CHEMISTRY 1220
CHAPTER 17 PRACTICE EXAM

All questions listed below are problems taken from old Chemistry 123 exams given here at The Ohio State University. Read Chapter 17.4 – 17.7 and complete the following problems. These problems will not be graded or collected, but will be very similar to what you will see on an exam.

K_{sp} and Molar Solubility (Section 17.4)

1. The solubility product expression for $La_2(CO_3)_3$ is K_{sp} = ?

2. The solubility product expression for $Zn_3(PO_4)_2$ is K_{sp} = ?

3. The solubility product expression for $La_2(CO_3)_3$ is K_{sp} = ?

4. The solubility product expression for $Fe(OH)_3$ is K_{sp} = ?

5. Calculate the molar solubility of CrF_3 in water. K_{sp} for CrF_3 is 6.6×10^{-11}.

6. What is the molar solubility for $PbCrO_4$? K_{sp} $PbCrO_4 = 2.8 \times 10^{-13}$

7. The solubility of BaF_2 is 1.3 g/L. What is the solubility product constant?

8. One liter of a saturated solution of silver sulfate contains 4.5 g of Ag_2SO_4. Calculate the solubility product constant for Ag_2SO_4.

9. The solubility of copper(II) iodate, $Cu(IO_3)_2$, is 1.3 g/L at 25 °C. Calculate the solubility product constant for copper(II) iodate.

10. Calculate the K_{sp} value for Bi_2S_3, which has a solubility of 1.0×10^{-15} mol/L at 25°C.

11. The solubility of lead (II) chloride is 1.6×10^{-2} M. What is the K_{sp} of $PbCl_2$?

12. The solubility of $CaCO_3$ (limestone) is 9.5 mg in 1800 mL. What is the K_{sp} of $CaCO_3$ (Formula Weight = 100.1 g/mol)?

13. The K_{sp} for CaF_2 is 3.9×10^{-11}. What is the solubility of CaF_2 in water in grams/liter?

14. The K_{sp} for $Sn(OH)_2$ is 2.0×10^{-26}. What is the solubility of $Sn(OH)_2$ in water in grams/liter?

15. What is the solubility of iodide ions in a saturated solution of lead (II) iodide ($K_{sp} = 1.4 \times 10^{-8}$)?

16. Which compound is the **least** soluble (mol/L) in water?
    (a) $CaCO_3$ $K_{sp} = 2.8 \times 10^{-9}$
    (b) PbI_2 $K_{sp} = 8.7 \times 10^{-9}$
    (c) AgBr $K_{sp} = 5.0 \times 10^{-13}$
    (d) $Fe(OH)_2$ $K_{sp} = 8.0 \times 10^{-16}$
    (e) $Co(OH)_2$ $K_{sp} = 1.6 \times 10^{-15}$

17. Which of the following salts has the highest concentration of silver ion when dissolved in water?

AgCl	$K_{sp} = 1.6 \times 10^{-10}$
Ag_2CO_3	$K_{sp} = 8.1 \times 10^{-12}$
AgBr	$K_{sp} = 5.0 \times 10^{-13}$

18. Which compound is least soluble in water?

a) $Co(OH)_2$	$K_{sp} = 1.6 \times 10^{-15}$
b) $Fe(OH)_2$	$K_{sp} = 8.0 \times 10^{-16}$
c) AgBr	$K_{sp} = 5.0 \times 10^{-13}$
d) $CaCO_3$	$K_{sp} = 2.8 \times 10^{-9}$
e) PbI_2	$K_{sp} = 8.7 \times 10^{-9}$

Factors Influencing Solubility (Section 17.5)

24. How many moles of MgF_2 ($K_{sp} = 6.4 \times 10^{-9}$) will dissolve in 0.50 L of 0.20 M NaF?

25. Calculate the molar solubility of CrF_3 in 0.20 M NaF.

26. What is the molar solubility of MgF_2 in 0.40 M F^-? K_{sp} $MgF_2 = 6.4 \times 10^{-9}$

27. The solubility product constant for BiI_3 is 8.1×10^{-19}. Calculate the molar solubility of BiI_3 in 0.20 M $Bi(NO_3)_3$.

28. As the pH decreases, how will the solubility of $Cu(OH)_2$ be affected?

29. The K_{sp} for $Zn(OH)_2$ is 5.0×10^{-17}. Determine the molar solubility of $Zn(OH)_2$ in buffered solution with a pH of 11.50?

