOW ECF** for transcription errors in first sum **ALLOW** 10 up to calculator value of 10.00979992 **ALLOW** 22200 **ALLOW** 2.20 $\times$ 10^4 **OR** 22000 (use of 10) **ALLOW** alternatives (k)Pa^{-2} **OR** N^{-2} m^4 **OR** $mmHg^{-2}$ **OR** PSI^{-2} **OR** bar^{-2} **Common errors for 1 mark:** 22400 (use of 8.31) 4.50 x 10^{-5} (use of -10.01)
			Total	**14**		