AP Chemistry
Ms. Ye

Name _____
Date _____Block _____

**Do Now: Le Chatelier's Principle**

Answer the following questions regarding equilibrium systems:

1. The equilibrium system $\mathbf{Br_{2\,(l)} + Cl_{2\,(g)} \leftrightarrows 2\ BrCl_{(g)}}$ $\mathbf{\Delta H = +29.4\ kJ/mol}$ is analyzed and used in an industrial setting. Which of the following would be appropriate methods to increase the yield of $BrCl_{(g)}$ being produced? Circle all that apply.
   a. Increasing the temperature
   b. Increasing the pressure of the flask by adding Ar
   c. Increasing the volume of the flask
   d. Adding $Br_{2\,(l)}$
   e. Removing $Cl_{2\,(g)}$
   f. Adding $BrCl_{(g)}$
   g. Adding a catalyst

2. A student obtained a test tube with a suspension of white, slightly soluble calcium hydroxide in water. This system was at equilibrium as represented by the following equation:

$$\mathbf{Ca(OH)_{2\,(s)} \leftrightarrows Ca^{2+}_{(aq)} + 2\ OH^{-}_{(aq)}}$$

   a. What would you expect to observe if hydrochloric acid, $HCl_{(aq)}$, is added? Explain.
   b. What would you expect to observe if calcium nitrate, $Ca(NO_3)_{2\,(aq)}$, was added? Explain.
   c. When the solution was placed in an ice bath and cooled, it was observed that more calcium hydroxide was produced. Based on this observation, is the reaction endothermic or exothermic? Explain.

**Equilibrium Constant, K**

- Consider the following system at equilibrium: $\mathbf{N_2O_{4\,(g)} \rightleftharpoons 2\,NO_{2\,(g)}}$
- For the forward reaction: $N_2O_{4\,(g)} \longrightarrow 2\,NO_{2\,(g)}$, the rate law can be written as:

  _____

- For the reverse reaction: $2\,NO_{2\,(g)} \longrightarrow N_2O_{4\,(g)}$ the rate law can be written as:

  _____

- At equilibrium, _____, therefore: _____
- Rewriting this, it becomes $\frac{k_f}{k_r} = \frac{[NO_2]^2}{[N_2O_4]}$
- The ratio of the rate constants is a constant at that temperature, and the expression becomes:
- The equilibrium expression for the generalized reaction $aA + bB \rightleftharpoons cC + dD$ can be written as: $K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$
- Some notes about the equilibrium constant K
  - It does not have units
  - _____ as part of the equilibrium expression. Solids and liquids are omitted from equilibrium expressions.
  - There are different types of K constants depending on the reaction

**Types of K (Equilibrium Constants)**

- $K_c$ – Equilibrium Constant Using Concentration (Molarity)
- $K_p$ – Equilibrium Constant Using Gas Partial Pressures
- $K_{sp}$ – Solubility Product Constant (used for partially soluble solids)

**Remember, **only gases and aqueous substances** are included as part of the K equilibrium expression!

- Meaning of K:
  - If K < 1, the _____
  - If K > 1, the _____

**Practice:**

Write the equilibrium expression for $K_c$ for the following reactions:

a) $2\ O_3\ (g) \rightleftharpoons 3\ O_2(g)$

c) $Ag^+(aq) + 2\ NH_3\ (aq) \rightleftharpoons Ag(NH_3)_2^+(aq)$

b) $2\ NO\ (g) + Cl_2\ (g) \rightleftharpoons 2\ NOCl\ (g)$

d) $2\ Ag\ (s) + Zn^{2+}\ (aq) \rightleftharpoons 2\ Ag^+\ (aq) + Zn\ (s)$

**<u>Equilibrium Constant HW</u>**

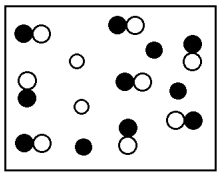
1. Can the equilibrium constant ever be a negative number? Explain.

2. When the following reactions come to equilibrium, does the equilibrium mixture contain mostly reactants or mostly products?
   a. $N_{2\ (g)} + O_{2\ (g)} \rightleftharpoons 2\ NO_{\ (g)}$ $K_c = 1.5 \times 10^{-10}$

   b. $2\ SO_{2\ (g)} + O_{2\ (g)} \rightleftharpoons 2\ SO_{3\ (g)}$ $K_c = 2.5 \times 10^{9}$

3. Suppose a reaction has the equilibrium constant $K = 1.3 \times 10^8$. What does the magnitude of this constant tell you about the relative concentrations of products and reactants that will be present once equilibrium is reached? Compare the rate constants of the forward and reverse reaction – are they the same or is one larger? Which one?

4. The following diagram represents an equilibrium mixture produced a reaction of the type A + X ⇌ AX. If the volume is 1 L, is K greater than or smaller than 1? Justify numerically.



5. Write the equilibrium expression (K) for each of the reactions:
   a. $HF_{(aq)} \rightleftharpoons H^{+}_{(aq)} + F^{-}_{(aq)}$
   b. $Mg(OH)_2\,(s) \rightleftharpoons Mg^{+2}\,(aq) + OH^{-1}\,(aq)$
   c. $3\ NO_{(g)} \rightleftharpoons N_2O_{(g)} + NO_{2\,(g)}$
   d. $Ni(CO)_{4\,(g)} \rightleftharpoons Ni_{(s)} + 4\ CO_{(g)}$

6. For each of the following questions
   - Write the equilibrium expression, K, for the reaction
   - Solve for the missing value
   - Indicate whether the reaction favors the reactants or the products.

a) $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$.
What is the equilibrium constant if the equilibrium concentrations are as follows:
$PCl_5$ is 0.0096 mol/L, $PCl_3$ is 0.0247 mol/L and $Cl_2$ is 0.0247 mol/L? (Ans: 0.064)

b) $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$.

At 1000oC, a 1.00 L container has an equilibrium mixture consisting of 0.102 mol of ammonia, 1.03 mol of nitrogen, and 1.62 mol of hydrogen. Calculate the $K_{eq}$ for the equilibrium system.

(Ans: 0.00238)

c) At a given temperature, the $K_{eq}$ for the reaction $2HI(g) \leftrightarrow H_2(g) + I_2(g)$ is $1.40 \times 10^{-2}$. If the concentration of both $H_2$ and $I_2$ at equilibrium are $2.00 \times 10^{-4}$M, find the concentration of HI. (Ans: 0.00169M)

d) Acetic acid dissociates in water: $HC_2H_3O_2(aq) \leftrightarrow H^+(aq) + C_2H_3O_2^-(aq)$. If $K_{eq} = 1.80 \times 10^{-5}$ and the equilibrium concentrations of acetic acid is 0.09986M, what is the concentration of $H^+(aq)$ and $C_2H_3O_2^-(aq)$? (Ans: 0.00134M)

e) At 60.2°C the equilibrium constant for the reaction $N_2O_4(g) \leftrightarrow 2NO_2(g)$ is $8.75 \times 10^{-2}$. At equilibrium at this temperature a vessel contains $N_2O_4$ at a concentration of $1.72 \times 10^{-2}$M. What concentration of $NO_2$ does it contain? (Ans: 0.0388M)

f) At equilibrium, K for the decomposition of HI(g) was found to be $1.07 \times 10^{-5}$. The equilibrium concentration of HI(g) was found to be 0.129M. Calculate the concentration of $I_2$ at equilibrium. $2HI(g) \rightarrow H_2(g) + I_2(g)$ (Ans: 0.000422M)

g) Rank the reactions in order of increasing tendency to proceed toward completion.