

3.7 Entropy Quick Quiz

Name -

Class -

Answer all of the questions in the spaces provided.

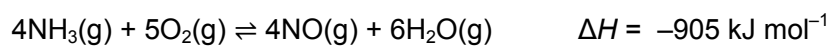
Additional space and a data booklet are at the end of the paper.

Please circle your class below.

Class	Teacher
13A1	Mrs Jones
13A2	Mr Bevan
13B	Ms Sheldon
13C1	Mr Madden
13C2	Mr Sharp
13D	Mr Madden
13E	Mr Sharp

0 3

The equation for the reaction between ammonia and oxygen is shown.



Some standard entropies are given in **Table 3**.

Table 3

Gas	$S^\circ / \text{J K}^{-1} \text{mol}^{-1}$
$\text{NH}_3(\text{g})$	193
$\text{O}_2(\text{g})$	205
$\text{NO}(\text{g})$	211
$\text{H}_2\text{O}(\text{g})$	189

0 3 . 1

Calculate the entropy change for the reaction between ammonia and oxygen.

[2 marks]

Entropy change _____ $\text{J K}^{-1} \text{mol}^{-1}$



03.2

Calculate a value for the Gibbs free-energy change (ΔG), in kJ mol^{-1} , for the reaction between ammonia and oxygen at 600°C

(If you were unable to obtain an answer to Question **03.1**, you should assume that the entropy change is $211 \text{ J K}^{-1} \text{ mol}^{-1}$. This is **not** the correct answer.)

[2 marks]

ΔG _____ kJ mol^{-1}

03.3

The reaction between ammonia and oxygen was carried out at a higher temperature.

Explain how this change affects the value of ΔG for the reaction.

[2 marks]

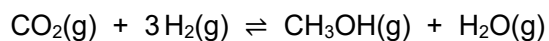
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MARK SCHEME – A-LEVEL CHEMISTRY – 7405/1 – JUNE 2018

Question	Answers	Additional Comments/Guidance	Mark
03.1	$(\Delta S = \Sigma(S_{\text{products}}) - \Sigma(S_{\text{reactants}}))$ $= [(4 \times 211) + (6 \times 189)] - [(4 \times 193) + (5 \times 205)] = (1978 - 1797)$ $181 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$		1 1
03.2	$(\Delta G = \Delta H - T\Delta S) = -905 - (600 + 273) \times 181 \times 10^{-3}$ $\Delta G = -1063 / -1060 \text{ (kJ mol}^{-1}\text{)}$ If alternative value of $\Delta S = 211$ used, answer = $-1089 \text{ (kJ mol}^{-1}\text{)}$	If answer to 03.1 is incorrect, mark consequentially: • $-905 - (873 \times 0.3.1 \times 10^{-3})$	1 1
03.3	ΔG becomes more negative/less positive The entropy change / ΔS is positive / $T\Delta S$ gets bigger / $-T\Delta S$ gets more negative.	Ignore increase/decrease/larger/smaller ΔG Consequential on wrong 03.1 If candidate does a calculation in 03.1 to produce ΔS negative then allow ΔG becomes less negative or more positive	1 1

1 0

Methanol is formed when carbon dioxide and hydrogen react.

