Unit 7 Review for Midterms

Equilibrium

You should be able to:

- Explain equilibrium in terms of rates of forward and reverse reactions
- Explain equilibrium in terms of observations of a reversible chemical reaction
- Interpret graphs of concentration, partial pressure, or reaction rates vs time and equilibrium
- Explain the relationship between direction of a reaction and relative rates of forward and reverse reactions
- Write equilibrium expressions for reversible reactions (K_c and K_p)
- Know when to use brackets in an equilibrium expression
- Know when to use an equilibrium expression (K) or reaction quotient (Q) calculation
- Explain which direction a reaction will proceed based on a comparison of Q and K
- Calculate K_c or K_p based on equilibrium concentrations or pressures
- Explain the relationship between very large or very small values of K and the relative concentrations of reactants and/or products at equilibrium
- Manipulate reversible equations and their respective K values to achieve an overall equilibrium expression
- Use an ICE chart to determine equilibrium concentrations or pressures given initial concentrations/pressures and K
- Draw a particulate model representing reversible reactions
- Identify the response of a system at equilibrium to a stress using Le Chatelier's principle
- Relate Le Chatelier's principle to Q and K
- Write solubility-product expressions for salt dissolutions
- Calculate the solubility of a salt based on K_{sp}
- Perform solubility calculations in the presence of a common ion
- Understand how the presence of a common ion affects solubility of a salt
- Identify the effect of pH on the solubility of a salt

1. For each of the equations below, write the expression for K_p:
   a. $SO_2Cl_2\ (g) \rightleftharpoons SO_2\ (g) + Cl_2\ (g)$
   b. b. $CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$
   c. $C_6H_{12}O_6\ (s) + 6\ O_2\ (g) \rightleftharpoons 6\ CO_2\ (g) + 6\ H_2O\ (g)$
2. Put the following K values in order of increasing product-favored ability.
   a. $K = 4x10^{-5}$
   b. $K = 2x10^{-9}$
   c. $K = 7x10^{-5}$
   d. $K = 3x10^{-3}$

3. For the reaction: $2\ NO_2\ (g) \rightleftharpoons N_2O_4\ (g)$ At equilibrium $[N_2O_4] = 0.25$ M & $[NO_2] = 0.175$ M. Calculate K_c
4. For the reaction: $2\ NH_3\ (g) \rightleftharpoons N_2\ (g) + 3\ H_2\ (g)$ $K_p = 32$. At equilibrium $P_{NH_3} = 0.64$ atm & $P_{N_2} = 1.18$ atm. Calculate P_{H_2}

5. Given the following equations:

   $H_2O\ (g) + CO\ (g) \rightleftharpoons H_2\ (g) + CO_2\ (g)$ $K_c = 4.8$

   $FeO\ (s) + CO\ (g) \rightleftharpoons Fe\ (s) + CO_2\ (g)$ $K_c = 0.48$

   Calculate the K_c value for:

   $Fe\ (s) + H_2O\ (g) \rightleftharpoons FeO\ (s) + H_2\ (g)$ $K_c = ???$
6. For the reaction: $2\ NOCl\ (g) \rightleftharpoons 2\ NO\ (g) + Cl_2\ (g)$

   $K_c = 1.2 \times 10^{-3}$

   If the initial $[NOCl] = 0.15$ M, $[NO] = 0.75$ M, and $[Cl_2] = 0.05$ M, is the system at equilibrium? If not, which way will the reaction shift, left or right?
7. For the equation: $2\ KClO_3\ (s) \rightleftharpoons 2\ KCl\ (s) + 3\ O_2\ (g)$, you start with some $KClO_3$ that decomposes into the products. At equilibrium, there is some solid remaining and the total pressure in the flask is 0.29 atm. Calculate the value of K_p.

8. Write the equilibrium-constant expression K_c.

   $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$

   $K_c = 4.56 \times 10^9$

   a. What does the value of K_c indicate for this reaction?

   b. If the initial concentration of CO is 0.55 M and the initial concentration of Cl_2 is 0.38 M, what are the equilibrium concentrations of all reactants and products?

