**Chapter 14 Problem Set**  **Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Acids & Bases Due Date : Monday, April 2, 2012**

***Circle/Box* all final answers to calculation based problems unless they are already boxed!!!**

***The Nature of Acids & Bases***

1. Write the dissociation reaction and the corresponding Ka equilibrium expression for each of the following acids in water.

Dissociation Reaction Equilibrium Expression

a) HCN

b) HOC6H5

c) C6H5NH3+

2. For each of the following aqueous reactions, identify the acid, the base, the conjugate base, and the conjugate acid.

a) Al(H2O)63+ + H2O ⬄ H3O+ + Al(H2O)5(OH)2+

Acid = \_\_\_\_\_\_\_\_\_\_\_\_ Base = \_\_\_\_\_\_\_\_\_\_\_\_ Conj. Base = \_\_\_\_\_\_\_\_\_\_\_\_ Conj. Acid = \_\_\_\_\_\_\_\_\_\_\_\_\_

b) H2O + HONH3+ ⬄ HONH2 + H3O+

Acid = \_\_\_\_\_\_\_\_\_\_\_\_ Base = \_\_\_\_\_\_\_\_\_\_\_\_ Conj. Base = \_\_\_\_\_\_\_\_\_\_\_\_ Conj. Acid = \_\_\_\_\_\_\_\_\_\_\_\_\_

c) HOCl + C6H5NH2 ⬄ OCl- + C6H5NH3+

Acid = \_\_\_\_\_\_\_\_\_\_\_\_ Base = \_\_\_\_\_\_\_\_\_\_\_\_ Conj. Base = \_\_\_\_\_\_\_\_\_\_\_\_ Conj. Acid = \_\_\_\_\_\_\_\_\_\_\_\_\_

3. Describe what happens when the following acids are dissolved in water (Are they strong or weak? Do they completely or partially dissociate?)

a) HNO2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b) HNO3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c) HCl \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

a) HF \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

a) HC2H3O2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. Use Table 14.2 to order the following from the strongest to the weakest acid.

HClO2 H2O NH4+ HClO4

5. Use Table 14.2 to order the following from the strongest to the weakest base.

ClO2- H2O NH3 ClO4-

6. You may need Table 14.2 to answer the following questions.

a) Which is the stronger base, Cl- or H2O?

b) Which is the stronger acid, H2O or NO2-?

c) Which is the stronger base, CN- or OC6H5-?

***Autoionization of Water and the pH Scale***

7. Calculate the [H+] of each of the following solutions at 25°C. Identify each solution as neutral, acidic, or basic.

a) [OH-] = 1.5 M c) [OH-] = 1.0 x 10-7 M

b) [OH-] = 3.6 x 10-15 M d) [OH-] = 7.3 x 10-4 M

8. At 40°C the value of Kw is 2.92 x 10-14.

a) Calculate the [H+] and [OH-] in pure water at 40°C.

b) What is the pH of pure water at 40°C?

c) If the hydroxide ion concentration in a solution is 0.10 M, what is the pH at 40°C?

9. Calculate [H+] and [OH-] for each solution at 25°C. Identify each solution as neutral, acidic, or basic.

a) pH = 7.40 (the normal pH of blood) d) pH = 3.20

b) pH = 15.3 e) pOH = 5.0

c) pH = -1.0 f) pOH = 9.60

10. Fill in the missing information in the following table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | pH | pOH | [H+] | [OH-] | Acidic, Basic, or Neutral? |
| Solution A | 9.63 |  |  |  |  |
| Solution B |  |  |  | 3.9 x 10-6 M |  |
| Solution C |  |  | 0.027 M |  |  |
| Solution D |  | 12.2 |  |  |  |

11. The pOH of a sample of baking soda dissolved in water is 5.74 at 25°C.   
a) Calculate the pH, [H+], and [OH-] for this sample.

b) Is the solution acidic or basic?

