Concentrations of ions in solutions and Ksp

1. Using Ksp and the equilibrium concentration of one ion, calculate the equilibrium concentration of the other ion.
   a. Cd(OH)$_2$, $K_{sp} = 2.5 \times 10^{-14}$, $[Cd^{2+}] = 1.5 \times 10^{-6}$M
   b. Li$_3$PO$_4$, $K_{sp} = 3.5 \times 10^{-9}$, $[PO_4^{3-}] = 7.5 \times 10^{-4}$M
   c. AgNO$_3$, $K_{sp} = 6.0 \times 10^{-4}$, $[Ag^+] = 0.025$

   answers: a. $[OH^-] = 1.3 \times 10^{-4}$ M, b. $[Li^+] = 0.016$ M, c. $[NO_3^-] = 0.024$ M

2. Calculate the equilibrium concentrations of Cu$^+$ and Cl$^-$ in a saturated solution of copper (I) chloride, given $K_{sp} = 1.02 \times 10^{-6}$. Ans. $[Cu^+] = [Cl^-] = 1.01 \times 10^{-3}$M

3. Calculate the equilibrium concentrations of Pb$^{2+}$ and F$^-$ in a saturated solution of lead (II) fluoride if $K_{sp} = 3.2 \times 10^{-8}$. Ans. $[Pb^{2+}] = 0.0020$ M, $[F^-] = 0.0040$ M

4. Calculate the equilibrium concentrations of Ba$^{2+}$ and PO$_4^{3-}$ in a saturated solution of Ba$_3$(PO$_4$)$_2$ if $K_{sp} = 6 \times 10^{-39}$. Ans. $[Ba^{2+}] = 2.7 \times 10^{-8}$M, $[PO_4^{3-}] = 1.8 \times 10^{-8}$M

Calculating solubilities using Ksp

5. Calculate the molar solubility of Fe(OH)$_3$ in water. $K_{sp} = 3 \times 10^{-39}$. Ans. $1 \times 10^{-10}$ mol/L

6. Calculate the molar solubility of Ag$_3$PO$_4$ in water. $K_{sp} = 1.8 \times 10^{-18}$. Ans. $1.6 \times 10^{-5}$ mol/L

7. Calculate the solubility in grams/liter of silver chloride (143.3 g/mol) in water. $K_{sp} = 1.8 \times 10^{-10}$.
   Ans. $1.9 \times 10^{-3}$ g/L

8. Calculate the solubility in grams/liter of magnesium hydroxide (58.3 g/mol) in water.
   $K_{sp} = 6 \times 10^{-12}$. Ans. $7 \times 10^{-3}$ g/L

9. How many grams of aluminum fluoride (84 g/mol) will dissolve in 250 mL of water?
   $K_{sp} = 1 \times 10^{-18}$. Ans. $3 \times 10^{-4}$ g

10. Calculate the molar solubility of Sr$_3$(PO$_4$)$_2$ in water. $K_{sp} = 1 \times 10^{-31}$. Ans. $2.5 \times 10^{-7}$ mol/L

Common Ion Effect

11. Calculate the solubility in grams/liter of silver chloride (143.3 g/mol) in the following solutions.
    $K_{sp}$ for AgCl = $1.8 \times 10^{-10}$.
    a. 0.025 M BaCl$_2$. Ans. $5.2 \times 10^{-7}$ g/L
    b. 0.17 M AgNO$_3$. Ans. $1.5 \times 10^{-5}$ g/L

12. Calculate the solubility in grams/liter of magnesium hydroxide (58.3 g/mol) in the following solutions. $K_{sp}$ for Mg(OH)$_2$ = $6 \times 10^{-12}$.
    a. 0.041 M Ba(OH)$_2$. Ans. $5 \times 10^{-8}$ g/L
    b. 0.0050 MgCl$_2$. Ans. $1 \times 10^{-3}$ g/L
13. What is the molar solubility of $Ca_3(PO_4)_2$ in a 0.20 M $Na_3PO_4$ solution? $K_{sp}$ for $Ca_3(PO_4)_2 = 1.3 \times 10^{-32}$. Ans. $2.3 \times 10^{-11}$ mol/L

**Predicting Precipitate Formation**

14. Water from a well is found to contain 3.0 mg of calcium ion per liter (Ca, 40. g/mol). If 0.5 mg of sodium sulfate (142 g/mol) is added to one liter of the well water without changing its volume, will a precipitate of $CaSO_4$ form? $K_{sp}$ for $CaSO_4 = 7.1 \times 10^{-5}$. Ans. $P = 2.6 \times 10^{-10} < K_{sp}$, no

