AR CHEMISTRY: EQUILIBRIUM PROBLEM SET

1. Suppose a sample of Cl_2 is placed in a closed container. It paritally dissociates to form Cl atoms: $Cl_{2\,(g)} \leftrightarrow 2\,Cl_{(g)}$
   How do the rates of forward and reverse reactions compare:
   a. at the beginning of the experiment?
   b. when equilibrium is reached?

2. At 250 C, the concentrations of compounds in a vessel are: $\frac{[PCl_3]\,[Cl_2]}{[PCl_5]} = 0.050$

   Would the ratio change if we changed:
   a. the volume of the container?
   b. the temperature?
   c. the original concentrations?

3. Write the Keq expressions for the following reactions:
   a. $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$
   b. $2\,NCl_{3\,(g)} \leftrightarrow N_{2\,(g)} + 3\,Cl_{2\,(g)}$
   c. $N_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\,NO_{(g)}$
   d. $N_2H_{4\,(g)} \leftrightarrow N_{2\,(g)} + 2\,H_{2\,(g)}$
   e. $2\,MgN_{3\,(s)} \leftrightarrow 2\,Mg_{(s)} + 3\,N_{2\,(g)}$
   f. $2\,H_2O_{2\,(l)} \leftrightarrow 2\,H_2O_{(l)} + O_{2\,(g)}$
   g. $2\,H_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\,H_2O_{(l)}$
   h. $SnO_{2\,(s)} + O_{2\,(g)} \leftrightarrow 2\,H_2O_{(g)} + Sn_{(s)}$
   i. $2\,SO_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\,SO_{3\,(g)}$
   j. $H_{2\,(g)} + Br_{2\,(g)} \leftrightarrow 2\,HBr_{(g)}$
   k. $Ca(OH)_{2\,(s)} \leftrightarrow CaO_{(s)} + O_{2\,(g)}$
   l. $CO_{(g)} + H_2O_{(l)} \leftrightarrow CO_{2\,(g)} + H_{2\,(g)}$
   m. $Fe_2O_{3\,(s)} + 3\,H_{2\,(g)} \leftrightarrow 2\,Fe_{(s)} + 3\,H_2O_{(g)}$
   n. $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$
   o. $2\,CO_{2\,(g)} \leftrightarrow 2\,CO_{(g)} + O_{2\,(g)}$
   p. $2\,NO_{(g)} + O_{2\,(g)} \leftrightarrow 2\,NO_{2\,(g)}$

4. For the equilibiurm: $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$ Calculate Keq if $[N_2] = 0.10$ M, $[H_2] = 0.20$ M, and $[NH_3] = 0.10$ M

5. Consider the system: $2\,SO_{3\,(g)} \leftrightarrow 2\,SO_{2\,(g)} + O_{2\,(g)}$
   What is the value of Keq if at equilibrium all the concentrations are 0.10 M

6. For the equilibrium: $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$ K = 60
   a. Calculate [HI] if the concentrations of hydrogen and iodine are both 0.10 M
   b. Calculate $[I_2]$ if [HI] = 0.60 M and $[H_2] = 0.10$ M

7. For the system: $2\,CO_{(g)} + O_{2\,(g)} \leftrightarrow 2\,CO_{2\,(g)}$ Keq = 2.0×10^5 (200,000 with two sig figs)
   a. Write the Keq expression for this reaction
   b. Calculate the concentration of oxygen if the concentrations of carbon monoxide and carbon dioxide are each 1.0 M.

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1a. At the beginning of a reaction: Forward rate is fast, Reverse rate is zero
1b. At equilibrium, Forward rate = Reverse rate
2a. Volume changes the initial and final concentrations, but NOT the final RATIO
2b. Temperature changes the RATIO--it changes the reaction rates so the ratio changes
2c. Original concentrations have no effect on the final RATIO
3a. $K_{eq} = [NH_3]^2 / [N_2] [H_2]^3$
3b. $K_{eq} = [N_2] [Cl_2]^3 / [NCl_3]^2$
3c. $K_{eq} = [NO]^2 / [N_2] [O_2]$
3d. $K_{eq} = [N_2] [H_2]^2 / [N_2H_4]$
3e. $K_{eq} = [N_2]^3$
3f. $K_{eq} = [O_2]$
3g. $K_{eq} = 1 / [H_2]^2 [O_2]$
3h. $K_{eq} = [H_2O]^2 / [O_2]$
3i. $K_{eq} = [SO_3]^2 / [SO_2]^2 [O_2]$
3j. $K_{eq} = [HBr]^2 / [H_2] [Br_2]$
3k. $K_{eq} = [O_2]$
3l. $K_{eq} = [CO_2] [H_2] / [CO]$
3m. $K_{eq} = [H_2O]^3 / [H_2]^3$
3n. $K_{eq} = [HI]^2 / [H_2] [I_2]$
3o. $K_{eq} = [CO]^2 [O_2] / [CO_2]^2$
3p. $K_{eq} = [NO_2]^2 / [NO]^2 [O_2]$

4. For the equilibiurm: $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$ Calculate Keq if $[N_2] = 0.10$ M, $[H_2] = 0.20$ M, and $[NH_3] = 0.10$ M

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{[0.10]^2}{[0.10][0.20]^3} = \mathbf{12.5}$$

5. Consider the system: $2\,SO_{3\,(g)} \leftrightarrow 2\,SO_{2\,(g)} + O_{2\,(g)}$

What is the value of Keq if at equilibrium all the concentrations are 0.10 M

$$K_{eq} = [SO_2]^2 [O_2] / [SO_3]^2 = \frac{[0.10]^2\ [0.10]}{[0.10]^2} = \mathbf{0.10}$$

6. For the equilibrium: $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$ K = 60

a. Calculate [HI] if the concentrations of hydrogen and iodine are both 0.10 M

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = 60, \quad 60 = \frac{[HI]^2}{[0.10][0.10]}, \quad 60 = [HI]^2, \quad \mathbf{[HI] = 0.77\ M}$$

b. Calculate $[I_2]$ if [HI] = 0.60 M and $[H_2]$ = 0.10 M

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = 60, \quad 60 = \frac{[0.60]^2}{[0.10][I_2]}, \quad [I_2] = \frac{[0.60]^2}{(60)[0.10]} \quad \mathbf{[I_2] = 0.060\ M}$$

7. For the system: $2\,CO_{(g)} + O_{2\,(g)} \leftrightarrow 2\,CO_{2\,(g)}$ $K_{eq} = 2.0 \times 10^5$ (200,000 with two sig figs)

a. Write the Keq expression for this reaction $\mathbf{K_{eq} = [CO_2]^2 / [CO]^2 [O_2]}$

b. Calculate the concentration of oxygen if the concentrations of carbon monoxide and carbon dioxide are each 1.0 M.

$$K_{eq} = \frac{[CO_2]^2}{[CO]^2[O_2]} = 200{,}000, \quad 200{,}000 = \frac{[1.0]^2}{[1.0]^2[O_2]} \quad [O_2] = \frac{1}{200{,}000} = \mathbf{0.0000050\ M}$$