***Solutions of Acids***

12. Calculate the pH of each of the following solutions of a strong acid in water.  
  
a) 0.10 M HCl c) 1.0 x 10-11 M HCl

b) 5.0 M HCl

13. A solution is prepared by mixing 90.0 mL of 5.00 M HCl and 30.0 mL of 8.00 M HNO3. Water is then added until the final volume is 1.00 L. Calculate [H+], [OH-], and the pH for this solution.

14. What mass of HNO3 is present in 250.0 mL of nitric acid solution having a pH of 5.10?

15. Calculate the pH of a 0.250 M solution of each of the following acids.

a) HOC6H5

b) HCN

16. For propanoic acid (HC3H5O2, Ka = 1.3 x 10-5), determine the concentration of all species present, the pH, and the percent dissociation of a 0.100 M solution.

17. Calculate the pH of a 0.20 M solution of iodic acid (HIO3, Ka = 0.17)

18. A typical aspirin tablet contains 325 mg of acetylsalicylic acid, HC9H7O4. Calculate the pH of a solution that is prepared by dissolving two aspirin tablets in one cup (237 mL) of solution. Assume the aspirin tablets are pure acetylsalicyclic acid, Ka = 3.3 x 10-4.

19. a) Calculate the pH of a solution that contains 1.0 M HF and 1.0 M HOC6H5.

b) Calculate the concentration of OC6H5- in this solution at equilibrium.

20. Using the Ka values in Table 14.2, calculate the percent dissociation in a 0.20 M solution of each of the following acids.

a) nitric acid (HNO3)

b) nitrous acid (HNO2)

c) phenol (HOC6H5)

21. An acid HX is 25% dissociated in water. If the equilibrium concentration of HX is 0.30 M, calculate the Ka value for HX.

22. Trichloroacetic acid (CCl3CO2H) is a corrosive acid that is used to precipitate proteins. The pH of a 0.050 M solution of trichloroacetic acid is the same as the pH of a 0.040 M HClO4 solution. Calculate Ka for trichloroacetic acid.

23. One mole of a weak acid HA was dissolved in 2.0 L of solution. After the system had come to equilibrium, the concentration of HA was found to be 0.45 M. Calculate Ka for HA.

***Polyprotic Acids***

24. Write out the stepwise Ka reactions for citric acid (H3C6H5O7), a triprotic acid.

25. a) Arsenic acid (H3AsO4) is a triprotic acid with Ka1 = 5 x 10-3, Ka2 = 8 x 10-8, and Ka3 = 6 x 10-10. Calculate the following concentrations in a 0.20 M arsenic acid solution: [H+], [OH-], [H3AsO4], [H2AsO4-], [HAsO4-2], and [AsO4-3].

b) Calculate the pH of the solution.

***Solutions of Bases***

26. Write the reaction and the corresponding Kb equilibrium expression for each of the following substances acting as bases in water.

a) aniline (C6H5NH2) b) dimethylamine, (CH3)2NH

27. Use Table 14.3 to help order the following acids from strongest to weakest.

HNO3 H2O NH4+ C5H5NH+

28. Use Table 14.3 to help answer the following questions.

a) Which is the stronger base, ClO4- or C6H5NH2?

b) Which is the stronger base, H2O or C6H5NH2?

c) Which is the stronger base, OH- or C6H5NH2?

d) Which is the stronger base, CH3NH2 or C6H5NH2?

29. Calculate [OH-], pOH, and pH for each of the following.

a) 0.00040 M Ca(OH)2

b) a solution containing 25 g of KOH per liter

c) a solution containing 150.0 g of NaOH per liter

30. What are the major species present in the following mixtures of bases?

a) 0.050 M NaOH and 0.050 M LiOH

b) 0.0010 M Ca(OH)2 and 0.020 M RbOH

c) What is the [OH-] and the pH of each of these solutions?

31. Calculate the concentration of an aqueous solution of Sr(OH)2 that has pH = 10.50.

32. For the reaction of hydrazine (N2H4) in water,

H2NNH2 (aq) + H2O (l) ⬄ H2NNH3+ (aq) + OH- (aq)

Kb is 3.0 x 10-6. Calculate the concentrations of all species and the pH of a 2.0 M solution of hydrazine in water.

