Equilibria

I. Balance each equation and write an equilibrium expression for each of the following reactions.

1. $SO_{2\,(g)} + O_{2\,(g)} \Leftrightarrow SO_{3\,(g)}$

2. $CO\ (g) + O_{2\,(g)} \Leftrightarrow CO_{2\,(g)}$

3 $N_{2\,(g)} + H_{2\,(g)} \Leftrightarrow NH_{3\,(g)}$

4. $H_{2\,(g)} + Cl_{2\,(g)} \Leftrightarrow HCl_{\,(g)}$

5. $N_{2\,(g)} + O_{2\,(g)} \Leftrightarrow N_2O_{\,(g)}$

6. $NO_{\,(g)} + O_{2\,(g)} \Leftrightarrow NO_{2\,(g)}$

7. $HC_2H_3O_{2\,(aq)} \Leftrightarrow H^{+}_{(aq)} + C_2H_3O_2^{-}{}_{(aq)}$

8. $HCN_{\,(aq)} \Leftrightarrow H^{+}_{\,(aq)} + CN^{-}_{\,(aq)}$

9. $AgCl_{\,(s)} \Leftrightarrow Ag^{+}_{\,(aq)} + Cl^{-}_{\,(aq)}$

10. $PbI_{2\,(s)} \Leftrightarrow Pb^{2+}_{\,(aq)} + I^{-}_{\,(aq)}$

11. $Bi_2S_{3\,(s)} \Leftrightarrow Bi^{3+}_{\,(aq)} + S^{2-}_{\,(aq)}$

II. In each of the following, determine the unknown quantity from the information given. The number in parentheses refers to the corresponding reaction in Part I to which you should refer.

1. Find K_{eq} if $[SO_2] = 1.0$ M; $[O_2] = 1.0$ M; $[SO_3] = 2.0$ M (1)

2. Find K_{eq} if $[CO] = 0.5$ M; $[O_2] = 0.5$ M; $[CO_2] = 2.5$ M (2)

3. Find K_{eq} if $[N_2] = 0.25$ M; $[H_2] = 0.10$ M; $[NH_3] = 0.010$ M (3)

4. Find K_{eq} if $[H_2] = 2.0 \times 10^{-3}$ M; $[Cl_2] = 2.5 \times 10^{-2}$ M; $[HCl] = 1.5 \times 10^{-3}$ M (4)

5. Find $[O_2]$ if $K_p = 45.0\ atm^{-1}$; $[N_2] = 1.0$ atm; $[N_2O] = 1.0$ atm (5)

6. Find [NO] if $[O_2] = 0.10$ M; $[NO_2] = 0.20$ M; $K_{eq} = 10.0$ (6)

7. Find $[N_2]$ if $[H_2] = 1.0 \times 10^{-2}$ M; $[NH_3] = 2.0 \times 10^{-3}$ M; $K_{eq} = 1.5 \times 10^{-4}$ (3)

8. Find [CO] if $[O_2] = 1.3 \times 10^{-3}$ M; $[CO_2] = 2.5 \times 10^{-4}$ M; $K_{eq} = 3.6 \times 10^{-3}$ (2)

9. Find K_a if $[HC_2H_3O_2] = 0.10$ M; $[H^+] = [C_2H_3O_2^-] = 0.0010$ M (7)

10. Find K_a if $[HCN] = 0.0010$ M; $[H^+] = 0.010$ M; $[CN^-] = 2.0 \times 10^{-8}$ (8)

11. Find $[C_2H_3O_2^-]$ if $[HC_2H_3O_2] = 1.5 \times 10^{-2}$ M; $[H^+] = 2.0 \times 10^{-3}$ M; $K_a = 1.8 \times 10^{-5}$ (7)

12. Find $[H^+]$ if [HCN] = 3.6×10^{-3} M and $[CN^-] = [H^+]$; $K_a = 5.8 \times 10^{-8}$ (8)

13. Find K_{sp} if the solubility of silver chloride is 4.3×10^{-6} g/100 mL (9)

14. Find K_{sp} if the solubility of bismuth (III) sulfide is 2.9×10^{-5} g/100 mL (11)

15. Find $[Pb^{2+}]$ if K_{sp} for PbI_2 is 7.5×10^{-9} (10)

III. Solve each of the following problems involving equilibria.

1. Calculate the equilibrium constant for the following reaction; $2A + B \Leftrightarrow 3C + D$, where the concentrations are A = 3.0 M; B = 2.0 M; C = 2.0 M; and D = 4.0 M

2. The equilibrium constant for the reaction A + B qe 2C is 50. After mixing equimolar quantities of A and B, the equilibrium concentration of C is found to be 0.50 M. What are the concentrations of A and B at equilibrium?

3. Consider the reaction $PCl_{5\,(g)}$ qe $PCl_{3\,(g)} + Cl_2$ *(g)*. the equilibrium mixture in a 9.0 L container was found to include 0.25 moles of PCl_5, 0.36 moles of PCl_3, and 0.36 moles of Cl_2. From this data calculate the equilibrium constant for the reaction at the reaction temperature of 225° C.

4. Nitrogen is caused to react with hydrogen to form ammonia at 450° C in a 4.0 L vessel. At equilibrium, the partial pressures observed for each of the species in the reaction was as follows: ammonia 900 mm Hg, nitrogen 180 mm Hg and hydrogen 305 mm Hg. From this information calculate the equilibrium constant for the reaction at this temperature.

5. Consider the reaction $H_{2\,(g)} + I_{2\,(g)}$ qe $2\,HI_{(g)}$. The equilibrium constant for this reaction is 32. If at equilibrium the concentration of HI is 0.40 M and that of I_2 is 0.05 M, what is the concentration of hydrogen?

6. The equilibrium constant of the following reaction is 8. What is the concentration of oxygen at equilibrium?

$$4\ Al_{(s)} + 3\ O_{2\,(g)} \Leftrightarrow\ 2\ Al_2O_{3\,(s)}$$

7. For the reaction $H_{2\,(g)} + I_{2\,(g)}$ $2\ HI_{(g)}$ what is the equilibrium constant if the following concentrations are observed at equilibrium? $[H_2] = 5.62$ M $[I_2] = 0.130$ M $[HI] = 7.89$ M

8. Given the equilibrium concentrations shown below, what is the dissociation constant for ammonia?

$[NH_3] = 0.0015$ M $[H_2]$ 0.032 M $[N_2] = 0.069$ M