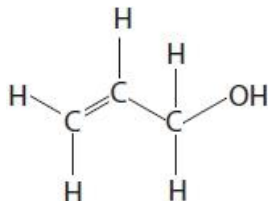

Questions

Q1.

Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.

A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.

(i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C
bond as they could use the value for a C–C bond and multiply it by two.
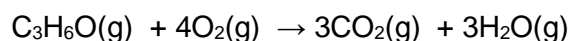Explain why the student is **incorrect**.

(2)

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(ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.

$$C_3H_6O(g) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$$

Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / kJ mol^{-1}	347	612	358	805	464	413	498

(3)

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.
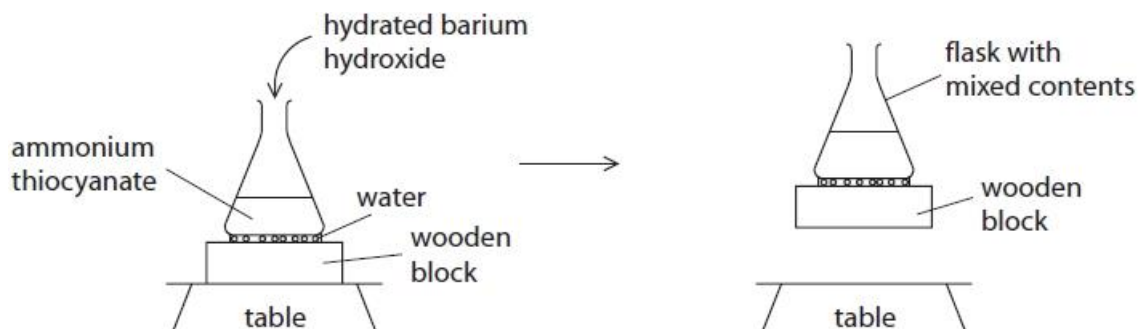
(2)

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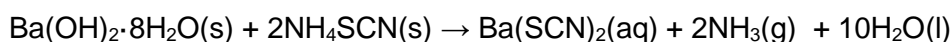
(Total for question = 7 marks)

Q2.

This question is about entropy.

Some hydrated barium hydroxide is added to ammonium thiocyanate in a flask which is placed on a few drops of water on a wooden block. After the addition, the contents are stirred and then the flask can be lifted up with the wooden block attached, as shown.

The equation for the reaction is

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(aq) + 2NH_3(g) + 10H_2O(l)$$

(i) Give **two** reasons why you would expect $\Delta S^{\ominus}_{system}$ to be positive.

(2)

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(ii) Explain why the wooden block is lifted up by the flask.

(2)

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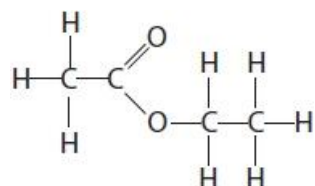
**(Total for question = 4 marks)**

Q3.

Ethyl ethanoate is an ester.

One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$
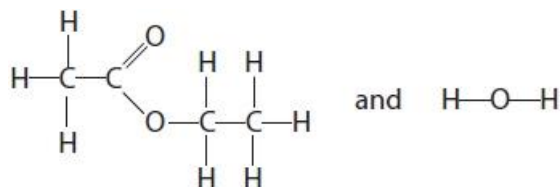
An incomplete simplified mechanism for this reaction is shown.

(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)
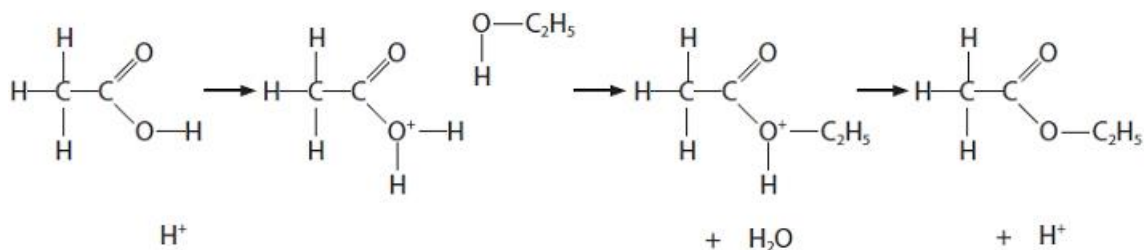
(ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O. The products of the esterification are

   and   H—O—H

Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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(iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, ΔG,
and the data in the table.