33. Calculate [OH-], [H+], and the pH of 0.20 M solution of each of the following amines (the Kb values are found in Table 14.3).

a) aniline

b) methylamine

34. Calculate the pH of a 0.050 M (C2H5)2NH solution (Kb = 1.3 x 10-3)

35. Codeine (C18H21NO3) is a derivative of morphine that is used as an analgesic, narcotic, or antitussive. It was once commonly used in cough syrups but is now available only by prescription because of its addictive properties. If the pH of a 1.7 x 10-3 M solution of codeine is 9.59, calculate Kb.

***Acid-Base Properties of Salts***

36. The Kb values for ammonia and methylamine are 1.8 x 10-5 and 4.4 x 10-4, respectively. Which is the stronger acid, NH4+ or CH3NH3+?

37. Calculate the concentrations of all species present (H+, OH-, C2H5NH2, C2H5NH3, Cl-) in a 0.25 M solution of ethylammonium chloride (C2H5NH3Cl).

38. Calculate the pH of each of the following solutions.

a) 0.12 M KNO2

b) 0.45 M NaOCl

c) 0.40 M NH4ClO4

39. Consider a solution of an unknown salt having a general formula BHCl, where B is one of the weak bases in Table 14.3. A 0.10 M solution of the unknown salt has a pH of 5.82. What is the actual formula of the salt?

40. Are solutions of the following salts acidic, basic, or neutral? For those that are not neutral, write balanced equations for the reactions causing the solution to be acidic or basic. The relevant Ka and Kb values are found in Tables 14.2 and 14.3.

a) KCl d) KF

b) NH4C2H3O2 e) NH4F

c) CH3NH3Cl f) CH3NH3CN

***Relationships between Structure & Strengths of Acids & Bases***

41. Place the species in each of the following groups in order of increasing acid strength. Explain the order you chose for each group.

a) HIO3 or HBrO3 c) HOCl or HOI

b) HNO2 or HNO3 d) H3PO4 or H3PO3

42. Place the species in each of the following groups in order of increasing base strength.

a) OH-, SH-, SeH-

b) NH3, PH3

c) NH3, HONH2

43. Will the following oxides give acidic, basic, or neutral solutions when dissolved in water? Write reactions to justify your answers.

a) Li2O

b) CO2

c) SrO

***Lewis Acids & Bases***

44. Identify the Lewis acid and the Lewis base in each of the following reactions.

a) Fe3+ (aq) + 6 H2O (l) ⬄ Fe(H2O)63+ (aq)

b) H2O (l) + CN- (aq) ⬄ HCN (aq) + OH- (aq)

c) HgI2 (s) + 2I- (aq) ⬄ HgI42- (aq)

45. Would you expect Fe3+ or Fe2+ to be the stronger Lewis acid? Explain.

***Answers to Selected Problems***

7. a) 6.7 x 10-15 M; b) 2.8; c) 1.0 x 10-7 M; d) 1.4 x 10-11 M

8. a) [H+] = [OH-] = 1.71 x 10-7 M; b) pH = 6.77; c) pH = 12.5

9. a) [H+] = 3.98 x 10-8 M, [OH-] = 2.51 x 10-7 M; b) [H+] = 5.01 x 10-16 M, [OH-] = 20.0 M

c) [H+] = 10 M, [OH-] = 1 x 10-15 M; d) [H+] = 6.31 x 10-4 M, [OH-] = 1.58 x 10-11 M

e) [H+] = 1 x 10-9 M, [OH-] = 1 x 10-5 M; f) [H+] = 3.98 x 10-5 M, [OH-] = 2.51 x 10-10 M

11. pH = 8.26; [H+] = 5.50 x 10-9 M; [OH-] = 1.82 x 10-6 M

12. a) 1.00; b) -0.699; c) 7.0 (concentration of hydrogen contributed by such a small concentration of HCl is insignifcant…the pH of the solution is based on the hydrogen ions contributed by the autoionization of water.

