

## CH 223 Practice Problem Set #4

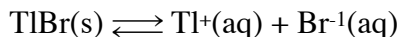
*This is a **practice problem set** and not the actual graded problem set that you will turn in for credit.  
Answers to each problem can be found at the end of this assignment.*

**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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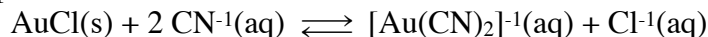
- Predict whether each of the following is insoluble or soluble in water.
  - $(\text{NH}_4)_2\text{CO}_3$
  - $\text{ZnSO}_4$
  - $\text{NiS}$
  - $\text{BaSO}_4$
- For each of the following insoluble salts, (i) write a balanced equation showing the equilibrium occurring when the salt is added to water and (ii) write the  $K_{sp}$  expression.
  - $\text{AgCN}$
  - $\text{NiCO}_3$
  - $\text{AuBr}_3$
- When 1.55 g of solid thallium(I) bromide is added to 1.00 L of water, the salt dissolves to a small extent.



The thallium(I) and bromide ions in equilibrium with TlBr each have a concentration of  $1.9 \times 10^{-3}$  M. What is the value of  $K_{sp}$  for TlBr?

- You add 0.979 g of  $\text{Pb(OH)}_2$  to 1.00 L of pure water at 25 °C. The pH is 9.15. Estimate the value of  $K_{sp}$  for  $\text{Pb(OH)}_2$ .
- Estimate the solubility of calcium fluoride,  $\text{CaF}_2$ , (a) in moles per liter and (b) in grams per liter of pure water.
$$\text{CaF}_2(\text{s}) \rightleftharpoons \text{Ca}^{2+}(\text{aq}) + 2 \text{F}^-(\text{aq}) \quad K_{sp} = 5.3 \times 10^{-11}$$
- The  $K_{sp}$  value for radium sulfate,  $\text{RaSO}_4$ , is  $3.7 \times 10^{-11}$ . If 25 mg of radium sulfate is placed in  $1.00 \times 10^2$  mL of water, does all of it dissolve? If not, how much dissolves?
- Use  $K_{sp}$  values to decide which compound in each of the following pairs is the more soluble.
  - $\text{PbCl}_2$  ( $K_{sp} = 1.7 \times 10^{-5}$ ) or  $\text{PbBr}_2$  ( $K_{sp} = 6.6 \times 10^{-6}$ )
  - $\text{HgS}$  ( $K_{sp} = 4.2 \times 10^{-11}$ ) or  $\text{FeS}$  ( $K_{sp} = 8.0 \times 10^{-19}$ )
  - $\text{Fe(OH)}_2$  ( $K_{sp} = 4.9 \times 10^{-17}$ ) or  $\text{Zn(OH)}_2$  ( $K_{sp} = 3.0 \times 10^{-17}$ )
- Compare the solubility, in milligrams per milliliter, of silver iodide,  $\text{AgI}$ , (a) in pure water and (b) in water that is 0.020 M in  $\text{AgNO}_3$ . ( $K_{sp}$  for  $\text{AgI} = 8.5 \times 10^{-17}$ )
- You have a solution that has a lead(II) concentration of 0.0012 M.
$$\text{PbCl}_2(\text{s}) \rightleftharpoons \text{Pb}^{2+}(\text{aq}) + 2 \text{Cl}^-(\text{aq})$$
If enough soluble chloride-containing salt is added so that the  $\text{Cl}^-$  concentration is 0.010 M, will  $\text{PbCl}_2$  precipitate? ( $K_{sp}$  for  $\text{PbCl}_2 = 1.7 \times 10^{-5}$ )
- Will a precipitate of  $\text{Mg(OH)}_2$  form when 25.0 mL of 0.010 M  $\text{NaOH}$  is combined with 75.0 mL of a 0.10 M solution of magnesium chloride? ( $K_{sp}$  for  $\text{Mg(OH)}_2 = 5.6 \times 10^{-12}$ )