**Table 5** contains enthalpy of formation and entropy data for these substances.**Table 5**

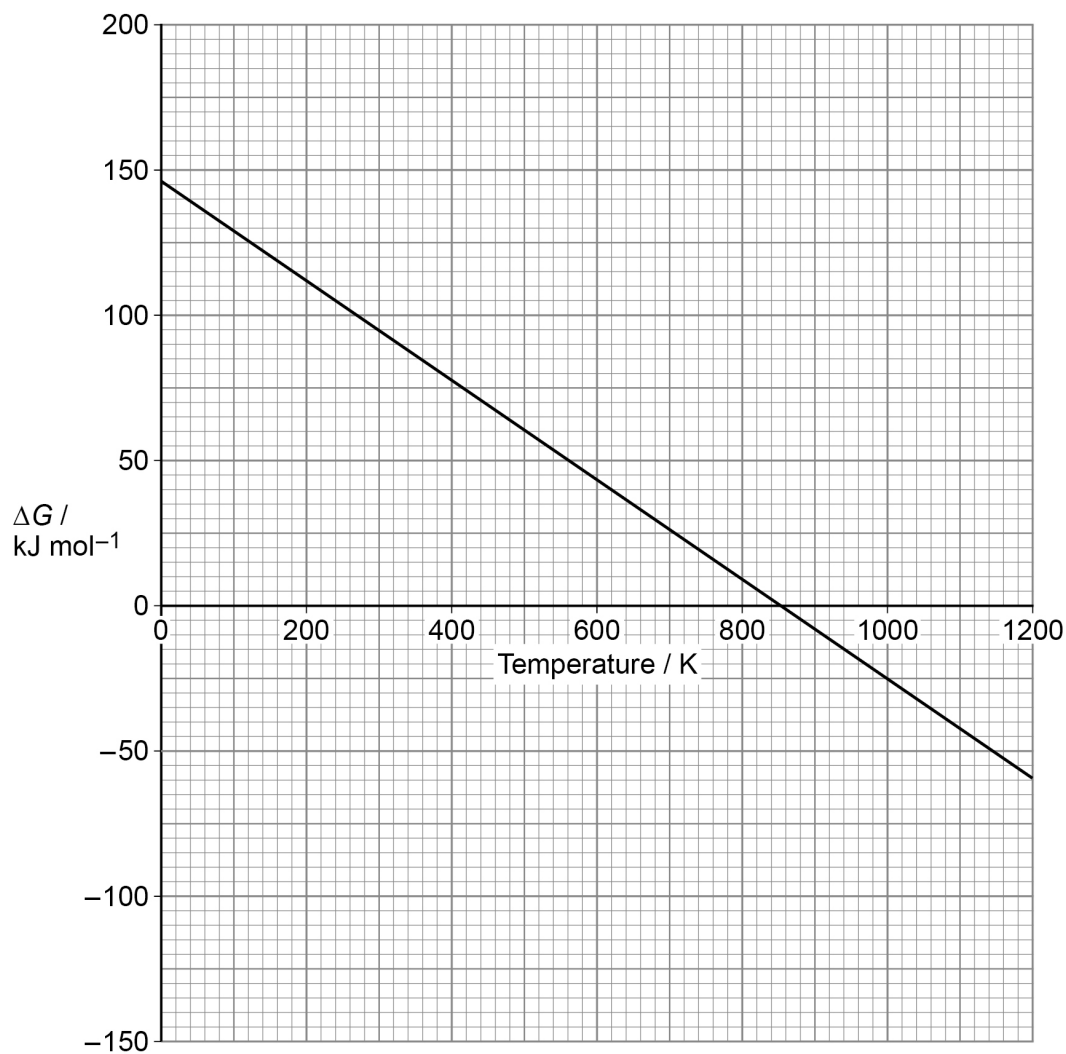
	CO₂(g)	H₂(g)	CH₃OH(g)	H₂O(g)
$\Delta_f H / \text{kJ mol}^{-1}$	−394	0	−201	−242
$S / \text{J K}^{-1} \text{mol}^{-1}$	214	131	238	189

1 0 . 1Use the equation and the data in **Table 5** to calculate the Gibbs free-energy change (ΔG), in kJ mol^{-1} , for this reaction at 890 K**[6 marks]** ΔG _____ kJ mol^{-1} **Turn over ►**

Figure 4 shows how the Gibbs free-energy change varies with temperature in a different gas phase reaction.

The straight line graph for this gas phase reaction has been extrapolated to zero Kelvin.

Figure 4



1 0 . 2

Use the values of the intercept and gradient from the graph in **Figure 4** to calculate the enthalpy change (ΔH), in kJ mol^{-1} , and the entropy change (ΔS), in $\text{J K}^{-1} \text{mol}^{-1}$, for this reaction.

[4 marks]

 ΔH _____ kJ mol^{-1}
 ΔS _____ $\text{J K}^{-1} \text{mol}^{-1}$

1 0 . 3

State what **Figure 4** shows about the feasibility of the reaction.

[1 mark]

Turn over ►



Question	Answers	Additional comments/Guidelines	Mark
10.1	M1 $\Delta H = (-201 + -242) - (-394)$	Allow consequential marking	1
	M2 $\Delta H = -49 \text{ (kJ mol}^{-1}\text{)}$	M2 1 mark for $\Delta H = +49 \text{ (kJ mol}^{-1}\text{)}$	1
	M3 $\Delta S = -180 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$		1
	M4 $\Delta G = \Delta H - T\Delta S$	M4 Recall this equation. If M4 incorrect cannot score M6	1
	M5 $\Delta G = -49 - \left[890 \times -\frac{180}{1000} \right]$ or M3 ÷ 1000	M5 Conversion of ΔS into kJ mol ⁻¹ $\Delta G = M2 - \frac{(890 \times M3)}{1000}$	1
	M6 $\Delta G = 111 \text{ (kJ mol}^{-1}\text{)}$	If ΔS not converted to kJ in M5, answer is +160151 kJmol ⁻¹ = 5 marks	1
10.2	M1 $\Delta H = \text{intercept of y axis} = 145 \text{ (kJ mol}^{-1}\text{)}$	M1 Value between 144 and 146 kJ mol ⁻¹	1
	M2 Gradient = $-\Delta S$ or a negative value		1
	M3 Gradient x 1000		1
	M4 $\Delta S = +167 \text{ to } +173 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$	M4 + 0.167 to +0.173 scores 2 for ΔS -167 to -173 scores 2 for ΔS -0.167 to -0.173 scores 1 for ΔS	1
10.3	Above 845 K reaction becomes (thermodynamically) feasible OR Below 845 K reaction is not (thermodynamically) feasible	Allow 845 to 860	1

0 7

This question is about thermodynamics.
Consider the reaction shown.