13. [H+] = 0.69 M; [OH-] = 1.45 x 10-14 M; pH = 0.161

14. 1.25 x 10-4 g HNO3

15. a) pH = 5.20; b) pH = 4.90

16. [H+] = [C3H5O2-] = 1.1 x 10-3 M, [HC3H5O2] = 0.100M, pH = 2.94, 1.1%

17. pH = 0.93

18. pH = 2.68

19. a) pH = 1.57; b) [OC6H5-] = 5.9 x 10-9 M

20. a) 100%; b) 4.5%; c) 2.8 x 10-3%

21. Ka = 0.033

22. Ka = 0.16

23. Ka = 6 x 10-3

25. a) [H+] = [H2AsO4-] = 0.03 M, [OH-] = 3 x 10-13 M, [H3AsO4] = 0.17 M, [HAsO4-2] = 8 x 10-8 M,

[AsO43-] = 2 x 10-15 M; b) pH = 1.5

29. a) [OH-] = 0.00080 M, pOH = 3.1, pH = 10.9; b) [OH-] = 0.45 M, pOH = 0.35, pH = 13.65;

c) [OH-] = 3.75 M, pOH = -0.57, pH = 14.57

30. c) a – [OH-] = 0.100M, pH = 13; b – [OH-] = 0.022 M, pH = 12.3

31. 1.58 x 10-4 M

32. [OH-] = [H2NNH3+] = 2.4 x 10-3 M, [N2H4] = 2.0 M, pH = 11.4

33. a) [OH-] = 8.7 x 10-6 M, [H+] = 1.1 x 10-9M, pH = 8.94; b) [OH-] = 9.4 x 10-3 M, [H+] = 1.1 x 10-12M, pH = 12

34. pH = 11.8

35. Kb = 8.9 x 10-7

37. [H+] = [C2H5NH2] = 2.1 x 10-6 M, [C2H5NH3] = [Cl-] = 0.25 M, [OH-] = 4.8 x 10-9 M

38. a) pH = 8.2; b) pH = 10.6; c) pH = 4.8

**Chapter 15 Problem Set**  **Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Applications of Aqueous Equilibria**

***Circle/Box* all final answers to calculation based problems unless they are already boxed!!!**

***Buffers***

1. A buffer is prepared by dissolving HONH2 and HONH3NO3 in some water. Write equations to show how this buffer neutralizes added H+ and OH-.
2. Calculate the pH of each of the following solutions.
   1. 0.100 M HONH2 (Kb = 1.1 x 10-8)
   2. 0.100 M HONH3Cl
   3. pure H2O
   4. a mixture containing 0.100 M HONH2 and 0.100 M HONH3Cl
3. Compare the percent ionization of the base in problem 2a with the percent ionization of the base in problem 2d. Explain any differences.
4. Calculate the pH after 0.020 mol HCl is added to 1.00 L of each of the four solutions in problem 2.


   3. d.
5. Which of the solutions in problem 2 is a buffered solution?
6. Calculate the pH of a solution that is 0.60 M HF and 1.00 M KF.
7. a. Calculate the pH after 0.10 mol of NaOH is added to 1.00 L of the solution in problem 6.

b. Calculate the pH after 0.20 mol of HCl is added to 1.00 L of the solution in problem 6.

1. A buffered solution is made by adding 50.0 g NH4Cl to 1.00 L of a 0.75 M solution of NH3. Calculate the pH of the final solution (assume no volume change).

9. An aqueous solution contains dissolved C6H5NH3Cl and C6H5NH2. The concentration of C6H5NH2 is 0.50 M and the pH is 4.20.

a. Calculate the concentration of C6H5NH3+ in this buffer solution.

b. Calculate the pH after 4.0 g of NaOH (s) is added to 1.0 L of this solution (neglect any volume changes).

1. What volumes of 0.50 M HNO2 and 0.50 M NaNO2 must be mixed to prepare 1.00 L of a solution buffered at

pH = 3.55?

