Chapter 17 Chemical Equilibrium

Homework Problems

1. At a given temperature, \( K = 1.3 \times 10^{-2} \) for the reaction: \( \text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) \)

   Calculate values of \( K \) for the following reactions at this temperature.

   a. \( \frac{1}{2} \text{N}_2(\text{g}) + \frac{3}{2} \text{H}_2(\text{g}) \rightleftharpoons \text{NH}_3(\text{g}) \)

   b. \( 2 \text{N}_2(\text{g}) + 6 \text{H}_2(\text{g}) \rightleftharpoons 4 \text{NH}_3(\text{g}) \)

2. Ammonia is placed in a reactor, and the temperature is increased to 745°C, where some will decompose to nitrogen and hydrogen. The initial concentration of ammonia was 0.0240 M. After equilibrium is attained, the concentration of ammonia is 0.0040 M.

   Calculate \( K_c \) at 745°C for the reaction.

3. The formation of phosgene, COCl\(_2\), was studied by sealing 0.96 atm of carbon monoxide and 1.02 atm of chlorine gas in a reaction vessel at 682 K. The pressure dropped smoothly from a total pressure of 1.98 atm to 1.22 atm as the system reached equilibrium.

   Calculate \( K_p \) for the reaction.

4. What will happen to the number of moles of SO\(_3\) in equilibrium with SO\(_2\) and O\(_2\) in each of the following cases for the reaction:

   \( 2 \text{SO}_3(\text{g}) \rightleftharpoons 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \quad \Delta H^\circ = 197 \text{ kJ} \)

   a. Oxygen gas is added.

   b. The pressure is increased by decreasing the volume of the reaction container.

   c. The pressure is increased by adding argon gas.

   d. The temperature is decreased.

   e. Gaseous sulfur dioxide is removed.
5. At a certain temperature, $K_c = 9.1 \times 10^{-4}$ for the reaction: \[ \text{FeSCN}^{2+}_{(aq)} \rightleftharpoons \text{Fe}^{3+}_{(aq)} + \text{SCN}^-_{(aq)} \]

Calculate the concentrations of Fe$^{3+}$, SCN$, FeSCN^{2+}$ in a solution that is initially 2.0 M FeSCN$^{2+}$.

6. Chromium(VI) forms two different oxyanions, the orange dichromate ion, Cr$_2$O$_7^{2-}$, and the yellow chromate ion, CrO$_4^{2-}$. The equilibrium reaction between the two ions is:
\[
\text{Cr}_2\text{O}_7^{2-}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons 2 \text{CrO}_4^{2-}_{(aq)} + 2 \text{H}^+_{(aq)}
\]

Give a logical written explanation why orange dichromate solutions turn yellow when sodium hydroxide is added.

7. Nitric oxide and bromine at initial pressures of 98.4 and 41.3 torr, respectively, were allowed to react at 300. K. At equilibrium the total pressure was 110.5 torr. The reaction is:
\[
2 \text{NO}_{(g)} + \text{Br}_2_{(g)} \rightleftharpoons 2 \text{NOBr}_{(g)}
\]

a. Calculate the value of $K_p$.

b. What would be the partial pressure of all species if NO and Br$_2$, both at an initial partial pressure of 0.30 atm, were allowed to come to equilibrium at this temperature?