Equilibria

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

1. $SO_{2\,(g)} + O_{2\,(g)} \leftrightarrows SO_{3\,(g)}$ $\quad K = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]^1}$

2. $CO\,(g) + O_{2\,(g)} \leftrightarrows CO_{2\,(g)}$ $\quad K = \dfrac{[CO_2]^2}{[CO]^2[O_2]^1}$

3. $N_{2\,(g)} + H_{2\,(g)} \leftrightarrows NH_{3\,(g)}$ $\quad K = \dfrac{[NH_3]^2}{[N_2]^1[H_2]^3}$

4. $H_{2\,(g)} + Cl_{2\,(g)} \leftrightarrows HCl_{\,(g)}$ $\quad K = \dfrac{[HCl]^2}{[H_2][Cl_2]}$

5. $N_{2\,(g)} + O_{2\,(g)} \leftrightarrows N_2O_{\,(g)}$ $\quad K = \dfrac{[N_2O]^2}{[N_2]^2[O_2]^1}$

6. $NO_{\,(g)} + O_{2\,(g)} \leftrightarrows NO_{2\,(g)}$ $\quad K = \dfrac{[NO_2]^2}{[NO]^2[O_2]^1}$

7. $HC_2H_3O_{2\,(aq)} \leftrightarrows H^+_{(aq)} + C_2H_3O^{2-}_{\,(aq)}$ $\quad K = \dfrac{[H^+]^1[C_2H_3O_2^-]^1}{[HC_2H_3O_3]^1}$

8. $HCN_{\,(aq)} \leftrightarrows H^+_{\,(aq)} + CN^-_{\,(aq)}$ $\quad K = \dfrac{[H^+]^1[CN^-]^1}{[HCN]^1}$

9. $AgCl_{\,(s)} \leftrightarrows Ag^+_{\,(aq)} + Cl^-_{\,(aq)}$ $\quad K = [Ag+]\,[Cl-]$

10. $PbI_{2\,(s)} \leftrightarrows Pb^{2+}_{\,(aq)} + I^-_{\,(aq)}$ $\quad K = [Pb^{2+}]\,[I-]^2$

11. $Bi_2S_{3\,(s)} \leftrightarrows Bi^{3+}_{\,(aq)} + S^{2-}_{\,(aq)}$ $\quad K = [Bi^{3+}]^2\,[S^{2-}]^3$

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) *4.0/M*
2. Find K_{eq} if $[CO] = 0.5$ M; $[O_2] = 0.5$ M; $[CO_2] = 2.5$ M (2) *50/M*
3. Find K_{eq} if $[N_2] = 0.25$ M; $[H_2] = 0.10$ M; $[NH_3] = 0.010$ M (3) *.40 M^{-2}*
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) *0.045*
5. Find $[O_2]$ if $K_p = 45.0\ atm^{-1}$; $[N_2] = 1.0$ atm; $[N_2O] = 1.0$ atm (5) *0.022 atm*
6. Find $[NO]$ if $[O_2] = 0.10$ M; $[NO_2] = 0.20$ M; $K_{eq} = 10.0$ (6) *0.20 M*

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) *2.67×10^{4} M*

8. Find [CO] if $[O_2] = 1.3 \times 10^{-3}$ M; $[CO_2] = 2.5 \times 10\text{-}^{4}$ M; $K_{eq} = 3.6 \times 10^{-3}$ (2) *0.116 M*

9. Find K_a if $[HC_2H_3O_2] = 0.10$ M; $[H^+] = [C_2H_3O_2^-] = 0.0010$ M (7) *1.0×10^{-5}*

10. Find K_a if [HCN] = 0.0010 M; $[H^+] = 0.010$ M; $[CN^-] = 2.0 \times 10^{-8}$ (8) *2.0×10^{-7}*

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) *1.35×10^{-4} M*

12. Find $[H^+]$ if [HCN] = 3.6×10^{-3} M and $[CN^-] = [H^+]$; $K_a = 5.8 \times 10^{-8}$ (8) *1.44×10^{-5}*

13. Find K_{sp} if the solubility of silver chloride is 4.3×10^{-6} g/100 mL (9) *9.0×10^{-14} M*

14. Find K_{sp} if the solubility of bismuth (III) sulfide is 2.9×10^{-5} g/100 mL (11) *6.16×10^{-30}*

15. Find $[Pb^{2+}]$ if K_{sp} for PbI_2 is 7.5×10^{-9} (10) *1.23×10^{-3} M*

III. Solve each of the following problems involving equilibria.

1. Calculate the equilibrium constant for the following reaction; $2A + B \leftrightarrows 3C + D$, where the concentrations are A = 3.0 M; B = 2.0 M; C = 2.0 M; and D = 4.0 M *1.78*

2. The equilibrium constant for the reaction $A + B \leftrightarrows 2C$ 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? *0.071 M*

3. Consider the reaction $PCl_{5\,(g)} \leftrightarrows PCl_{3\,(g)} + Cl_{2\,(g)}$. the equilibrium mixture in a 9.0 L container was found to include 0.25 moles of PCl5, 0.36 moles of PCl3, and 0.36 moles of Cl2. From this data calculate the equilibrium constant for the reaction at the reaction temperature of 225° C. *0.058 M*

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. *$K_{eq} = 3.5 \times 105$ $K_p = 2.5 \times 10\text{-}3$*

5. Consider the reaction $H2_{(g)} + I2_{(g)} \leftrightarrows 2\ HI_{(g)}$. The equilibrium constant for this reaction is 32. If at equilibrium the concentration of HI is 0.40 M and that of I2 is 0.05 M, what is the concentration of hydrogen? *0.10 M*

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

   $4\ Al_{(s)} + 3\ O_{2\,(g)} \leftrightarrows 2\ Al_2O_{3\,(s)}$ *0.5 M*

7. For the reaction $H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2\ HI_{(g)}$ 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 *85.2*

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

   K=1