1. Consider the bases in Table 14.3. Which base would be the best choice for preparing a pH = 5.00 buffer?

12. Which of the following mixtures would result in a buffered solution when 1.0 L of each of the two solutions are mixed?

a. 0.2 M HNO3 and 0.4 M NaNO3

b. 0.2 M HNO3 and 0.4 M HF

c. 0.2 M HNO3 and 0.4 M NaF

d. 0.2 M HNO3 and 0.4 M NaOH

13. Calculate the number of moles of HCl (g) that must be added to 1.0 L of 1.0 M NaC2H3O2 to produce a solution buffered at each pH.

a. pH = pKa

b. pH = 4.20

c. pH = 5.00

***Acid-Base Titrations***

14. Sketch the titration curve for the titration of a generic weak base B with a strong acid. The titration reaction is

B + H+ ⇔ BH+

On this curve, indicate the points that correspond to the following:

1. the stoichiometric (equivalence) point
2. the region with maximum buffering
3. pH = pKa
4. pH depends only on [B]
5. pH depends only on [BH+]
6. pH depends only on the amount of excess strong acid added

15. Consider the titration of 80.0 mL of 0.100 M Ba(OH)2 by 0.400 M HCl. Calculate the pH of the resulting solution after the following volumes of HCl have been added.  
 a. 0.0 mL

b. 20.0 mL

c. 30.0 mL

d. 40.0 mL

e. 80.0 mL

16. Consider the titration of 100.0 mL of 0.100 M H2NNH2 (Kb = 3.0 x 10-6) by 0.200 M HNO3. Calculate the pH of the resulting solution after the following volumes of HNO3 have been added.

a. 0.0 mL

b. 20.0 mL

c. 25.0 mL

d. 40.0 mL

e. 50.0 mL

f. 100.0 mL

17. A 25.0 mL sample of 0.100 M propanoic acid (HC3H5O2, Ka = 1.3 x 10-5) is titrated with 0.100 M NaOH solution. Calculate the pH after the addition of 0.0 ml, 4.0 mL, 8.0 mL, 12.5 mL, 20.0 mL, 24.0 mL, 24.5 mL, 24.9 mL, 25.0 mL, 25.1 mL, 26.0 mL, 28.0 mL, and 30.0 mL of the NaOH. Plot the results of your calculations as pH versus milliliters of NaOH (you may use Microsoft excel to plot the data if you wish).

18. Repeat the procedure in problem 17, but for the titration of 25.0 mL of 0.100 M NH3 (Kb = 1.8 x 10-5) with 0.100 M HCl.

19. In the titration of 50.0 mL of 1.0 M methylamine, CH3NH2 (Kb = 4.4 x 10-4), with 0.50 M HCl, calculate the pH under the following conditions.

a. after 50.0 mL of 0.50 M HCl has been added

b. at the stoichiometric point

20. A sample of an ionic compound NaA, where A- is the anion of a weak acid, was dissolved in enough water to make 100.0 mL of solution and was then titrated with 0.100 M HCl. After 500.0 mL of HCl was added, the pH was measured and found to be 5.00. The experimenter found that 1.00 L of 0.100 M HCl was required to reach the stoichiometric point of the titration.

a. What is the Kb value for A-?

b. Calculate the pH of the solution at the stoichiometric point of the titration.

***Indicators***

21. Methyl red is an indicator with Ka = 5.0 x 10-6 and it undergoes a color change from red to yellow as a solution gets more basic.

a. Calculate the approximate pH range for which methyl red is useful.

b. What is the color change and the pH at the color change when a weak acid is titrated with a strong base

using methyl red as an indicator?

c. What is the color change and the pH at the color change when a weak base is titrated with a strong acid

using methyl red as an indicator?

d. For which of the two types of titrations described in b and c is methyl red a possible indicator?

22. A certain indicator HIn has a pKa of 3.00 and a color change becomes visible with 7.00% of the indicator has been converted to In-. At what pH is this color change visible?