Include sign and units in your answer.
Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, R	$8.31 \, J \, mol^{-1} \, K^{-1}$
Temperature, T	$298 \, K$
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	$-6.0 \, kJ \, mol^{-1}$
Standard molar entropy of ethanoic acid, S^O	$159.8 \, J \, K^{-1} \, mol^{-1}$
Standard molar entropy of ethanol, S^O	$160.7 \, J \, K^{-1} \, mol^{-1}$
Standard molar entropy of water, S^O	$69.9 \, J \, K^{-1} mol^{-1}$

(6)

(Total for question = 12 marks)

Q4.

This question is about enthalpy changes and entropy changes.

Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{system} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

(Total for question = 3 marks)

Q5.

Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

The equation for the formation of sodium hydride is

$$Na(s) + \tfrac{1}{2}H_2(g) \rightarrow NaH(s) \qquad \Delta_f H^{\ominus} = -56\,kJ\,mol^{-1}$$
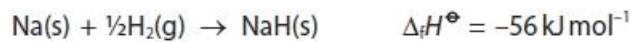
The standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for this reaction is -76.5 J K^{-1} mol^{-1}.

(i) Deduce the feasibility of this reaction at 298 K by calculating the free energy change, ΔG.

(2)

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....

(ii) Calculate the temperature at which $\Delta G = 0$.

(1)

(Total for question = 3 marks)

Q6.

Chemists are researching a process to make ethanol and ethene directly from carbon dioxide and water.

$4CO_2(g) + 5H_2O(l) \rightarrow CH_3CH_2OH(l) + C_2H_4(g) + 6O_2(g)$ $\Delta H^\ominus = +2778$ kJ mol^{-1}
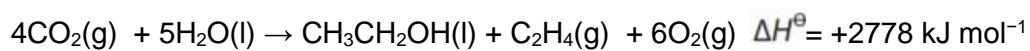
	$CO_2(g)$	$H_2O(l)$	$CH_3CH_2OH(l)$	$C_2H_4(g)$	$O_2(g)$
$S^\ominus$ / J K^{-1} mol^{-1}	213.6	69.9	160.7	219.5	205.0

Calculate $\Delta S^\ominus_{total}$ for the reaction and hence determine whether the reaction is feasible under standard conditions.

(5)

(Total for question = 5 marks)

Q7.

This question is about entropy and free energy.

Complete the table by giving the sign of the entropy change of the system, ΔS_{system} , for each reaction.

(2)

Reaction	Sign of ΔS_{system}
$CO_2(s) \rightarrow CO_2(g)$	
$NaCl(s) + aq \rightarrow NaCl(aq)$	
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	

(Total for question = 2 marks)

Q8.

This question is about entropy and free energy.

Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta_rH = -288.4\,kJ\,mol^{-1}$$
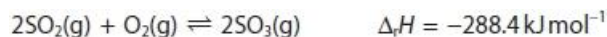
The standard molar entropy values at 298 K are given in the table.

	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
$S^{\ominus}$ / $JK^{-1}mol^{-1}$	+248.1	+205.0	+95.6

(i) Calculate the entropy change of the system, ΔS_{system}, for the forward reaction.

Include a sign and units in your answer.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$
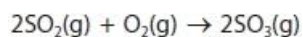
(2)

(ii) Calculate the free energy change, ΔG, at 298 K and hence deduce whether the reaction is feasible.

(3)

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(iii) In industry, the reaction is carried out at about 700 K using a vanadium(V) oxide catalyst.

