CH 223 Practice Problem Set #4

*This is a **practice problem set** and not the actual graded problem set that you will turn in for credit. Answers to each problem can be found at the end of this assignment.*

Covering: **Chapter Fifteen** *and* **Chapter Guide Four**
Important Tables and/or Constants: **Solubility Table** (*from the CH 221* Net Ionics *lab* or here: **https://mhchem.org/sol**), **"Solubility Product Constant (K_{sp}) Values at 25 °C"** *and* "**Complex Ion Formation Constant (K_f) Values at 25 °C"** *at the end of problem set #4*, "**Solubility Guide**" *(Handout)*

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1. Predict whether each of the following is insoluble or soluble in water.
   a. $(NH_4)_2CO_3$
   b. $ZnSO_4$
   c. NiS
   d. $BaSO_4$
2. For each of the following insoluble salts, (i) write a balanced equation showing the equilibrium occurring when the salt is added to water and (ii) write the K_{sp} expression.
   a. $AgCN$
   b. $NiCO_3$
   c. $AuBr_3$
3. When 1.55 g of solid thallium(I) bromide is added to 1.00 L of water, the salt dissolves to a small extent.

   $$TlBr(s) \rightleftharpoons Tl^{+}(aq) + Br^{-1}(aq)$$

   The thallium(I) and bromide ions in equilibrium with TlBr each have a concentration of 1.9×10^{-3} M. What is the value of K_{sp} for TlBr?
4. You add 0.979 g of $Pb(OH)_2$ to 1.00 L of pure water at 25 °C. The pH is 9.15. Estimate the value of K_{sp} for $Pb(OH)_2$.
5. Estimate the solubility of calcium fluoride, CaF_2, (a) in moles per liter and (b) in grams per liter of pure water.

   $$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\ F^{-1}(aq) \quad K_{sp} = 5.3 \times 10^{-11}$$

6. The K_{sp} value for radium sulfate, $RaSO_4$, is 3.7×10^{-11}. If 25 mg of radium sulfate is placed in 1.00×10^{2} mL of water, does all of it dissolve? If not, how much dissolves?
7. Use K_{sp} values to decide which compound in each of the following pairs is the more soluble.
   a. $PbCl_2$ ($K_{sp} = 1.7 \times 10^{-5}$) or $PbBr_2$ ($K_{sp} = 6.6 \times 10^{-6}$)
   b. HgS ($K_{sp} = 4.2 \times 10^{-11}$) or FeS ($K_{sp} = 8.0 \times 10^{-19}$)
   c. $Fe(OH)_2$ ($K_{sp} = 4.9 \times 10^{-17}$) or $Zn(OH)_2$ ($K_{sp} = 3.0 \times 10^{-17}$)
8. Compare the solubility, in milligrams per milliliter, of silver iodide, AgI, (a) in pure water and (b) in water that is 0.020 M in $AgNO_3$. (K_{sp} for AgI = 8.5×10^{-17})
9. You have a solution that has a lead(II) concentration of 0.0012 M.

   $$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\ Cl^{-1}(aq)$$

   If enough soluble chloride-containing salt is added so that the Cl^{-1} concentration is 0.010 M, will $PbCl_2$ precipitate? (K_{sp} for $PbCl_2 = 1.7 \times 10^{-5}$)
10. Will a precipitate of $Mg(OH)_2$ form when 25.0 mL of 0.010 M NaOH is combined with 75.0 mL of a 0.10 M solution of magnesium chloride? (K_{sp} for $Mg(OH)_2 = 5.6 \times 10^{-12}$)

11. Solid gold(I) chloride, AuCl, dissolves when excess cyanide ion, CN^{-1}, is added to give a water-soluble complex ion.

$$AuCl(s) + 2\ CN^{-1}(aq) \rightleftharpoons [Au(CN)_2]^{-1}(aq) + Cl^{-1}(aq)$$

Show that this equation is the sum of two other equations, one for dissolving AuCl to give its ions ($K_{sp} = 2.0 \times 10^{-13}$) and the other for the formation of the $[Au(CN)_2]^{-1}$ ion (using $K_{form} = 2.0 \times 10^{38}$) from Au^{+1} and CN^{-1}. Calculate K_{net} for the overall reaction.

