REVIEW—Chem Honors ***Name*** _____
Unit 14: Equilibrium ***Period*** _____

Topics:

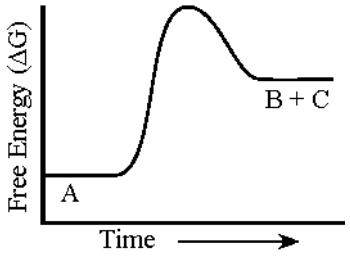
- Concept of equilibrium: the rate of the forward reaction = the rate of the reverse reaction. Concentrations of reactants and products are constant (but not necessarily equal)
- Saturated solutions are at equilibrium. The rate of dissolving equals the rate of crystalizing.
- Write K_{eq} expressions. Large value-- products favored. Solve expressions for any missing variables.
- K_{sp} expressions. Calculations with K_{sp}
- "Q" value calculations. Given concentration information, determine if system is at equilibrium.
- Le Châtelier's principle-- shifting equilibrium positions-- concentration, temperature and pressure effects
- LABS: Establishing Equilibrium lab (straw) and Le Châtelier's Lab

Practice Problems:

1) True or False?

_____ a) Disturbing an equilibrium system by adding more of a reactant changes the equilibrium constant.
_____ b) Disturbing an equilibrium system by increasing temperature changes the equilibrium constant.
_____ c) Disturbing an equilibrium system (of gases) by increasing pressure changes the equilibrium constant.
_____ d) Adding a catalyst changes the equilibrium constant.
_____ e) Adding a catalyst disturbs the equilibrium and the equilibrium position will shift.
_____ f) When a system is at equilibrium, the concentration of the reactants always equals the concentration of the products.
_____ g) When the concentration of reactants and products are constant, the system has reached equilibrium.
_____ h) When one increases the concentration of products, the rate of the forward reaction increases.
_____ i) When one increases the pressure of a system containing all gases, the system will shift towards the side which has fewer molecules.
_____ j) When $Q > K_{eq}$, the equilibrium will shift in the direction which forms more reactants and depletes the products.

2) Given this hypothetical equilibrium system, A (g) $\rightleftharpoons$ B (g) + C (g) and its energy diagram, answer the following questions:



_____ a) Look at the diagram. Is the ΔG **positive or negative** in the forward direction?
_____ b) At equilibrium **(reactants, products)** should be favored.
_____ c) The K_{eq} should be **(smaller, larger)** than 1.
_____ d) If heat were added, the ΔG for the forward reaction would **(increase, decrease)**. *HINT: the products are more disordered (a mixture, increase in gas moles)*
_____ e) Thus, when heat is added, the equilibrium will shift towards the **(reactants, products).**
_____ f) Thus, the K_{eq} is **(lower, higher)** when the system is at a higher temperature.
_____ g) Where should "heat" be written in the reaction equation? **(left or right)**?
_____ h) How would adding a catalyst affect the energy diagram above?
_____ i) How would adding a catalyst affect the relative rates of the forward and reverse reactions?

3) A crystal of radioactive AgCl is added to a saturated solution of non radioactive AgCl. After some time goes by we observe that the amount of undissolved AgCl (s) still has not changed. However, radioactivity can be detected in the liquid. **Explain** what is occurring at the molecular level to explain how it is possible for the liquid to become radioactive without the amount of solid changing.

4) Write the equilibrium constant expressions for each of the following reactions:
   a) $2\ ZnS\ (s) + 3\ O_2\ (g) \rightleftharpoons 2\ ZnO\ (s) + 2\ SO_2\ (g)$ b) $Fe^{2+}\ (aq) + 2\ Ag\ (s) \rightleftharpoons Fe\ (s) + 2\ Ag^{+}\ (aq)$

5) Consider the following equilibrium process at 700°C. $2\ H_2\ (g) + S_2\ (g) \rightleftharpoons 2\ H_2S\ (g)$
   Calculate the K_{eq} for this reaction, given the equilibrium concentrations given below.
   $[H_2] = 0.208\ M$ $[S_2] = 1.13 \times 10^{-6}\ M$ $[H_2S] = 0.725\ M$

6) This equilibrium system is studied: $2\ NO\ (g) \rightleftharpoons N_2\ (g) + O_2\ (g)$ $K_{eq} = 2.4 \times 10^3$ at 2000°C.
   At 2000°C, does the equilibrium favor the reactants or the products? _____ Why? (No calculation is needed.)