Calculate the value of the equilibrium constant, K, at 700 K.
ΔG at 700 K is –60 kJ mol^{-1}

(3)

(iv) The equilibrium constant has a larger value at 298 K than at 700 K.

Explain why the reaction is carried out at 700 K and not at 298 K.

(2)

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(Total for question = 10 marks)

Q9.

This question is about the white solid barium carbonate.

Barium carbonate decomposes under suitable conditions to form barium oxide and carbon dioxide.

$$BaCO_3(s) \rightarrow BaO(s) + CO_2(g) \qquad \Delta_rH^\ominus = +169.3\,kJ\,mol^{-1}$$
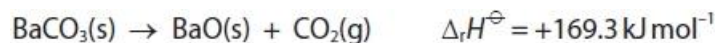
Standard molar entropy data related to this reaction are shown.

Substance	Standard molar entropy, $S^\ominus$ /$JK^{-1}mol^{-1}$
$BaCO_3(s)$	112.1
$BaO(s)$	70.4
$CO_2(g)$	213.6

(i) Show that barium carbonate is thermally stable at 298 K, using the data in the equation and in the table.

(5)

(ii) Calculate the lowest temperature, in °C, at which it is thermodynamically

feasible for barium carbonate to decompose.
Give your answer to three significant figures.

(3)

(Total for question = 8 marks)

Q10.

* A student wrote:

> Whether or not a reaction occurs depends only on the thermodynamic feasibility calculated using
>
> $$\Delta G = \Delta H - T\Delta S_{system}$$

Discuss this statement.

Include reference to:

- changes in the values and signs of the terms in the equation for both endothermic and exothermic reactions
- circumstances where a reaction that is predicted to be thermodynamically feasible may not occur in practice.

(6)

(Total for question = 6 marks)

Q11.

This question is about entropy and free energy.

Calculate the total entropy change, ΔS_{total} , for the thermal decomposition of calcium carbonate at 298 K.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

[Data: $\Delta_r H = +178\,kJ\,mol^{-1}$ $\Delta S_{system} = +160\,J\,K^{-1}\,mol^{-1}$]

(3)

(Total for question = 3 marks)

Mark Scheme

Q1.
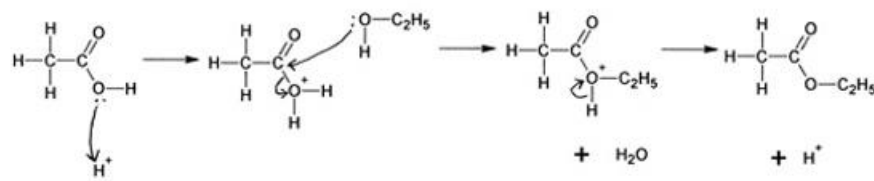
Question Number	Answer	Additional guidance	Mark
(i)	An explanation that makes reference to the following points • C=C bond is weaker than 2 x C-C bond **(1)** • as it consists of a pi and a sigma bond (rather than 2 sigma bonds) **(1)**	Ignore pi bond formed by sideways / less effective orbital overlap	**(2)**

