Chapter 13 - Equilibrium Study Guide

Purpose: This is a guide for your as you work through the chapter. The major topics are provided so that you can write notes on each topic and work the corresponding problems.

This should serve a s a study guide as you go on to do the problems in Sapling and take the quizzes and exams.

The Problems are embedded in the Topics and Space for Notes

Section 1 and 2: Chemical Equilibria and Equilibrium Constants

- **Describe the nature of equilibrium systems**
- **Explain the dynamic nature of a chemical equilibrium**
- **Derive reaction quotients from chemical equations representing homogeneous and heterogeneous reactions**
- **Calculate values of reaction quotients and equilibrium constants, using concentrations and pressures**
- **Relate the magnitude of an equilibrium constant to properties of the chemical system**

Some thoughts:

1. K = $\frac{Products}{Reactants}$
2. Understand Equilibrium. Know that it is a dynamic process. The Equilibrium constant (K) is always derived from the balanced reaction at equilibrium.
3. For the reaction aA + bB ⇄ cC + dD (Using the Law of Mass Action)

   K = $\frac{[C]^c[D]^d}{[A]^a[B]^b}$ This is will be known as the "equation"

   Write a balanced reaction.. then write the "equation".. then solve for something!!

   Homogeneous Equilibria: For the reaction aA + bB ⇄ cC + dD **K =** $\frac{[C]^c[D]^d}{[A]^a[B]^b}$

   Heterogeneous equilibria. Leave any pure liquid of pure solid out of the expression for K (we can replace the amount of the pure liquid or solid with a 1. For example: $H_2O(l)$ ⇄ $H_2O(g)$ K = $[H_2O(g)]/1$

   <u>Know:</u>

   Dynamic Equilibria

   Homogeneous Equilibria

   Heterogeneous Equilibria

   The Law of Mass action

Understand what the size of K tells you.

If K is large, products are favored. If K is small, reactants are favored. If K is close to 1, products and reactants are favored equally.

Know: K_c and K_p and the relevant units the reactants and products in each. (Does K itself have units?)

(A) Write the equation K_c (or the form of K_c) for:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$

(B) Give the direction of the reaction, if K >> 1. Is???

a) The forward reaction is favored.
b) The reverse reaction is favored.
c) Neither direction is favored.

(C) Remembering the solubility rules previously discussed is the statement: All chlorides are soluble except Hg_2Cl_2, AgCl, $PbCl_2$, and CuCl.

Write the expression for the equilibrium constant for the reaction represented by the equation:
Pb^{2+} (aq) + 2 Cl^- (aq) $\rightleftharpoons$ $PbCl_2$(s) Is Kc>1, <1 or ~1?

(D) Calculate the value of K_c for the reaction given the following concentrations:

$2NH_3$ (g) $\rightleftharpoons$ 3 H_2 (g) + N_2 (g) [NH_3] = 0.020 *M*, [N_2] = 1.00 *M*, [H_2] = .500 *M*

Thoughts: Comparing initial values to the equilibrium constant. (Comparing Q to K)

Calculate Q, the reaction quotient. Q is the ratio of Products over reactions **initially** rather than at equilibrium. We can compare Q with K (the "equation" is the same..different numbers..Q is initial amounts, K is with equilibrium amounts.)

We can compare the initial ratio of the amounts (Q) versus the equilibrium ratio (K).

If Q >K we have too much products and the reaction shifts to reactants.

If Q < K we have too many reactants and the reaction shifts to products.

If Q = K, we are at equilibrium.

(E) If $K_p = 6.8x10^4$ for the reaction: $2NH_3$ (g) $\rightleftharpoons$ 3 H_2 (g) + N_2 (g) at some Temperature (remember that K depends on T) Is the reaction at equilibrium if the initial pressures are:
NH_3 = 3.0 atm, N_2 = 2.0 atm, H_2 = 1.0 atm?

If the reaction is not at equilibrium, does the reaction shits to products or reactants?

Some Thoughts:

For gases only…. Compare K_c and K_p. $K_p=K_c(RT)^{\Delta n}$. R = 0.08206 (L atm)/(mole K). T is Temp in Kelvins. Δn = total number of moles of products – total number of moles of reactants (gases only.)

(F) Convert the values of K_c to values of K_P or the values of K_P to values of K_c.

Cl_2 (g) + Br_2 (g) $\rightleftharpoons$ 2 BrCl (g) Where $K_c = 4.7x10^{-2}$ at 25 °C.

$2SO_2$ (g) + O_2 (g) $\rightleftharpoons$ $2SO_3$ (g) K_p = 48.2 at 500. °C

(G) Given: Cl_2 (g) + Br_2 (g) $\rightleftharpoons$ 2 BrCl (g) Where $K_c = 4.7x10^{-2}$,

Calculate K_c for: 2 BrCl (g) $\rightleftharpoons$ Cl_2 (g) + Br_2 (g)

Calculate K_c for 4 BrCl (g) $\rightleftharpoons$ $2Cl_2$ (g) + $2Br_2$ (g)

Section 3: Shifting Equilibria: Le Chatelier's Principle

- **Describe the ways in which an equilibrium system can be stressed**
- **Predict the response of a stressed equilibrium using Le Châtelier's principle**
- **Le Chatelier's Principle. If a stress is placed on a system at equilibrium, the equilibrium shifts (using only what is currently has in its container) to reduce the stress.**

Change	What Occurs	Effect on Equilibrium	Effect on K
Addition of Reactant	Added reactant consumed	Shift to right	No Change
Addition of Product	Added product consumed	Shift to left	No Change
Decrease V, Increase P	Pressure Increases	Shift to fewer gas molecules	No Change
Increase V, Decrease P	Pressure Decreases	Shift to more gas molecules	No Change
Increase T	Heat is consumed	Shift in endo direction	Change
Decrease T	Heat is generated	Shift in exo direction	Change

(A) . Consider the following system at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + 92.94\ kJ$$

Which way will the equilibrium shift if:

I. The temperature is increased

II. The volume is increased

III. Some NH_3 is removed

IV. Some N_2 is added

V. A catalyst is added.

Section 4: Equilibrium Calculations:

- **Write equations representing changes in concentration and pressure for chemical species in equilibrium systems**
- **Use algebra to perform various types of equilibrium calculations**
- **Calculate K or equilibrium amounts. Plug and chug using the equation for K**
- **ICE Charts!! Finding equilibrium amounts from initial amounts and K**

Understand ICE Charts!!

(A) For the reaction: 2 NO (g) + Br_2 (g) $\rightleftharpoons$ 2NOBr (g), 1.0 atm NO and 1.0 Br_2 are mixed in an empty flask and allowed to reach equilibrium. At equilibrium 0.60 atm NOBr is present. What is K_P for the reaction?

(B) An empty flask contains 1.00 atm Xe and 1.50 atm F2. If at equilibrium, total pressure in the flask is 2.00 atm, find the equilibrium constant (Kp) for the reaction. Xe(g) + 2 F_2(g) $\rightleftharpoons$ XeF_4(g)

(C) H_2(g) + I_2(g) $\rightleftharpoons$ 2HI(g) has a K_c = 5.0 at some temperature. If 1.0 M H_2 is mixed with 2.0 M I_2 in an evacuated flask, what are the equilibrium concentrations of all three species?

(D) **For the reaction: 2 NO(g) + Br_2(g) $\rightleftharpoons$ 2NOBr(g), $K_c = 2.5 \times 10^{-6}$ at some temperature. If 0.10 M of NO and Br_2 are placed in an empty flask, what are the concentrations after the reaction has been allowed to reach equilibrium?**