9. If 1.40 mole of N_2 and 2.86 mole of O_2 are mixed in a 3.00 L container at 1100 C, what are the concentrations of NO, N_2, and O_2 at equilibrium? $K_c = 2.60 \times 10^{-7}$

   $N_2 + O_2 \rightleftharpoons 2\ NO$

10. For the following reaction: $2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3\ (g)$ $\Delta H = -50$ kJ/mol

    What will be the effect of doing each of the following actions on the above equilibrium?

a) Decreasing temperature	Left	Right	No Change
b) Increasing O_2 (g)	Left	Right	No Change
c) Decreasing SO_2 (g)	Left	Right	No Change
d) Increasing volume	Left	Right	No Change
e) Increasing SO_3 (g)	Left	Right	No Change
f) Adding N_2 (g)	Left	Right	No Change

11. Solid calcium phosphate is dissolved in water.
    a. Write the equation for this dissolution.
    b. Write the solubility-product expression.
    c. If $K_{sp} = 2.0 \times 10^{-29}$, calculate the molar solubility of calcium phosphate.
    d. Calculate the molar solubility of calcium phosphate in 0.0010 M calcium nitrate.

12. Calcium fluoride has a solubility of 0.016 g/L.
    a. Calculate the molar solubility of calcium fluoride.
    b. Write the equation for this dissolution.
    c. Write the solubility-product expression.
    d. Calculate the K_{sp} value.
    e. Using your K_{sp} value from part d, calculate the molar solubility of cacium fluoride in 0.10 M sodium fluoride solution.
13. Does a precipitate form when 0.10 L of 8.0×10^{-3} M $Pb(NO_3)_2$ is added to 0.40 L of 5.0×10^{-3} M Na_2SO_4? Explain. The K_{sp} value of lead (II) sulfate is 6.3×10^{-7}.

AP Questions

1. Several reactions are carried out using AgBr, a cream-colored silver salt for which the value of the solubility-product constant, K_{sp}, is 5.0×10^{-13} at 298 K.

   (a) Write the expression for the solubility-product constant, K_{sp}, of AgBr.

   (b) Calculate the value of $[Ag^+]$ in 50.0 mL of a saturated solution of AgBr at 298 K.

   (c) A 50.0 mL sample of distilled water is added to the solution described in part (b), which is in a beaker with some solid AgBr at the bottom. The solution is stirred and equilibrium is reestablished. Some solid AgBr remains in the beaker. Is the value of $[Ag^+]$ greater than, less than, or equal to the value you calculated in part (b)? Justify your answer.

   (d) Calculate the minimum volume of distilled water, in liters, necessary to completely dissolve a 5.0 g sample of AgBr(s) at 298 K. (The molar mass of AgBr is 188 g mol^{-1}.)

   (e) A student mixes 10.0 mL of 1.5×10^{-4} M $AgNO_3$ with 2.0 mL of 5.0×10^{-4} M NaBr and stirs the resulting mixture. What will the student observe? Justify your answer with calculations.

   (f) The color of another salt of silver, AgI(s), is yellow. A student adds a solution of NaI to a test tube containing a small amount of solid, cream-colored AgBr. After stirring the contents of the test tube, the student observes that the solid in the test tube changes color from cream to yellow.

      (i) Write the chemical equation for the reaction that occurred in the test tube.

      (ii) Which salt has the greater value of K_{sp}: AgBr or AgI? Justify your answer.

$$C(s) + H_2O(g) \leftrightarrows CO(g) + H_2(g) \qquad \Delta H^\circ = +131 \text{ kJ}$$

A rigid container holds a mixture of graphite pellets ($C(s)$), $H_2O(g)$, $CO(g)$, and $H_2(g)$ at equilibrium. State whether the number of moles of $CO(g)$ in the container will increase, decrease, or remain the same after each of the following disturbances is applied to the original mixture. For each case, assume that all other variables remain constant except for the given disturbance. Explain each answer with a short statement.

(a) Additional $H_2(g)$ is added to the equilibrium mixture at constant volume.

(b) The temperature of the equilibrium mixture is increased at constant volume.

(c) The volume of the container is decreased at constant temperature.

(d) The graphite pellets are pulverized.