

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 $\text{La}_2(\text{CO}_3)_3$ is $K_{sp} = ?$
2. The solubility product expression for $\text{Zn}_3(\text{PO}_4)_2$ is $K_{sp} = ?$
3. The solubility product expression for $\text{La}_2(\text{CO}_3)_3$ is $K_{sp} = ?$
4. The solubility product expression for $\text{Fe}(\text{OH})_3$ 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} $\text{PbCrO}_4 = 2.8 \times 10^{-13}$
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, $\text{Cu}(\text{IO}_3)_2$, 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 $\text{Sn}(\text{OH})_2$ is 2.0×10^{-26} . What is the solubility of $\text{Sn}(\text{OH})_2$ 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) $\text{Fe}(\text{OH})_2$ $K_{sp} = 8.0 \times 10^{-16}$
 - (e) $\text{Co}(\text{OH})_2$ $K_{sp} = 1.6 \times 10^{-15}$

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 ₂ CO 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 MgF₂ ($K_{sp} = 6.4 \times 10^{-9}$) will dissolve in 0.50 L of 0.20 M NaF?

25. Calculate the molar solubility of CrF₃ in 0.20 M NaF.

26. What is the molar solubility of MgF₂ in 0.40 M F⁻? K_{sp} MgF₂ = 6.4×10^{-9}

27. The solubility product constant for BiI₃ is 8.1×10^{-19} . Calculate the molar solubility of BiI₃ in 0.20 M Bi(NO₃)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 = 1.6×10^{-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, [Cd²⁺], in a solution that contains 0.20 M Cd(NO₃)₂ in 2.0 M NaCN. Cadmium ion forms the complex ion, Cd(CN)₄²⁻ for which K_f is 6.0×10^{18} .

35. Calculate the molar solubility of CdCO₃ in 1.5 M NH₃. Note that Cd²⁺ forms the Cd(NH₃)₄²⁺ complex ion for which K_f is 1.3×10^7 . K_{sp} for CdCO₃ is 5.2×10^{-12} .

36. What is the concentration of free cobalt ion in a solution that is 4.75×10^{-2} M Co²⁺ and 5.0 M NH₃? K_f Co(NH₃)₆²⁺ = 8.3×10^4

37. Calculate the molar solubility of AgCl in 12 M NH₃.

$$K_{sp} \text{ AgCl} = 1.8 \times 10^{-10} \qquad K_f \text{ Ag(NH}_3)_2 = 1.7 \times 10^7$$

38. Calculate the concentration of free aluminum ion, [Al³⁺], in 1.0 L of solution that contains 0.040 mol Al(NO₃)₃ and 2.00 mol NaF. K_f for AlF₆³⁻ 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, $[\text{Cu}^{2+}]$, in a 1.0 L solution containing 3.7×10^{-2} mol Cu^{2+} and 2.5 M NH_3 . K_f for $\text{Cu}(\text{NH}_3)_4^{2+} = 5 \times 10^{12}$.

44. What is the concentration of Cd^{2+} in a solution that is 0.10 M $\text{Cd}(\text{NH}_3)_4^{2+}$?
 K_f for $\text{Cd}(\text{NH}_3)_4^{2+}$ is 4.0×10^6

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

46. The formation constant, K_f , for $\text{Ni}(\text{NH}_3)_6^{2+}$ 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, $\text{AgC}_2\text{H}_3\text{O}_2$ ($K_{sp} = 1.9 \times 10^{-3}$). Which of the following reagents will increase the solubility of silver acetate?

$\text{NaC}_2\text{H}_3\text{O}_2$ HNO_3 NH_3 AgNO_3

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

BaC_2O_4 CaS AuCl_3 PbF_2 ZnCO_3

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

CuCl_2 HCl NH_3 NaOH

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

$\text{Ca}(\text{NO}_3)_2$ 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 $\text{Cu}_3(\text{PO}_4)_2$ 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 ?

$\text{Na}_2\text{C}_2\text{O}_4$ NH_3 NaOH HCl ZnCl_2

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



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) $\text{Ca}(\text{NO}_3)_2$
- b) CaF_2
- c) CaCl_2
- d) CaBr_2
- e) CaI_2

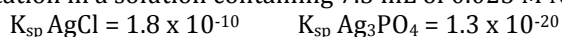
Precipitation and Separation of Ions (Section 17.6)

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?