Question number	Answer	Additional guidance	Mark
(ii)	• calculation of energy required to break reactant bonds **(1)** • calculation of energy release when product bonds form **(1)** • calculation of enthalpy change **(1)**	Example of calculation: $5(C-H) + (C=C)+(C-C)+(C-O)+(O-H)+4(O=O)$ $5(413) + (612) + (347) + (358) + (464) + (4 \times 498)$ $= 5838$ (kJ mol^{-1}) $6(C=O) + 6(O-H)$ $(6 \times 805) + (6 \times 464)$ $= 7614$ (kJ mol^{-1}) $5838 - 7614 = -1776$ (kJ mol^{-1}) Ignore SF except 1 SF Allow TE from M1 and M2 Correct answer no working scores 3	**(3)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to one of the following points EITHER • ΔS_{total} is always positive (1) **(1)** • As both $\Delta S_{surroundings}$ and ΔS_{system} are positive **(1)** • OR • ΔG is always negative **(1)** • as ΔH is negative and $\Delta S_{(system)}$ is positive **(1)**	If no marking points awarded allow 1 mark for idea that ΔS_{system} / $\Delta S_{surroundings}$ / entropy increases with correct explanation	**(2)**
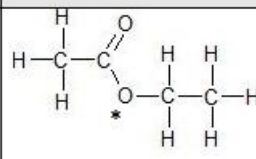
Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • there is an increase of number of moles (1) • change of state as gas / liquid / solution are produced from solids (1)	Allow particles for moles 3 to 13 moles Do not award 11 to 13 moles Do not award reference to 'more types' of products than reactants Ignore references to ΔH	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • the reaction is endothermic (1) • (and so) freezes the water (which attaches the wooden block to the flask) (1)	Allow description of endothermic	(2)

Q3.

	Answer	Additional Guidance	Mark
(i)	- oxygen lone pair and curly arrow to the H+ **(1)** - curly arrow from oxygen lone pair on the ethanol to the carbon of the C = O **(1)** - curly arrow from C-O bond to oxygen of water molecule **(1)** - curly arrow from O–H bond back to the O+ oxygen **(1)**		**(4)**

Example of reaction mechanism

Penalise additional curly arrows for each marking point

Penalise missing lone pair on oxygen once only in M1 and M2

Question Number	Answer	Additional Guidance	Mark
(ii)	- correct oxygen identified **(1)** - the single bond C–O in the carboxylic acid breaks rather than the one in ethanol **or** the oxygen in ethanol acts as the nucleophile (to attack the carbon of the carboxylic acid group and so ends up in the ester) **(1)**	 Allow 'loss of OH from the carboxylic acid'	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)		<u>Example of calculation</u>	(6)
	• (M1) calculation of ΔG (1)	$\Delta G = -RT \ln K = -8.31 \times 298 \times \ln 4.0$ $= -3433$ (J mol^{-1})	
	• (M2) correct equation (1)	$\Delta G = \Delta H - T\Delta S_{system}$	
	• (M3) rearrangement of equation (1)	$\Delta S_{system} = (\Delta H - \Delta G) \div T$	
	• (M4) calculation of ΔS_{system} (1)	$\Delta S_{system} = (-6.0 \times 10^3 - (-3433)) \div 298$ $= -8.614....$ (J mol^{-1} K^{-1})	
	• (M5) rearrangement of equation so $S_{(ethyl\ ethanoate)} =$ (1)	$(\Delta S_{system} = \sum S_{(products)} - \sum S_{(reactants)})$ $S_{(ethyl\ ethanoate)} = \Delta S + \sum S_{(reactants)} - S(water)$	
	• (M6) calculation of $S_{(ethyl\ ethanoate)}$ with sign and units (1)	$S_{(ethyl\ ethanoate)} = (-8.614 + (159.8+160.7) - 69.9)$ $= +242/240$ J mol^{-1} K^{-1} Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	

Q4.

Question Number	Answer	Additional Guidance	Mark
		Penalise incorrect units in M1 or M3 once only	(3)
		Working is not required for the calculations	
	• calculation of ΔG **(1)**	Example of calculation $\Delta G = 178 - (298 \times \dfrac{165}{1000})$ $= (+)128.83 / 129$ (kJ mol^{-1}) or $\Delta G = 178000 - (298 \times 165)$ $= (+)128830 / 129000$ (J mol^{-1})	
	• ΔG is positive / >0 so reaction is not feasible **(1)**	Stand alone mark Allow ΔG must be negative for a reaction to be feasible Ignore 'so reaction is not feasible' without a reason No TE on a calculated negative value	
	• calculation of T **(1)**	Example of calculation $\Delta G = 0$, so $\Delta H = T\Delta S_{(sys)}$ or $T = \Delta H/\Delta S_{(sys)}$ or $\Delta S_{total} = \Delta S_{sys} - \Delta H/T = 0$, so $T = \Delta H/\Delta S_{(sys)}$ $T = 178/0.165 = 1078.8 / 1079 / 1080$ (K) or $T = 178000/165 = 1078.8 / 1079 / 1080$ (K) or $T = 806$ (°C) Ignore SF except 1 SF	

Q5.