12. Each pair of ions below is found together in aqueous solution. Using a table of solubility product constants, devise a way to separate these ions by precipitating one of them as an insoluble salt and leaving the other in solution.
    a. Ba^{2+} and Na^{+}
    b. Ni^{2+} and Pb^{2+}
13. A solution contains Ca^{2+} and Pb^{2+} ions, both at a concentration of 0.010 M. You wish to separate the two ions from each other as completely as possible by precipitating one but not the other using aqueous Na_2SO_4 as the precipitating agent.
    a. Which will precipitate first as sodium sulfate is added, $CaSO_4$ or $PbSO_4$?
    b. What will be the concentration of the first ion that precipitates (Ca^{2+} or Pb^{2+}) when the second, more soluble salt begins to precipitate?
14. Explain why the solubility of Ag_3PO_4 can be greater in water than is calculated from the K_{sp} value of the salt.
15. Decide whether each of the following substances should be classified as a Lewis acid or a Lewis base.
    a. H_2NOH in the reaction: $H_2NOH(aq) + HCl(aq) \rightarrow [H_3NOH][Cl](aq)$
    b. $Fe^{2+}(aq)$
    c. CH_3NH_2
16. A solution contains 0.10 M iodide ion, I^{-1}, and 0.10 M carbonate ion, CO_3^{2-}.
    a. If solid $Pb(NO_3)_2$ is slowly added to the solution, which salt will precipitate first, PbI_2 or $PbCO_3$? (K_{sp} for $PbI_2 = 9.8 \times 10^{-9}$, K_{sp} for $PbCO_3 = 7.4 \times 10^{-14}$)
    b. What will be the concentration of the first ion that precipitates (CO_3^{2-} or I^{-1}) when the second, more soluble salt begins to precipitate?
17. You place 2.234 g of solid $Ca(OH)_2$ in 1.00 L of pure water at 25 °C. The pH of the solution is found to be 12.68. Estimate the K_{sp} for $Ca(OH)_2$.
18. What is the solubility, in milligrams per milliliter, of BaF_2 (a) in pure water, and (b) in water containing 5.0 mg/mL KF? (K_{sp} for $BaF_2 = 1.8 \times 10^{-7}$)
19. Sodium carbonate is added to a solution in which the concentration of Ni^{2+} ion is 0.0024 M. Will precipitation of $NiCO_3$ ($K_{sp} = 1.4 \times 10^{-7}$) occur (a) when the concentration of the carbonate ion is 1.0×10^{-6} M or (b) when it is 100 times greater (or 1.0×10^{-4} M)? The equation: $NiCO_3(s) \rightleftharpoons Ni^{2+}(aq) + CO_3^{2-}(aq)$

Answers to the Practice Problem Set:

1. (a) and (b): soluble, (c) and (d): insoluble
2. *Answers:*
   a. $AgCN(s) \rightleftharpoons Ag^+(aq) + CN^-(aq)$ $\quad K_{sp} = [Ag^+][CN^-]$
   b. $NiCO_3(s) \rightleftharpoons Ni^{2+}(aq) + CO_3^{2-}(aq)$ $\quad K_{sp} = [Ni^{2+}][CO_3^{2-}]$
   c. $AuBr_3(s) \rightleftharpoons Au^{3+}(aq) + 3\ Br^-(aq)$ $\quad K_{sp} = [Au^{3+}][Br^-]^3$
3. 3.6×10^{-6}
4. 1.4×10^{-15}
5. a. 2.4×10^{-4} b. 0.018
6. No; 0.20 mg dissolves
7. a. $PbCl_2$ b. HgS b. $Fe(OH)_2$
8. a. 2.2×10^{-6} b. 1.0×10^{-13}
9. $Q < K_{sp}$ so no precipitate
10. $Q > K_{sp}$ so precipitate forms
11. $K_{net} = 4.0 \times 10^{25}$
12. a. SO_4^{2-} will precipitate Ba^{2+} b. Cl^{-1} will precipitate Pb^{2+}
13. a. $PbSO_4$ b. 5.1×10^{-6} M
14. PO_4^{3-} acts as a base, increasing solubility upon formation of HPO_4^{2-}
15. a. Lewis base b. Lewis acid c. Lewis base
16. a. $PbCO_3$ b. $[CO_3^{2-}] = 7.6 \times 10^{-8}$ mol/L
17. $K_{sp} = 5.5 \times 10^{-5}$
18. a. 0.63 mg/mL b. 4.2×10^{-3} mg/mL
19. a. no. b. yes