23. Which of the indicators in Figure 15.8 of the textbook could be used for the titrations in problems 15 and 16?

24. Which of the indicators in Figure 15.8 of the textbook could be used for the titration in problem 17?

25. Estimate the pH of a solution in which bromcresol green is blue and thymol blue is yellow (see Figure 15.8).

26. A solution has a pH of 7.0. What would be the color of the solution if each of the following indicators were added (see Figure 15.8)?

a. thymol blue

b. bromthymol blue

c. methyl red

d. crystal violet

***Solubility Equilibria***

27. Write balanced equations for the dissolution reactions and the corresponding solubility product expressions for each of the following solids.

a. Ag2CO3

b. Ce(IO3)3

c. BaF2

28. Use the following data to calculate the Ksp value for each solid.

a. The solubility of Pb3(PO4)2 is 6.2 x 10-12 mol/L.

b. The solubility of Li2CO3 is 7.4 x 10-2 mol/L.

29. The concentration of Ag+ in a solution saturated with Ag2C2O4 (s) is 2.2 x 10-4 M. Calculate Ksp for Ag2C2O4.

30. Calculate the solubility of each of the following compounds in moles per liter. Ignore any acid-base properties.

a. PbI2, Ksp = 1.4 x 10-8

b. CdCO3, Ksp = 5.2 x 10-12

c. Sr3(PO4)2, Ksp = 1 x 10-31

31. A solution contains 0.018 mol each of I-, Br-, Cl-. When the solution is mixed with 200. mL of 0.24 M AgNO3, what mass of AgCl (s) precipitates out, and what is the [Ag+]? Assume no volume change.

AgI, Ksp = 1.5 x 10-16

AgBr, Ksp = 5.0 x 10-13

AgCl, Ksp = 1.6 x 10-10

32. Calculate the molar solubility of Cd(OH)2, Ksp = 5.9 x 10-11.

33. For each of the following pairs of solids, determine which solid has the smallest molar solubility.

a. FeC2O4, Ksp = 2.1 x 10-7, or Cu(IO4)2, Ksp = 1.4 x 10-7

b. Ag2CO3, Ksp = 8.1 x 10-12, or Mn(OH)2, Ksp = 2 x 10-13

34. The Ksp for silver sulfate (Ag2SO4) is 1.2 x 10-5. Calculate the solubility of silver sulfate in each of the following.

a. water

b. 0.10 M AgNO3

c. 0.20 M K2SO4

35. The solubility of Ce(IO3)3 in a 0.20 M KIO3 solution is 4.4 x 10-8 mol/L. Calculate Ksp for Ce(IO3)3.

36. The concentration of Mg2+ in seawater is 0.052 M. At what pH will 99% of the Mg2+ be precipitated as the hydroxide salt? [Ksp for Mg(OH)2 = 8.9 x 10-12.]

37. For which salt in each of the following groups will the solubility depend on pH?

a. AgF, AgCl, AgBr

b. Pb(OH)2, PbCl2

c. Sr(NO3)2, Sr(NO2)2

d. Ni(NO3)2, Ni(CN)2

38. Will a precipitate form when 100.0 mL of 4.0 x 10-4 M Mg(NO3)2 is added to 100.0 mL of 2.0 x 10-4 M NaOH?

39. A solution is prepared by mixing 50.0 mL of 0.10 M Pb(NO3)2 with 50.0 mL of 1.0 M KCl. Calculate the concentrations of Pb2+ and Cl- at equilibrium. Ksp for PbCl2 (s) is 1.6 x 10-5.

***Complex Ion Equilibria***

40. Write equations for the stepwise formation of each of the following complex ions.

a. CoF63-

b. Zn(NH3)42+

41. In the presence of CN-, Fe3+ forms the complex ion Fe(CN)63-. The equilibrium concentrations of Fe3+ and Fe(CN)63- are 8.5 x 10-40 M and 1.5 x 10-3 M, respectively, in a 0.11 M KCN solution. Calculate the value for the overall formation constant of Fe(CN)63-.

Fe3+ (aq) + 6 CN- (aq) ⇔ Fe(CN)63- Koverall = ?