30. Calculate the solubility of $Cu(OH)_2$ in a solution buffered at pH = 8.50. K_{sp} for $Cu(OH)_2 = 1.6 \times 10^{-19}$

31. Calculate the molar solubility of $Mn(OH)_2$ when buffered at pH = 11.40. The K_{sp} for $Mn(OH)_2$ is 1.6×10^{-13}.

32. What is the pH of a saturated solution of $Cu(OH)_2$ ($K_{sp} = 2.6 \times 10^{-19}$)?

33. What is the molar solubility (mol/L) of $Cr(OH)_3$ at pH = 10.00? K_{sp} for $Cr(OH)_3$ is 6.3×10^{-31} and K_f for $Cr(OH)_4^-$ is 8×10^{29}.

34. Calculate the concentration of free cadmium ion, $[Cd^{2+}]$, in a solution that contains 0.20 M $Cd(NO_3)_2$ in 2.0 M NaCN. Cadmium ion forms the complex ion, $Cd(CN)_4^{2-}$ for which K_f is 6.0×10^{18}.

35. Calculate the molar solubility of $CdCO_3$ in 1.5 M NH_3. Note that Cd^{2+} forms the $Cd(NH_3)_4^{2+}$ complex ion for which K_f is 1.3×10^7. K_{sp} for $CdCO_3$ is 5.2×10^{-12}.

36. What is the concentration of free cobalt ion in a solution that is 4.75×10^{-2} M Co^{2+} and 5.0 M NH_3? K_f $Co(NH_3)_6^{2+} = 8.3 \times 10^4$

37. Calculate the molar solubility of AgCl in 12 M NH_3.

K_{sp} AgCl = 1.8×10^{-10} K_f $Ag(NH_3)_2 = 1.7 \times 10^7$

38. Calculate the concentration of free aluminum ion, $[Al^{3+}]$, in 1.0 L of solution that contains 0.040 mol $Al(NO_3)_3$ and 2.00 mol NaF. K_f for AlF_6^{3-} is 7.1×10^{19}.

39. The Cd^{2+} ion forms the complex ion $CdCl_4^{2-}$ for which $K_f = 6.3 \times 10^2$. Determine the equilibrium constant for the solubility of $CdCO_3$ in contact with a solution that contains Cl^- ion. K_{sp} for $CdCO_3$ is 5.2×10^{-12}.

40. Use information from problem 39 to calculate the molar solubility of $CdCO_3$ in 3.0 M NaCl.

41. The Ag^+ ion forms the complex ion $AgCl_2^-$ for which $K_f = 2.5 \times 10^5$. Determine the equilibrium constant for the solubility of AgCl in the presence of excess chloride ion. K_{sp} of AgCl is 1.8×10^{-10}.

42. Use the information from problem 41 to calculate the molar solubility of AgCl in 8.5 M HCl.

43. Calculate the concentration of free copper ion, $[Cu^{2+}]$, in a 1.0 L solution containing 3.7×10^{-2} mol Cu^{2+} and 2.5 M NH_3. K_f for $Cu(NH_3)_4^{2+} = 5 \times 10^{12}$.

44. What is the concentration of Cd^{2+} in a solution that is 0.10 M $Cd(NH_3)_4^{2+}$?
K_f for $Cd(NH_3)_4^{2+}$ is 4.0×10^6

45. Calculate the molar solubility of ZnS in 2.5 M NaOH. K_{sp} ZnS = 3.0×10^{-23} K_f $Zn(OH)_4^{2-} = 2.9 \times 10^{15}$

46. The formation constant, K_f, for $Ni(NH_3)_6^{2+}$ is 5.5×10^8. What is the concentration of free nickel ions in a solution that contains 0.045 M Ni^{2+} and 3.0 M NH_3 (concentrations refer to the moment before the formation of the complex ion)?

47. A solution is saturated with silver acetate, $AgC_2H_3O_2$ ($K_{sp} = 1.9 \times 10^{-3}$). Which of the following reagents will increase the solubility of silver acetate?

$NaC_2H_3O_2$ HNO_3 NH_3 $AgNO_3$

48. How many of the following salts would be more soluble in acidic solution that in pure water?

BaC_2O_4 CaS $AuCl_3$ PbF_2 $ZnCO_3$

49. Would each of the following reagents increase, decrease, of have no effect on the solubility of $Cu(OH)_2$?

$CuCl_2$ HCl NH_3 NaOH

50. Which salt solubility would be most sensitive to pH?

$Ca(NO_3)_2$ CaF_2 $CaCl_2$ $CaBr_2$ CaI_2

51. The solubility of which of the listed salts would be unaffected by the presence of a strong acid?

$KClO_4$ BaF_2 $FePO_4$ SnI_2

52. How many of the following reagents, when added to a solution in contact with solid $NiCO_3$ would change the solubility of $NiCO_3$?

HCl $NiCl_2$ NaCl Na_2CO_3 NH_3

53. The solubility of how many of the following salts will be affected by strong acid?

AgBr $Cu_3(PO_4)_2$ $NaNO_3$ BaF_2

54. Zinc oxalate is a slightly soluble salt. How many of the following reagents would be expected to decrease the solubility of ZnC_2O_4?

