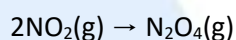


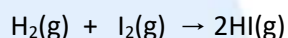
HL Questions on Entropy and spontaneity

1. Given that the standard entropy of gaseous water is $189 \text{ J K}^{-1} \text{ mol}^{-1}$ and the standard entropy of liquid water is $69.9 \text{ J K}^{-1} \text{ mol}^{-1}$ calculate the standard entropy change when one mol of gaseous water condenses to the liquid state, $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$.

2. (a) Predict the sign (positive or negative) for the entropy change for the reaction:



(b) Explain why the entropy change for the above reaction is considerably more than for the reaction:

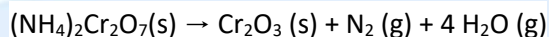


3. Use the information below to calculate the entropy change of formation of copper(I) oxide.

Substance	Entropy / $\text{J K}^{-1} \text{ mol}^{-1}$
Cu(s)	33.3
O ₂ (g)	205
Cu ₂ O(s)	101

4. You are unlikely to use orange crystals of ammonium dichromate, $(\text{NH}_4)_2\text{Cr}_2\text{O}_7(\text{s})$, in a school laboratory as it is a highly toxic substance. It is also carcinogenic and can explode when heated.

When it thermally decomposes (see image on right) it is both oxidised and reduced according to the equation:



(a) State what is being oxidized and what is being reduced.

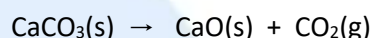
Clearly the thermal decomposition of ammonium dichromate is very exothermic ($\Delta H^\ominus = -1794 \text{ kJ mol}^{-1}$). What can you also deduce about the change in entropy?



Thermal decomposition of ammonium dichromate (image from Flickr)

(HL Questions on Entropy and spontaneity continued)

5. In a blast furnace limestone (calcium carbonate) is decomposed into calcium oxide and carbon dioxide according to the equation:



- (a) The standard enthalpies of formation of $\text{CaCO}_3(\text{s})$, $\text{CaO}(\text{s})$ and $\text{CO}_2(\text{g})$ are $-1207 \text{ kJ mol}^{-1}$, -635 kJ mol^{-1} and -394 kJ mol^{-1} respectively.

Calculate the standard enthalpy change, ΔH^\ominus , for the thermal decomposition of calcium carbonate.

- (b) The standard entropy values for $\text{CaCO}_3(\text{s})$, $\text{CaO}(\text{s})$ and $\text{CO}_2(\text{g})$ are $92.9 \text{ J K}^{-1} \text{ mol}^{-1}$, $40.0 \text{ J K}^{-1} \text{ mol}^{-1}$ and $214 \text{ J K}^{-1} \text{ mol}^{-1}$ respectively.

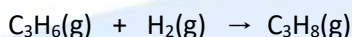
Calculate the change in entropy, ΔS^\ominus , for the thermal decomposition of calcium carbonate.

- (c) Calculate the change in free energy, ΔG^\ominus , for the thermal decomposition of calcium carbonate at 298 K.

- (d) State whether the thermal decomposition of calcium carbonate is spontaneous or non-spontaneous at 298K.

- (e) Explain why limestone cliffs are thermodynamically stable whereas limestone decomposes readily in a blast furnace.

6. Propene reacts with hydrogen at 180°C in the presence of a nickel catalyst to give propane.



- (a) Use the information below to determine the value for the free enthalpy change for this reaction at 180°C .

- (b) At 180°C this reaction is spontaneous.

Determine the temperature above which the reaction becomes non-spontaneous.

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{H}_2(\text{g})$	0	131
$\text{C}_3\text{H}_6(\text{g})$	+ 20.4	267
$\text{C}_3\text{H}_8(\text{g})$	- 104	270