7) This equilibrium reaction is studied: $2\ NO_2\ (g) \rightleftharpoons N_2O_4\ (g)$ $K_{eq} = 170$ at 25°C.
   Experiment shows that a particular system has the following concentrations:
   $[NO_2] = 2.0 \times 10^{-4}\ M$ $[N_2O_4] = 1.5 \times 10^{-4}\ M$
   Is this system at equilibrium? _____If it is not at equilibrium, which way must the equilibrium position shift in order to reach equilibrium-- right or left?

8) Suppose you have two saturated solutions-- one of $PbCl_2\ (aq)$ and one of $PbF_2\ (aq)$. Which solution has the greater concentration of Pb^{2+}, ***saturated $PbCl_2$ (aq) or saturated PbF_2 (aq)?*** Why?
   K_{sp} for $PbCl_2 = 1.6 \times 10^{-5}$ K_{sp} for $PbF_2 = 3.7 \times 10^{-8}$ HINT: NO calculation needed!!

9) Here is the equation for the dissolution of Ag_2SO_4: $Ag_2SO_4\ (s) \rightleftharpoons 2\ Ag^{+}\ (aq) + SO_4^{2-}\ (aq)$
   $Ag_2SO_4\ (s)$ is added to water until a saturated solution is obtained. $[Ag^{+}]$ is determined to be 0.0288 M.

   a) What must be the concentration of SO_4^{2-} in this saturated solution? _____
   b) Write the K_{sp} expression for Ag_2SO_4.

   c) Calculate the K_{sp} for Ag_2SO_4

10) $In(IO_3)_3\ (s)$ is dissolved into water. A saturated solution is produced. K_{sp} of $In(IO_3)_3 = 1.05 \times 10^{-4}$
   a) Complete the chemical equation for the dissolution of $In(IO_3)_3$ in water. Then balance it.
      $In(IO_3)_3\ (s) \rightleftharpoons$ _____ $+ IO_3^{-1}\ (aq)$
   b) Write the K_{sp} expression for this reaction.

   c) What will be the equilibrium concentration of the dissolved ions in this saturated solution?

11) A solution is prepared by dissolving 0.00010 mol of $Zn(OH)_2$ in 50. mL of hot water. Will a precipitate form if the solution is cooled to 25°C? K_{sp} of $Zn(OH)_2$ at 25°C = 4.5×10^{-17}
(HINT: You need to find the "Q" value. Make sure you write the chemical reaction first!!!)

12) Given this equilibrium system. $2\ H_2\ (g)\ +\ S_2\ (g)\ \rightleftharpoons\ 2\ H_2S\ (g)\ +$ heat
a) List five ways one could increase the concentration of H_2S produced. Give brief explanation for each.

b) What would be the effect of adding a catalyst to the system before it had reached equilibrium?

13) Given the following equilibrium equations.

Eq A: $NH_3\ (g)\ +\ H_2O\ (l)\ \rightleftharpoons\ NH_4^+\ (aq)\ +\ OH^-(aq)$
pungent smell *colorless* *colorless*

Eq B: $H^+\ (aq)\ +\ OH^-\ (aq)\ \rightleftharpoons\ H_2O\ (l)$
colorless *colorless* *colorless*

Eq C: $Ca(OH)_2\ (s)\ \rightleftharpoons\ Ca^{2+}(aq)\ +\ OH^-\ (aq)$
white solid *colorless* *colorless*

Suppose an equilibrium system is obtained by making a saturated solution of $Ca(OH)_2$ (aq) for which the undissolved solid has been removed. Then, this equilibrium system is disturbed by sequentially making the changes listed below. For each disturbance, state in what direction the equation(s) stated shift, why they shift and what would be observed.
a) $Ca(NO_3)_2$ (aq) is added. Discuss shift of Eq C.

b) HCl (aq) is added. Discuss shifts of Eq B and C.

c) NH_4CH_3COO (aq) is added. Discuss shift of Eq A.

Answers: 5) $K_{eq} = 1.08 \times 10^7$; 7) $Q = 3.8 \times 10^3$; 9c) $K_{sp} = 1.19 \times 10^{-5}$; 10c) $[In^{3+}] = 0.0444\ M$, $[IO_3^-] = 0.133\ M$; 11) $Q = 3.2 \times 10^{-8}$