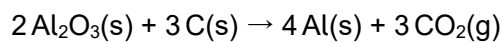


Table 7 shows some thermodynamic data.

Table 7

Substance	$\text{Al}_2\text{O}_3(\text{s})$	$\text{Al}(\text{s})$	$\text{C}(\text{s})$	$\text{CO}_2(\text{g})$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-1669	0	0	-394
$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$	51	28	6	214

0 7 . 1

Explain why the standard entropy value for carbon dioxide is greater than that for carbon.

[1 mark]

0 7 . 2

State the temperature at which the standard entropy of aluminium is $0 \text{ J K}^{-1} \text{mol}^{-1}$

[1 mark]



0	7	.	3
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Use the equation and the data in **Table 7** to calculate the minimum temperature, in K, at which this reaction becomes feasible.

[7 marks]

Minimum temperature _____ K

9

Turn over ►

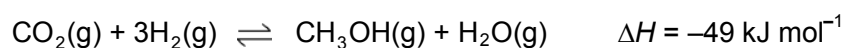


Question	Answers	Additional comments/Guidelines	Mark
07.1	CO ₂ / gas is more disordered (than solid)	Allow answers based on carbon Ignore CO ₂ is a gas and C is a solid	1
Question	Answers	Additional comments/Guidelines	Mark
07.2	0 K	Units essential Allow absolute zero OR –273 °C	1
Question	Answers	Additional comments/Guidelines	Mark
07.3	<p>M1 $\Delta H = (3 \times -394) - (-1669 \times 2)$</p> <p>M2 = 2156 (kJ mol⁻¹)</p> <p>M3 $\Delta S = (28 \times 4 + 214 \times 3) - (51 \times 2 + 6 \times 3)$</p> <p>M4 = 634 (J K⁻¹mol⁻¹)</p> <p>M5 $\Delta G = \Delta H - T \Delta S$ or $\Delta H = T \Delta S$ or $T = \Delta H \div \Delta S$</p> <p>M6 $\Delta S = 0.634 \text{ kJ K}^{-1}\text{mol}^{-1}$</p> <p>M7 $T = \frac{2156}{0.634} = 3400 \text{ to } 3401 \text{ (K)}$</p>	<p>M1 correct expression</p> <p>M2 if –2156 seen allow 1 mark out M1 and M2</p> <p>M3 correct expression</p> <p>M4 if – 634 allow 1 mark from M4 and M4</p> <p>M5 expression or rearranged expression or with numbers</p> <p>M6 $\Delta S = M4 \div 1000$</p> <p>M7 = M2 ÷ M6 but must be a positive answer</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>

- 5** **Table 3** contains some entropy data relevant to the reaction used to synthesise methanol from carbon dioxide and hydrogen. The reaction is carried out at a temperature of 250 °C.

Table 3

Substance	CO ₂ (g)	H ₂ (g)	CH ₃ OH(g)	H ₂ O(g)
Entropy (S ^o) / J K ⁻¹ mol ⁻¹	214	131	238	189



- 0 5** . **1** Use this enthalpy change and data from **Table 2** to calculate a value for the free-energy change of the reaction at 250 °C.
Give units with your answer.

[4 marks]

Free-energy change = _____ Units = _____

0 5 . **2** Calculate a value for the temperature when the reaction becomes feasible.

[2 marks]

Temperature = _____ K

0 5 . **3** Gaseous methanol from this reaction is liquefied by cooling before storage.

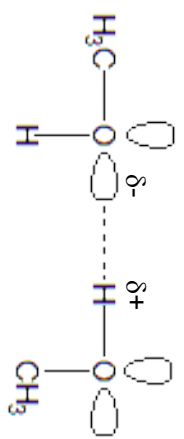
Draw a diagram showing the interaction between two molecules of methanol.
Explain why methanol is easy to liquefy.

[4 marks]

Diagram

Explanation _____

Question	Marking guidance	Mark	AO	Comments
05.1	$\Delta S = 238 + 189 - 214 - 3 \times 131 = -180 \text{ J K}^{-1} \text{ mol}^{-1}$ $\Delta G = \Delta H - T\Delta S$ $= -49 - \frac{523 \times (-180)}{1000}$ $= +45.1 \text{ kJ mol}^{-1}$	1	AO1b	Units essential
		1	AO1a	
		1	AO1b	
		1	AO1b	
05.2	When $\Delta G = 0$, $\Delta H = T\Delta S$ therefore $T = \Delta H/\Delta S$ $= -49 \times 1000/-180 = 272 \text{ (K)}$	1 1	AO1b AO1b	Mark consequentially to ΔS in 5.1

05.3	Diagram marks		
			
	Diagram of a molecule showing O–H bond and two lone pairs on each oxygen	1	AO2a
	Labels on diagram showing δ^+ and δ^- charges	1	AO2a
	Diagram showing δ^+ hydrogen on one molecule attracted to lone pair on a second molecule	1	AO2a
	Explanation mark		
	Hydrogen bonding (the name mentioned) is a strong enough force (to hold methanol molecules together in a liquid)	1	AO2a