59. Will a precipitate form when 4.5 mL of 0.025 M $\text{Pb}(\text{NO}_3)_2$ 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 ?



61. Will a precipitate form when 38 mL of 0.25 M $\text{Pb}(\text{NO}_3)_2$ and 12 mL of 0.35 M KBr are mixed? Why or why not?

62. A solution contains 0.10 M $\text{Mg}(\text{NO}_3)_2$ and 0.10 M $\text{Ca}(\text{NO}_3)_2$. If solid sodium oxalate, $\text{Na}_2\text{C}_2\text{O}_4$, is added to the solution, what is $[\text{Ca}^{2+}]$ (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?



65. Three beakers contain the following solutions:

- 1) 40.0 mL of 0.020 M $\text{Ca}(\text{NO}_3)_2$
- 2) 40.0 mL of 0.020 M $\text{Fe}(\text{NO}_3)_2$
- 3) 40.0 mL of 0.020 M $\text{Pb}(\text{NO}_3)_2$

If 10.0 mL of 0.050 M NaF is added to each beaker, in which beakers will a precipitate form?



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 ($K_{\text{sp}} = 1.7 \times 10^{-6}$) 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:



In what order will these salts precipitate? K_{sp} for $\text{Ag}_3\text{AsO}_4 = 1.0 \times 10^{-22}$ $\text{AgI} = 8.3 \times 10^{-17}$ $\text{Ag}_2\text{CO}_3 = 8.1 \times 10^{-12}$

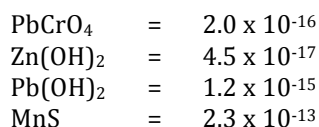
69. A solution contains three anions with the following concentrations, 0.20 M CrO_4^{2-} , 0.10 M CO_3^{2-} and 0.01 M Cl^- . If a dilute AgNO_3 solution is slowly added to the solution what precipitate forms first?

Ag_2CrO_4 ($K_{\text{sp}} = 1.2 \times 10^{-12}$), Ag_2CO_3 ($K_{\text{sp}} = 8.1 \times 10^{-12}$), AgCl ($K_{\text{sp}} = 1.8 \times 10^{-10}$)?

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?



- a) PbCrO_4 , $\text{Zn}(\text{OH})_2$, and $\text{Pb}(\text{OH})_2$ 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 $[\text{Pb}^{2+}]$ than a saturated $\text{Pb}(\text{OH})_2$ 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 $\text{pH} = 2.00$. 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? $K_1 \text{H}_2\text{S} = 9.5 \times 10^{-8}$

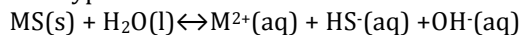
K_{sp} : $\text{MnS} = 3 \times 10^{-14}$ $\text{NiS} = 3 \times 10^{-21}$ $\text{PbS} = 7 \times 10^{-29}$

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

K_{sp} for $\text{MnS} = 3 \times 10^{-14}$, $\text{FeS} = 6 \times 10^{-19}$, $\text{CoS} = 5 \times 10^{-22}$

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:



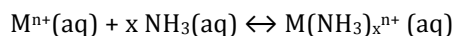
	K_{sp}
CdS	8.0×10^{-28}
CoS	5.0×10^{-22}
CuS	6.0×10^{-37}
FeS	6.0×10^{-19}
PbS	3.0×10^{-28}
MnS	3.0×10^{-14}
NiS	1.1×10^{-21}
SnS	1.0×10^{-26}
ZnS	2.0×10^{-25}

In the laboratory the following experimental conditions were observed: $[\text{M}^{2+}] = 0.01 \text{ M}$, $[\text{H}_2\text{S}] = 0.10 \text{ M}$, $[\text{HNO}_3] = 0.3 \text{ M}$. 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 $\text{Al}(\text{OH})_3$, $\text{Cr}(\text{OH})_3$, and $\text{Fe}(\text{OH})_3$. The solids were treated with NaOH and H_2O_2 which dissolved $\text{Al}(\text{OH})_3$ and $\text{Cr}(\text{OH})_3$ and left $\text{Fe}(\text{OH})_3$ as a solid. What chemical principle is responsible for this difference in solubility?

83. Consider the following reaction:



where $\text{M}^{n+} = \text{Al}^{3+}$, 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?