HL Questions on Entropy and spontaneity

1. Given that the standard entropy of gaseous water is 189 J K^{-1} mol^{-1} and the standard entropy of liquid water is 69.9 J K^{-1} mol^{-1} calculate the standard entropy change when one mol of gaseous water condenses to the liquid state, $H_2O(g) \rightarrow H_2O(l)$.

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

$$2NO_2(g) \rightarrow N_2O_4(g)$$

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

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$

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

Substance	Entropy / J K^{-1} mol^{-1}
Cu(s)	33.3
$O_2(g)$	205
$Cu_2O(s)$	101

4. You are unlikely to use orange crystals of ammonium dichromate, $(NH_4)_2Cr_2O_7(s)$, 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:

$$(NH_4)_2Cr_2O_7(s) \rightarrow Cr_2O_3(s) + N_2(g) + 4\,H_2O(g)$$

Thermal decomposition of ammonium dichromate (image from Flickr)

(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 kJ mol^{-1}). What can you also deduce about the change in entropy?

(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:

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

(a) The standard enthalpies of formation of $CaCO_3(s)$, $CaO(s)$ and $CO_2(g)$ are – 1207 kJ mol^{-1}, – 635 kJ mol^{-1} and – 394 kJ mol^{-1} respectively.
Calculate the standard enthalpy change, $\Delta H^{\ominus}$, for the thermal decomposition of calcium carbonate.

(b) The standard entropy values for $CaCO_3(s)$, $CaO(s)$ and $CO_2(g)$ are 92.9 J K^{-1} mol^{-1}, 40.0 J K^{-1} mol^{-1} and 214 J K^{-1} mol^{-1} respectively.
Calculate the change in entropy, $\Delta S^{\ominus}$, for the thermal decomposition of calcium carbonate.

(c) Calculate the change in free energy, $\Delta G^{\ominus}$, 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.

$$C_3H_6(g) + H_2(g) \rightarrow C_3H_8(g)$$

(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	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
$H_2(g)$	0	131
$C_3H_6(g)$	+ 20.4	267
$C_3H_8(g)$	– 104	270