42. As sodium chloride solution is added to a solution of silver nitrate, a white precipitate forms. Ammonia is added to the mixture and the precipitate dissolves. When potassium bromide solution is then added, a pale yellow precipitate appears. When a solution of sodium thiosulfate is added, the yellow precipitate dissolves. Finally potassium iodide is added to the solution and a yellow precipitate forms. Write reactions for all the changes mentioned above. What conclusions can you draw concerning the sizes of the Ksp values for AgCl, AgBr, and AgI?

43. A solution is formed by mixing 50.0 mL of 10.0 M NaX with 50.0 mL of 2.0 x 10-3 M CuNO3. Assume that Cu(I) forms complex ions with X- as follows:

Cu+ (aq) + X- (aq) ⇔ CuX (aq) K1 = 1.0 x 102

CuX (aq) + X- (aq) ⇔ CuX2- (aq) K2 = 1.0 x 104

CuX2- (aq) + X- (aq) ⇔ CuX3-2 (aq) K3 = 1.0 x 103

with an overall reaction

Cu+ (aq) + 3 X- (aq) ⇔ CuX32- (aq) K = 1.0 x 109

Calculate the following concentrations at equilibrium

a. CuX32-

b. CuX2-

c. Cu+

44. Solutions of sodium thiosulfate are used to dissolve unexposed AgBr (Ksp = 5.0 x 10-13) in the developing process for black and white film. What mass of AgBr can dissolve in 1.00 L of 0.500 M Na2S2O3? Ag1+ reacts with S2O32- to form a complex ion:

Ag+ (aq) + 2 S2O32- (aq) ⇔ Ag(S2O3)23- (aq) K = 2.9 x 1013

45. The copper (I) ion forms a chloride salt that has Ksp = 1.2 x 10-6. Copper (I) also forms a complex ion with Cl-:

Cu+ (aq) + 2 Cl- (aq) ⇔ CuCl2- (aq) K = 8.7 x 104

1. Calculate the solubility of copper (I) chloride in pure water. (Ignore CuCl2- formation for this part).
2. Calculate the solubility of copper (I) chloride in 0.10 M NaCl.

***Answers to Selected Problems***

2. a) 9.52; b) 3.52; c) 7.00; d) 6.04

3. a) 0.033%; d) 1.1 x 10-5%

4. a) 6.64; b) 1.70; c) 1.70; d) 5.86

6. 3.36

7. a) 3.49; b) 3.14

8. 9.15

9. a) 1.2 M; b) 4.32

10. 0.41 L HNO2 and 0.59 L NaNO2

13. a) 0.50 mols HCl; b) 0.78 mols HCl; 0.35 mols HCl

15. a) 13.3; b) 12.9; c) 12.6; d) 7.0; e) 1.0

16. a) 10.7; b) 8.66; c) 8.48; d) 7.87; e) 4.83; f) 1.30

17. 2.94, 4.18, 4.55, 4.89, 5.50, 6.28, 6.58, 7.29, 8.79, 10.3, 11.3, 11.8, 12.0

18. 11.1, 9.97, 9.59, 9.26, 8.66, 7.88, 7.57, 6.86, 5.28, 3.70, 2.71, 2.25, 2.04

19. a) 10.6; b) 5.56

20. a) 1 x 10-9; b) 3.02

21. a) 4.30-6.30

22. 1.88

28. a) 9.9 x 10-55; b) 1.6 x 10-3

29. 5.32 x 10-12

30. a) 1.5 x 10-3 M; b) 2.3 x 10-6 M; c) 2 x 10-7 m

31. 1.72 g AgCl; [Ag+] = 5.3 x 10-9M

32. 2.5 x 10-4

34. a) 1.4 x 10-2M; b) 1.2 x 10-3 M; c) 3.9 x 10-3 M

35. 3.5 x 10-10

36. 10.1

39. [Pb2+] = 1.0 x 10-4 M; [Cl-] = 0.40 M

41. 1.0 x 1042

43. [Cu2+] = 8.0 x 10-15 M; [CuX32-] = 1.0 x 10-3 M; [CuX2-] = 2.0 x 10-7 M

44. 42 g AgBr

45. a) 1.1 x 10-3M; b) 9.1 x 10-3 M