Question Number		Answer		Additional Guidance	Mark
		Penalise incorrect or missing units in (b)(i) and (b)(ii) once only			
(i)	•	calculation of ΔG	(1)	Example of calculation $\Delta G = -56 -(298 \times \dfrac{-76.5}{1000})$ $=-33.203$ (kJ mol^{-1}) or $\Delta G = -56000 -(298 \times -76.5)$ $= -33203$ (J mol^{-1})	(2)
	•	ΔG is negative/ <0 and so reaction is feasible **(1)**		Ignore SF except 1 Allow ≤0 and so reaction is feasible Standalone mark Allow TE on own ΔG calculated value	

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of T	**Example of calculation** $\Delta G = 0$, so $\Delta H = T\Delta S_{(system)}$ or $T = \Delta H/\Delta S_{(system)}$ $T = 56/0.0765 = 732$ K **or** $T = 56000/76.5 =$ 732 K **or** $T = 459°C$ Ignore SF except 1 SF Do not award −732K TE on incorrect values penalised already in (b)(i)	(1)

Q6.

Question Number	Answer	Additional Guidance	Mark
	• expression for ΔS_{system} **(1)** • calculation of ΔS_{system} **(1)** • expression for $\Delta S_{surroundings}$ **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • calculation of ΔS_{total}, correct units and comment on feasibility **(1)**	**Example of calculation** $\Delta S_{system} = [(6\times205)+(219.5)+(160.7)] - [(4\times213.6)+(5\times69.9)]$ $= 1610.2 - 1203.9 = (+)\ 406.3\ (\text{J K}^{-1}\text{mol}^{-1})$ $\Delta S_{surroundings} = -\Delta H/T = -2778 \times 10^3 \div 298$ $= -9322.14765\ (\text{J K}^{-1}\text{mol}^{-1})$ $\Delta S_{total} = 406.3 - 9322.14765$ $= -8915.85\ \text{J K}^{-1}\text{mol}^{-1}$, (negative) so not feasible Ignore SF except 1 SF. Allow TE and KJ throughout	(5)

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• all 3 correct **(2)** • any 2 correct **(1)**	**Example of table** | Reaction	Sign of ΔS_{system}
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$CO_2(s) \rightarrow CO_2(g)$	positive / + / +ve / plus
$NaCl(s) + aq \rightarrow NaCl(aq)$	positive / + / +ve / plus
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	negative / − / −ve / minus		(2)

Q8.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• correct working	(1)	Example of calculation (2 x 95.6) – ((2 x 248.1) + 205.0) / (2 x 95.6) – (2 x 248.1) – 205.0	(2)
	• correct answer **and** sign	(1)	-510(.0) (J K^{-1} mol^{-1}) **or** -0.510 (kJ K^{-1} mol^{-1}) TE on working Ignore SF except 1SF Correct answer with sign and working scores both marks	

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• use of $\Delta G = \Delta H - T\Delta S_{system}$ **(1)**	Example of calculation The equation may be stated or numbers substituted directly e.g. –288.4 – (298 x –0.510) / –288400 – (298 x –510) –136(.42) kJ mol^{-1} / –136420 J mol^{-1} TE on ΔS_{system} in (i) Ignore SF except 1SF Correct answer with sign and units without working scores both marks Conditional on a stated number TE on sign of ΔG: ΔG is positive / greater than 0 / >0 so the reaction is not feasible	(3)
	• calculation of ΔG and sign **and** units **(1)**		
	• ΔG is negative / less than 0 / <0 **and** so the reaction is feasible **(1)**		