$Na_2C_2O_4$ NH_3 NaOH HCl $ZnCl_2$

55. Which of the following reagents would increase the solubility of $Ni(OH)_2(s)$?

$Ni(NO_3)_2$ NaOH HCl NH_3

56. The molar solubility of _____ is not affected by the pH of the solution.
a) MnS
b) $AlCl_3$
c) KNO_3
d) NaF
e) Na_3PO_4

57. For which salt should the aqueous solubility be most sensitive to pH?
a) $Ca(NO_3)_2$
b) CaF_2
c) $CaCl_2$
d) $CaBr_2$
e) CaI_2

Precipitation and Separation of Ions (Section 17.6)

58. A solution contains Ca^{2+} at a concentration of 2.0×10^{-4} M. If 40.0 mL of this solution is added to 25.0 mL of 5.0×10^{-3} M NaF, will a precipitate form? If 40.0 mL of the Ca^{2+} solution is added to 25.0 mL of 5.0×10^{-3} M Na_3PO_4 will a precipitate form?

For CaF_2, $K_{sp} = 3.9 \times 10^{-11}$
For $Ca_3(PO_4)_2$, $K_{sp} = 2.0 \times 10^{-29}$

59. Will a precipitate form when 4.5 mL of 0.025 M $Pb(NO_3)_2$ and 1.5 mL of 0.0065 M KF are mixed? How could you tell?

60. Which salt precipitates first and what is the minimum concentration of Ag^+ necessary to cause this precipitation in a solution containing 7.5 mL of 0.025 M NaCl and 7.5 mL of 0.025 M Na_3PO_4?
K_{sp} AgCl = 1.8×10^{-10} K_{sp} Ag_3PO_4 = 1.3×10^{-20}

61. Will a precipitate form when 38 mL of 0.25 M $Pb(NO_3)_2$ and 12 mL of 0.35 M KBr are mixed? Why or why not?

62. A solution contains 0.10 M $Mg(NO_3)_2$ and 0.10 M $Ca(NO_3)_2$. If solid sodium oxalate, $Na_2C_2O_4$, is added to the solution, what is $[Ca^{2+}]$ (M) when MgC_2O_4 begins to precipitate? (Assume no volume changes.) At 25 °C, K_{sp} of CaC_2O_4 is 2.3×10^{-9} and K_{sp} of MgC_2O_4 is 8.6×10^{-5}.

63. The K_{sp} for BaF_2 is 1.0×10^{-6}. When 10 mL of 0.010 M NaF is mixed with 10 mL of 0.01 M $BaNO_3$ will a precipitate form? Why or why not?

64. A solution contains 0.005 M AsO_4^{3-}, 0.005 M I^-, and 0.005 M CO_3^{2-}. If $AgNO_3$ is slowly added, in what order would the silver salts precipitate?

For Ag_3AsO_4, $K_{sp} = 1.0 \times 10^{-22}$
For AgI, $K_{sp} = 8.3 \times 10^{-17}$
For Ag_2CO_3, $K_{sp} = 8.1 \times 10^{-12}$

65. Three beakers contain the following solutions:

1) 40.0 mL of 0.020 M $Ca(NO_3)_2$
2) 40.0 mL of 0.020 M $Fe(NO_3)_2$
3) 40.0 mL of 0.020 M $Pb(NO_3)_2$

If 10.0 mL of 0.050 M NaF is added to each beaker, in which beakers will a precipitate form?
For CaF_2, $K_{sp} = 1.5 \times 10^{-10}$, FeF_2 $K_{sp} = 2.4 \times 10^{-6}$, PbF_2 $K_{sp} = 7.1 \times 10^{-7}$

66. A solution contains 0.010 M Al^{3+} and 0.010 M Ag^{+}. Solid Na_3PO_4 is slowly added to separate the two cations. K_{sp} for $AlPO_4$ is 1.3×10^{-20} and K_{sp} for Ag_3PO_4 is 1.3×10^{-20}. Which cation would precipitate first, and after it precipitates, what concentration of PO_4^{3-} ion should be obtained in the solution for the best separation?

67. A solution of NaF is added dropwise to a solution that is 0.0144 M in Ba^{2+}. BaF_2 ($K_{sp} = 1.7 \times 10^{-6}$) will begin to precipitate when the concentration of F^- ions reaches what value? Neglect volume changes associated with the addition of NaF solution.

