HL Answers to Entropy & spontaneity questions

1. $\Delta S^{\ominus} = S^{\ominus}_{products} - S^{\ominus}_{reactants} = 69.9 - 189 = -119.1 \text{ J K}^{-1}\text{mol}^{-1}$.

2. (a) Negative. It is becoming more ordered as two moles of gas are converted into one mole of gas.

(b) In the second reaction there is no change in state or in the amount of moles present (two moles of reactants and products) so there is little change in disorder, whereas the amount of moles is reduced in the first reaction resulting in the system becoming less disordered.

3. $2Cu(s) + \frac{1}{2} O_2(g) \rightarrow Cu_2O(s)$

$S^{\ominus}_{reactants} = (2 \times 33.3) + (\frac{1}{2} \times 205) = 169.1 \text{ J K}^{-1} \text{ mol}^{-1}$

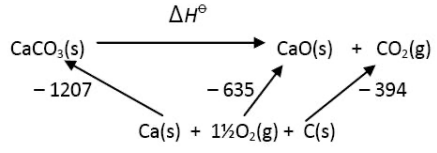
$S^{\ominus}_{products} = 101 \text{ J K}^{-1} \text{ mol}^{-1}$

$\Delta S^{\ominus} (Cu_2O) = 101 - 169.1 = -68.1 \text{ J K}^{-1} \text{ mol}^{-1}$

4. (a) Nitrogen is oxidised as its oxidation state increases from – 3 in NH_4^+ to 0 in N_2.
Chromium is reduced as its oxidation state decreases from + 6 in $Cr_2O_7^{2-}$ to +3 in Cr_2O_3.

(b) One mole of solid produces five moles of gas (and another one mole of solid) so the system has become much more disordered and therefore the change in entropy, ΔS, will have a high positive value.

5. (a)

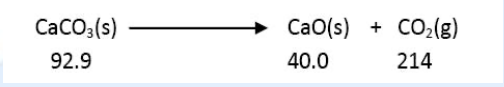


Using Hess's law

$-1207 + \Delta H^{\ominus} = -635 + (-394)$

$\Delta H^{o\ominus} = +178 \text{ kJ mol}^{-1}$

(b)



$\Delta S^{\ominus} = S^{\ominus}_{products} - S^{\ominus}_{reactants}$

$= (40.0 + 214) - 92.9 = +161 \text{ J K}^{-1} \text{ mol}^{-1}$

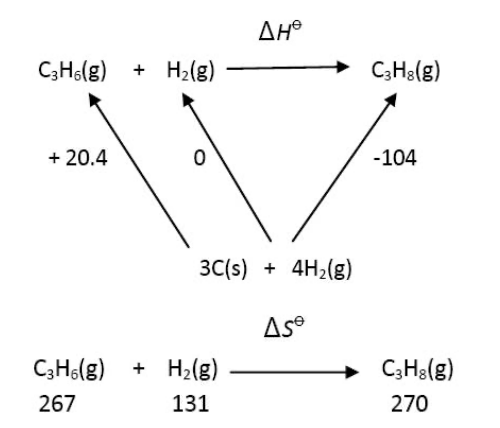
(c) $\Delta G^{o\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} = +178 - (298 \times 161/1000) = +130 \text{ kJ mol}^{-1}$

HL Answers to Entropy & spontaneity questions continued

(d) Since ΔG^o has a positive value $\Delta G^\ominus > 0$) the thermal decomposition of calcium carbonate is non-spontaneous at 298 K.

(e) At normal atmospheric temperatures $\Delta^\ominus > 0$ so limestone cliffs will be thermally stable as the reaction is non-spontaneous.
$\Delta G^\ominus = 0$ when $\Delta H^\ominus = T\,\Delta S^\ominus$. This is when T = 178 x 1000/161 = 1106 K (or 833 °C). Hence at temperatures higher than 833 °C in the blast furnace the decomposition proceeds readily as the reaction is spontaneous at this temperature.

6. (a)



Using Hess's law
$\Delta H^\ominus = -104 - (20.4 + 0) = -124.4$ kJ mol^{-1}

$\Delta S^\ominus = S^\ominus_{\text{products}} - S^\ominus_{\text{reactants}}$
$= 270 - (267 + 131) = -128$ J K^{-1} mol^{-1}

$\Delta G^\ominus = \Delta H^\ominus - T\,\Delta S^\ominus = -124.4 - [(180 + 273) \times -128/1000] = -66.4$ kJ mol^{-1}

(b) The reaction becomes non-spontaneous above the temperature when $\Delta G^\ominus = 0$
$\Delta G^\ominus = 0$ when $-124.4 = -T(128/1000)$
$T = -124.4 \times (1000/128) = 972$ K
The reaction becomes non-spontaneous above 972 K (or 699 °C).