Question Number	Acceptable Answer		Additional Guidance	Mark
(iii)	• use of $\Delta G = -RT\ln K$	(1)	<u>Example of calculation</u> $-60000 = -8.31 \times 700 \ln K$	(3)
	• rearrangement of equation **and** substitution of correct values	(1)	($\ln K = -\Delta G/RT$) $\ln K = \underline{-(-60000)}$ (8.31×700) Allow $\ln K = \underline{60000}$ 8.31×700 Allow $\ln K = 10.3146 / 10.315 / 10.32 / 10.3 / 10$	
		(1)	TE on equation, provided equation involves all of ΔG, K, R and T and no others e.g. S	
	• calculation of K		$K = e^{10.315} = 3.016975 \times 10^4 / 30169.75$ TE on $\ln K$ expression / value Allow answers based on earlier correct rounding Ignore SF **including** 1SF Ignore units Correct answer without working scores 3 marks	

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to any **two** of the following points:	Allow reverse argument for M1 and M2 Ignore reference to changing the pressure	(2)
	• **Yield** - even though the (percentage) yield / amount of SO_3 is higher at 298 K / lower temperature **(1)**	Allow the unused reactants can be recycled to increase the yield / products are removed to increase the yield Allow the reaction does not reach equilibrium in industry so there is no effect on the yield Ignore just a reference to 'equilibrium shifting'	
	• **Rate** - the rate of reaction is slower at 298 K / lower temperature **(1)**	Ignore references to activation energy	
	• **Compromise** - so 700 K is a compromise between a (high) yield and (high) rate **(1)**	Allow at 700K the amount of product per unit time is larger Ignore just '700 K is more economically viable' **Note** If three points are made related to yield, rate and compromise and one of these is incorrect, maximum mark is (1) for 1 correct point	

Q9.

Question Number	Answer	Additional Guidance	Mark
(i)	• calculation of ΔS_{system} **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • conversion of ΔS_{system} or $\Delta S_{surroundings}$ for consistent units **(1)** • calculation of ΔS_{total} **and** corresponding units **(1)** • comment on thermal stability at 298 K **(1)** **Alternative method on next page**	Marks should be awarded for method 1 or method 2 but not via mixed methods. If both methods used, then award higher mark. <u>Example of calculation</u> $(213.6 + 70.4) - 112.1 = 171.9$ (J K^{-1} mol^{-1}) $-169.3 / 298 = -0.56812$ (kJ K^{-1} mol^{-1}) or $(-169.3 \times 1000) / 298 = -568.12$ (J K^{-1} mol^{-1}) $\Delta S_{surroundings}$ converted to J K^{-1} mol^{-1} **or** ΔS_{system} converted to kJ K^{-1} mol^{-1} M3 could be subsumed as part of either M1 or M2 $171.9 + (-568.12) = -396.22$ J K^{-1} mol^{-1} **or** $0.1719 + (-0.56812) = -0.39622$ kJ K^{-1} mol^{-1} Allow units to be missing here if correct units given for ΔS_{system} **and** $\Delta S_{surroundings}$ Correct answer with units with some or no working scores (4) Ignore SF except 1 SF Allow TE throughout calculation Stand alone mark on any negative value for ΔS_{total} Negative value / <0 **and** so reaction is not feasible / it is thermodynamically stable (at 298 K)/ Ignore just 'so the reaction is not feasible' No TE for positive values for ΔS_{total}	**(5)**