68. $AgNO_3$ is slowly added to a solution containing the following anions:
0.02 M AsO_4^{2-} 0.02 M I^- 0.02 M CO_3^{2-}
In what order will these salts precipitate? K_{sp} for $Ag_3AsO_4 = 1.0 \times 10^{-22}$ AgI = 8.3×10^{-17} $Ag_2CO_3 = 8.1 \times 10^{-12}$

69. A solution contains three anions with the following concentrations, 0.20 M CrO_4^{2-}, 0.10 M CO_3^{2-} and 0.01 M Cl^-. If a dilute $AgNO_3$ solution is slowly added to the solution what precipitate forms first?
Ag_2CrO_4 ($K_{sp} = 1.2 \times 10^{-12}$), Ag_2CO_3 ($K_{sp} = 8.1 \times 10^{-12}$), AgCl ($K_{sp} = 1.8 \times 10^{-10}$)?

70. In which one of the following solutions is silver chloride the most soluble?
a) 0.181 M HCl solution
b) 0.0176 M NH_3 solution
c) Pure water
d) 0.744 M $LiNO_3$ solution
e) 0.181 M NaCl solution

71. Given the following K_{sp} values, which statement about solubility in water is correct?

$PbCrO_4$	=	2.0×10^{-16}
$Zn(OH)_2$	=	4.5×10^{-17}
$Pb(OH)_2$	=	1.2×10^{-15}
MnS	=	2.3×10^{-13}

a) $PbCrO_4$, $Zn(OH)_2$, and $Pb(OH)_2$ have the same solubilities in water.
b) $PbCrO_4$ has the lowest solubility in water.
c) The solubility of MnS in water will not be pH dependant
d) MnS has the highest molar solubility in water.
e) A saturated $PbCrO_4$ solution will have a higher $[Pb^{2+}]$ that a saturated $Pb(OH)_2$ solution.

Qualitative Analysis Group II & III (Section 17.7)

72. A solution contains 0.015 M Cu^{2+} and 0.015 M Ni^{2+}. The solution is saturated with H_2S (0.10M) and adjusted to pH = 2.00. Which of the metal sulfides will precipitate?
K_{sp} of NiS is 3×10^{-20}, K_{sp} of CuS is 6×10^{-37}.

73. Solutions were prepared using 0.03 M metal ion, 0.10 M H_2S and a pH of 5.25. Which metal sulfides will precipitate? K_1 $H_2S = 9.5 \times 10^{-8}$

K_{sp}: MnS = 3×10^{-14} NiS = 3×10^{-21} PbS = 7×10^{-29}

74. Which of the following metal sulfides would form a precipitate from a solution of pH = 3.75 containing 0.10 M H_2S ($K_1 = 9.5 \times 10^{-8}$) and 0.01 M metal ion?

K_{sp} for MnS = 3×10^{-14}, FeS = 6×10^{-19}, CoS = 5×10^{-22}

75. A solution containing Zn^{2+}, Co^{2+}, Pb^{2+}, Ni^{2+}, Cu^{2+}, Sn^{2+}, Fe^{2+}, Sb^{3+}, Al^{3+}, Cr^{3+}, and Bi^{3+} ions is treated with HNO_3 and H_2S. What is the identity of the precipitate(s) that form and which ions remain in solution?

77. For the sulfide equilibrium of the type:

$$MS(s) + H_2O(l) \leftrightarrow M^{2+}(aq) + HS^-(aq) + OH^-(aq)$$

	K_{sp}
CdS	8.0×10^{-28}
CoS	5.0×10^{-22}
CuS	6.0×10^{-37}
FeS	6.0×10^{-19}
PbS	3.0×10^{-28}
MnS	3.0×10^{-14}
NiS	1.1×10^{-21}
SnS	1.0×10^{-26}
ZnS	2.0×10^{-25}

In the laboratory the following experimental conditions were observed: $[M^{2+}] = 0.01$ M, $[H_2S] = 0.10$ M, $[HNO_3] = 0.3$ M. Which of the following metal ions from the chart will precipitate under these conditions?

78. At what pH will each of the nine sulfides begin to precipitate?

80. A solution containing Al^{3+}, Cr^{3+}, and Fe^{3+} was treated with NH_3 to precipitate out $Al(OH)_3$, $Cr(OH)_3$, and $Fe(OH)_3$. The solids were treated with NaOH and H_2O_2 which dissolved $Al(OH)_3$ and $Cr(OH)_3$ and left $Fe(OH)_3$ as a solid. What chemical principle is responsible for this difference in solubility?

83. Consider the following reaction:

$$M^{n+}(aq) + x\ NH_3(aq) \leftrightarrow M(NH_3)_x^{n+}(aq)$$

where $M^{n+} = Al^{3+}$, Cr^{3+}, Fe^{3+}, Ni^{2+}, Co^{2+}, Zn^{2+}.

(a) Upon addition of NH_3 which complex ions will form?
(b) NH_3 was added and was also buffered with NH_4Cl. Which complex ions will form?