CH1011 Tutorial 6 Answers

1. Explain the term **standard enthalpy of formation**. Illustrate your answer using $\Delta H^o_{f(\ CH4(g)\ )}$ as an example (ie write the balanced equation).

ΔH^o_f is the enthalpy change accompanying the formation reaction of 1 mole of compound from its elements with all the substances in their standard states at p = 1 atm.

$C(graphite, s) + 2H_2(g) \rightarrow CH_4(g)$ $\Delta H^o_{f(\ CH4(g)\ )}$ -75 kJ

2. Calculate the heat of combustion $\mathbf{\Delta H^o_{c(\ CH4(g)\ )}}$ when methane is combusted to form $CO_2(g)$ and $H_2O(l)$.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

$\Delta H^o_{c(\ CH4(g)\ )} = \Sigma m\Delta H^o_{f\ (products)} - \Sigma n\Delta H^o_{f\ (reactants)}$
$= (-394 + 2 \times -286) - (-75)$ kJ
$= -891$ kJ

3. 0.045 mol of $COCl_2$ gas (phosgene) is placed in a reaction vessel at 500°C. The total pressure in the vessel is 0.60 atm. and the partial pressures of CO and Cl_2 are 0.10 atm. and 0.20 atm., respectively Write down the expression for K_p and determine the value of K_p in the above system.

$COCl_2(g) \rightarrow CO(g) + Cl_2(g)$

$p(COCl_2) = p(Total) - [p(CO) + p(Cl_2)]$
$= 0.60 - [0.10 + 0.20]$
$= 0.30$

$Kp = p(CO)p(Cl_2) / p(COCl_2)$
$= 0.10 \times 0.20 / 0.30$
$= \mathbf{0.067}$

4. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H^o = -91$ kJ mol^{-1}

In an equilibrium reaction mixture of the above reaction how would $p(H_2)$ and K_p change if the temperature of the reaction vessel were raised? Explain your answer.

$p(H_2)$ would increase. K_p would decrease.
Le Chatalier's principle states that for an exothermic reaction external heating will result in an increase in the reverse (endothermic) reaction to reduce the effect of the change.
This will result in an increase in $p(H_2)$ and $p(N_2)$ and a decrease in pNH_3 hence K_p will decrease.

Additional information:

$\Delta H^o_{f(\ CH4(g)\ )}$ -75 kJ/mol $\Delta H^o_{f(\ CO2(g)\ )}$ -394 kJ/mol $\Delta H^o_{f(\ H2O(l)\ )}$ -286 kJ/mol

5. Define the term **free energy** of a substance. How is the change in free energy important in a chemical reaction?

$G = H - TS$ free energy is an energetic term which is a measure of the reactivity of a substance and is defined by the above equation where H = enthalpy, T = temperature (K) and S = entropy. The units are J.
The change in free energy for a reaction determines the spontaneity of a reaction.
ΔG is -ve for a spontaneous reaction and +ve for a non-spontaneous reaction.

6. The combustion of graphite (carbon) forms carbon dioxide. Write a **balanced equation** and calculate $\mathbf{K^o}$ for this reaction at 25°C.

$C(graphite) + O_2(g) \rightarrow CO_2(g)$

$\Delta G^o = \Sigma \Delta G^o_f(products) - \Sigma \Delta G^o_f(reactants)$
$= [\Delta G^o_f(CO_2)] - [\Delta G^o_f(O_2) + \Delta G^o_f(graphite)]$
$= [-386.2 \text{ kJ/mol}] - [0 + 0]$
$= -386.2 \text{ kJ / mol}$

$\Delta G^o = -RT \ln K^o$

$K^o = e(-\Delta G^o/RT) = e(-386.2 \times 10^3 \text{ J / mol} / -8.31 \text{ J/mol K} \times (25 + 273) \text{ K})$
$= \mathbf{5.37 \times 10^{67}}$

Additional information:

$\Delta G^o_f(_{CO2(g)}) -386.2 \text{ kJ/mol}$ $\Delta G = -RT \ln K^o$
$R = 8.31 \text{ J/mol K}$ $0^oC = 273K$