(i) continued	**Alternative method using ΔG**	Example of calculation	(5)
	• calculation of ΔS_{system} (1)	$(213.6 + 70.4) - 112.1 = 171.9$ (J K^{-1} mol^{-1})	
	• calculation of TΔS_{system} (1)	$298 \times 171.9 = 51226$ (J mol^{-1}) M2 could be subsumed as part of M3	
	• conversion of TΔS_{system} or ΔS_{system} or ΔH for consistent units (1)	ΔH converted to J mol^{-1} **or** ΔS_{system} converted to kJ K^{-1} mol^{-1} **or** TΔS_{system} converted to kJ mol^{-1} M3 could be subsumed as part of M4	
	• calculation of ΔG_{total} **and** corresponding units (1)	$169300 - 51226 = (+) 118074$ J mol^{-1} **or** (+) 118.074 kJ mol^{-1} Correct answer with units with some or no working scores (4) Ignore SF except 1 SF Allow TE from M1 to M4	
	• comment on thermal stability at 298 K (1)	Stand alone mark on any positive value for ΔG Positive value / >0 **and** so reaction is not feasible (at 298 K) Ignore just 'so reaction is not feasible' No TE on negative values for ΔG	

Question Number	Answer	Additional Guidance	Mark
(ii)	recognition that $\Delta S_{surroundings} \geq -171.9 \ J \ K^{-1} \ mol^{-1}$ • for decomposition to be feasible **(1)** substitution **and** rearrangement to find T • **(1)** • calculation of T **and** conversion to °C **and** answer given to 3 SF **(1)**	Example of calculation $$\Delta S_{total} = \Delta S_{system} - \frac{\Delta H}{T} = 0$$ Or $$\Delta S_{system} = \frac{\Delta H}{T}$$ Allow this equation rearranged This may be subsumed in M2 $-171.9 = (-169.3 \times 1000) \ / \ T$ $T = (-169.3 \times 1000) \ / -171.9$ TE on ΔS_{system} from 4(a)(i) $(= 984.87 \ K)$ $(= 711.87°C)$ $= 712°C$ TE on M1 and M2 but do not award any temperature below 0°C Correct answer to 3 SF and in °C scores (3) Alternative method for M1 and M2 $\Delta G = \Delta H - T\Delta S = 0$ or $\Delta H = T\Delta S$ This may be subsumed in M2 (1) $169300 = T \times 171.9$ $T = 169300/171.9$ (1) TE on ΔS_{system} from 4(a)(i)	**(3)**

Q10.

Question Number	Answer	Additional Guidance	Mark
*	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages). Accept any six indicative content points More than one indicative marking point may be made within the same comment or explanation	(6)

Indicative content • ΔG needs to be negative for a reaction to be feasible • if ΔS_{system} and ΔH are both negative then a reaction is feasible if the magnitude of ΔH > (magnitude of) $T\Delta S_{system}$ • if ΔS_{system} and ΔH are both positive then a reaction is feasible if the magnitude of $T\Delta S_{system}$ > (magnitude of) ΔH • if ΔS_{system} is positive and ΔH is negative then the reaction is (always) feasible • if ΔS_{system} is negative and ΔH is positive then the reaction is never feasible • even if it is feasible the reaction may not occur because of kinetic factors	High activation energy/energy barrier/physical barrier e.g. oxide layer Ignore just reference to slow rate of reaction Ignore reference to non-standard conditions

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $\Delta S_{surroundings} = -\Delta H/T$ (1) • calculation of $\Delta S_{surroundings}$ (1) • calculation of ΔS_{total} **and** sign **and** units (1)	<u>Example of calculation</u> $-(178000 \div 298) / -(178 \div 298)$ $-597(.315)$ (J K^{-1} mol^{-1}) **or** $-0.597(315)$ (kJ K^{-1} mol^{-1}) TE on equation with minus sign missing $\underline{160} + (-0.597315) = -0.437(315)$ kJ K^{-1} mol^{-1} 1000 **or** $160 + (-0.597315 \times 1000)$ $= -437.(315)$ J K^{-1} mol^{-1} TE on $\Delta S_{surroundings}$ Allow correct units shown once in answer for ΔS_{total} or $\Delta S_{surroundings}$ Ignore SF except 1SF Correct answer with sign and units without working scores 3 marks	(3)