CHEM1612 Problem Sheet 4 (Week 4)

Work through the ChemCAL module "*Chemical Equilibrium*"

1. Ammonium carbamate ($NH_2CO_2NH_4$) is a salt of carbamic acid that is found in the blood and urine of mammals. At 250 ºC, based on a standard state of 1 M, $K_c = 1.58 \times 10^{-8}$ for the following equilibrium:

$$NH_2CO_2NH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

If 7.80 g of $NH_2CO_2NH_4$ is introduced into a 0.500 L evacuated container, what is the total pressure inside the container at equilibrium at 250 °C?

2. Water is oxidized to give hydrogen peroxide according to the reaction below.

$$H_2O(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons H_2O_2(g)$$

(a) Using the data below, calculate $\Delta G°$ at 600 K for this reaction.

$H_2(g) + O_2(g) \rightleftharpoons H_2O_2(g)$ $\quad K_p = 2.3 \times 10^6$ at 600 K

$2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$ $\quad K_p = 1.8 \times 10^{37}$ at 600 K

Both values of K_p are based on a standard state of 1×10^5 Pa.

(b) Calculate the equilibrium constant K_c for the reaction.

(c) At 600 K, the entropy change, $\Delta S°$, for the reaction is +60 J K^{-1} mol^{-1}. Using this value and the value for $\Delta G°$ from (a), calculate the enthalpy change, $\Delta H°$, at 600 K.

(d) What is the effect on $[H_2O_2]$ if the system is subjected to the following changes:

(i) The volume of the container is decreased
(ii) The temperature is increased
(iii) A solid catalyst is added at constant temperature and volume.

3. The equilibrium constant, K_p, for the reaction below is 11.5 at 600 K based on a standard state of 1×10^5 Pa.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

2.450 g of PCl_5 is placed in an evacuated 500 mL bulb, which is heated to 600 K.

(a) What would be the initial pressure of $PCl_5(g)$ before it dissociates?
(b) What is the partial pressure of $PCl_5(g)$ at equilibrium?
(c) What is the total pressure in the bulb at equilibrium?
(d) What is the degree of dissociation of $PCl_5(g)$ at equilibrium?

Hint for part (b) As K_p is not very small, you *cannot* assume that the amount of product formed is small compared to the amount of starting material. You will need to solve the quadratic formula.