15. Before lead in paint was discontinued, lead chromate was a common pigment in yellow paint. A 1.0-L solution is prepared by mixing 0.50 mg of lead nitrate (331.2 g/mol) with 0.020 mg of potassium chromate ($K_2CrO_4$, 194.2 g/mol). Will a precipitate of $PbCrO_4$ form? $K_{sp}$ for $PbCrO_4 = 2 \times 10^{-14}$. Ans. $P = 1.6 \times 10^{-13} > K_{sp}$, yes

16. Will a precipitate form when 75.0 mL of 0.020 M $BaCl_2$ and 125 mL of 0.040 M $Na_2SO_4$ are mixed together? $K_{sp}$ for $BaSO_4 = 1.1 \times 10^{-10}$. Ans. $P = 1.9 \times 10^{-4} > K_{sp}$, yes

17. A solution is prepared by mixing 35.00 mL of a 0.061 M solution of zinc nitrate with 20.0 mL of KOH with a pH of 9.00. Will a precipitate of zinc hydroxide form? $K_{sp} = 4 \times 10^{-17}$. Ans. $P = 5.13 \times 10^{-13}$, yes.

18. Solid $Ba(NO_3)_2$ is added to a solution of 0.025 M NaF. At what concentration of $Ba^{2+}$ does a precipitate start to form? Assume that the volume does not change when $Ba(NO_3)_2$ is added. $K_{sp}$ for $BaF_2 = 1.8 \times 10^{-7}$. Ans. $2.9 \times 10^{-4}$

19. Solid $CdCl_2$ is added to a solution of KOH with a pH of 9.62. At what concentration of $Cd^{2+}$ does a precipitate first start to form? Assume that the volume does not change when $CdCl_2$ is added. $K_{sp}$ for $Cd(OH)_2 = 2.5 \times 10^{-14}$. Ans. $1.4 \times 10^{-5}$

**Dissolving Precipitates in Acid**

20. Which substances listed below show increased solubility as the pH of a solution becomes more acidic? Write equations for the reactions that occur to increase the solubility.
   a. $Ag_3PO_4$   b. $CaCO_3$   c. $PbI_2$   d. $CdCO_3$   e. $Sr_3(PO_4)_2$   f. $AgF$   g. $AgBr$   h. $Pb(OH)_2$
   i. $Sr(NO_3)_2$   j. $Sr(NO_2)_2$   k. $Ni(CN)_2$   l. $Cu_2S$

   **Answers:**
   a. $Ag_3PO_4 + 3H^+ \rightarrow 3Ag^+ + H_3PO_4$
   b. $CaCO_3 + 2H^+ \rightarrow Ca^{2+} + H_2CO_3 \rightarrow Ca^{2+} + CO_2 + H_2O$
   c. no reaction
   d. $CdCO_3 + 2H^+ \rightarrow Cd^{2+} + H_2CO_3 \rightarrow Cd^{2+} + CO_2 + H_2O$
   e. $Sr_3(PO_4)_2 + 6H^+ \rightarrow 3Sr^{2+} + 2H_3PO_4$
   f. $AgF + H^+ \rightarrow Ag^+ + HF$
   g. no reaction
   h. $Pb(OH)_2 + 2H^+ \rightarrow Pb^{2+} + 2H_2O$
   i. no reaction
   j. $Sr(NO_2)_2 + 2H^+ \rightarrow Sr^{2+} + 2HNO_2$
   k. $Ni(CN)_2 + 2H^+ \rightarrow Ni^{2+} + 2HCN$
   l. $Cu_2S + 2H^+ \rightarrow 2Cu^++H_2S$
Calculating Ksp

21. Lead azide, Pb(N₃)₂, is used as a detonator in car airbags. The impact of a collision causes Pb(N₃)₂ to be converted into an enormous amount of gas that fills the airbag. At 25°C, a saturated solution of lead azide is prepared by dissolving 25 mg in water to make 100.0 mL of solution. What is Ksp for lead azide? The molar mass is 291.3 g. Ans. 2.5 x 10⁻⁹

22. A saturated solution of silver (I) sulfate (molar mass = 311.9 g) at 25°C can be prepared by dissolving 1.2 g of silver (I) sulfate in water to make 250.0 mL of solution. What is Ksp? Ans. 1.5 x 10⁻⁵