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



Show that this equation is the sum of two other equations, one for dissolving AuCl to give its ions ( $K_{\text{sp}} = 2.0 \times 10^{-13}$ ) and the other for the formation of the  $[\text{Au(CN)}_2]^{-1}$  ion (using  $K_{\text{form}} = 2.0 \times 10^{38}$ ) from  $\text{Au}^{+1}$  and  $\text{CN}^-$ . Calculate  $K_{\text{net}}$  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.
- $\text{Ba}^{2+}$  and  $\text{Na}^+$
  - $\text{Ni}^{2+}$  and  $\text{Pb}^{2+}$
13. A solution contains  $\text{Ca}^{2+}$  and  $\text{Pb}^{2+}$  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  $\text{Na}_2\text{SO}_4$  as the precipitating agent.
- Which will precipitate first as sodium sulfate is added,  $\text{CaSO}_4$  or  $\text{PbSO}_4$ ?
  - What will be the concentration of the first ion that precipitates ( $\text{Ca}^{2+}$  or  $\text{Pb}^{2+}$ ) when the second, more soluble salt begins to precipitate?
14. Explain why the solubility of  $\text{Ag}_3\text{PO}_4$  can be greater in water than is calculated from the  $K_{\text{sp}}$  value of the salt.
15. Decide whether each of the following substances should be classified as a Lewis acid or a Lewis base.
- $\text{H}_2\text{NOH}$  in the reaction:  $\text{H}_2\text{NOH(aq)} + \text{HCl(aq)} \rightarrow [\text{H}_3\text{NOH}][\text{Cl}](\text{aq})$
  - $\text{Fe}^{2+}(\text{aq})$
  - $\text{CH}_3\text{NH}_2$
16. A solution contains 0.10 M iodide ion,  $\text{I}^-$ , and 0.10 M carbonate ion,  $\text{CO}_3^{2-}$ .
- If solid  $\text{Pb(NO}_3)_2$  is slowly added to the solution, which salt will precipitate first,  $\text{PbI}_2$  or  $\text{PbCO}_3$ ? ( $K_{\text{sp}}$  for  $\text{PbI}_2 = 9.8 \times 10^{-9}$ ,  $K_{\text{sp}}$  for  $\text{PbCO}_3 = 7.4 \times 10^{-14}$ )
  - What will be the concentration of the first ion that precipitates ( $\text{CO}_3^{2-}$  or  $\text{I}^-$ ) when the second, more soluble salt begins to precipitate?
17. You place 2.234 g of solid  $\text{Ca(OH)}_2$  in 1.00 L of pure water at 25 °C. The pH of the solution is found to be 12.68. Estimate the  $K_{\text{sp}}$  for  $\text{Ca(OH)}_2$ .
18. What is the solubility, in milligrams per milliliter, of  $\text{BaF}_2$  (a) in pure water, and (b) in water containing 5.0 mg/mL KF? ( $K_{\text{sp}}$  for  $\text{BaF}_2 = 1.8 \times 10^{-7}$ )
19. Sodium carbonate is added to a solution in which the concentration of  $\text{Ni}^{2+}$  ion is 0.0024 M. Will precipitation of  $\text{NiCO}_3$  ( $K_{\text{sp}} = 1.4 \times 10^{-7}$ ) occur (a) when the concentration of the carbonate ion is  $1.0 \times 10^{-6}$  M or (b) when it is 100 times greater (or  $1.0 \times 10^{-4}$  M)? The equation:
- $$\text{NiCO}_3(\text{s}) \rightleftharpoons \text{Ni}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$$

### Answers to the Practice Problem Set:

1. (a) and (b): soluble, (c) and (d): insoluble
2. *Answers:*
  - a.  $\text{AgCN(s)} \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{CN}^-(\text{aq}) \quad K_{\text{sp}} = [\text{Ag}^+][\text{CN}^-]$
  - b.  $\text{NiCO}_3(\text{s}) \rightleftharpoons \text{Ni}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \quad K_{\text{sp}} = [\text{Ni}^{2+}][\text{CO}_3^{2-}]$
  - c.  $\text{AuBr}_3(\text{s}) \rightleftharpoons \text{Au}^{3+}(\text{aq}) + 3 \text{Br}^-(\text{aq}) \quad K_{\text{sp}} = [\text{Au}^{3+}][\text{Br}^-]^3$
3.  $3.6 \times 10^{-6}$
4.  $1.4 \times 10^{-15}$
5. a.  $2.4 \times 10^{-4}$  b. 0.018
6. No; 0.20 mg dissolves
7. a.  $\text{PbCl}_2$  b.  $\text{HgS}$  c.  $\text{Fe(OH)}_2$
8. a.  $2.2 \times 10^{-6}$  b.  $1.0 \times 10^{-13}$
9.  $Q < K_{\text{sp}}$  so no precipitate
10.  $Q > K_{\text{sp}}$  so precipitate forms
11.  $K_{\text{net}} = 4.0 \times 10^{25}$
12. a.  $\text{SO}_4^{2-}$  will precipitate  $\text{Ba}^{2+}$  b.  $\text{Cl}^-$  will precipitate  $\text{Pb}^{2+}$
13. a.  $\text{PbSO}_4$  b.  $5.1 \times 10^{-6} \text{ M}$
14.  $\text{PO}_4^{3-}$  acts as a base, increasing solubility upon formation of  $\text{HPO}_4^{2-}$
15. a. Lewis base b. Lewis acid c. Lewis base
16. a.  $\text{PbCO}_3$  b.  $[\text{CO}_3^{2-}] = 7.6 \times 10^{-8} \text{ mol/L}$
17.  $K_{\text{sp}} = 5.5 \times 10^{-5}$
18. a. 0.63 mg/mL b.  $4.2 \times 10^{-3} \text{ mg/mL}$
19. a. no. b. yes