Hello everyone! This week’s resource will cover problem-solving strategies in Chapter 15 of the approved textbook, Chemistry: An Atoms First Approach.

Our Group Tutoring sessions will be every Thursday from 5:15-6:15PM at Sid Richardson Room 74. We will spend time solving problems and answering individual questions. I hope to see you there!

**Keywords:** Solubility Equilibria & The Solubility Product, Complex Ions, Precipitation & Qualitative Analysis

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**TOPIC OF THE WEEK**

**Solubility Equilibria & The Solubility Product**

**PRACTICE PROBLEM 1:**
Approximately 0.14 g nickel(II) hydroxide, Ni(OH)$_2$(s), dissolves per liter of water at 20°C. Calculate $K_{sp}$ for Ni(OH)$_2$(s) at this temperature.

**HOW TO SOLVE:**
**Step 1** - Find the solubility of Ni(OH)$_2$ by dividing the mass by its molar mass (92.708g/mol).
**Step 2** - Write a balanced equation of reaction for the dissolution reaction: Ni(OH)$_2$(s) $\rightarrow$ Ni$^{2+}$(aq) + 2OH$^-$ (aq)
**Step 3** - Create an ICE table with Initial reaction (I) for both ions formed as zero and Change (C) for 1 mole of each ion as the value obtained in step 1, since 1 mole of Ni(OH)$_2$ produces 1 mole of Ni$^{2+}$ and 2 x (1 mole of OH$^-$).
**Step 4** - Write the solubility product constant ($K_{sp}$) expression and substitute the equilibrium concentration obtained from step 3 to get the answer; $K_{sp} = [Ni^{2+}][OH^-]^2$

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**HIGHLIGHT #1: Complex Ions**

**PRACTICE PROBLEM 2:**
$K_f$ for the complex ion Ag(NH$_3$)$_2^+$ is $1.7 \times 10^7$. $K_{sp}$ for AgCl is $1.6 \times 10^{-10}$. Calculate the molar solubility of AgCl in 1.0 M NH$_3$.

**HOW TO SOLVE:**
**Step 1** – AgCl is first dissolved in solution and the Ag$^+$ ion combines with NH$_3$ in a stepwise manner to form the complex ion. Note: $k_f = k_1 x k_2$. The equations are:

$$\text{AgCl}(s) \rightleftharpoons \text{Ag}^+ (aq) + \text{Cl}^- (aq) \quad K_{sp} = 1.6 \times 10^{-10} $$
$$\text{Ag}^+ (aq) + \text{NH}_3(aq) \rightleftharpoons \text{Ag(NH}_3)^+ (aq) \quad K_1$$
Ag(NH$_3$)$_2^+(aq) + NH_3(aq) \rightleftharpoons Ag(NH$_3$)$_2^+(aq)$ K$_2$

Combining all the reactions gives the overall reaction:
AgCl(s) + 2NH$_3$(aq) \rightleftharpoons Ag(NH$_3$)$_2^+(aq) + Cl^-(aq)$

**Step 2** – Set up an ICE table using the overall reaction and use 1.0 M as the initial concentration of NH$_3$. The equilibrium concentration of NH$_3$ should be 1.0 - 2x, and that of each of Ag(NH$_3$)$_2^+$ and Cl$^-$ should be x.

**Step 3** – Write out the equilibrium constant expression for the overall reaction, and substitute equilibrium concentration values to obtain x (the concentration of Ag(NH$_3$)$_2^+$ ions); K = K$_{sp}$ = K$_f$ = [Ag(NH$_3$)$_2^+$][Cl$^-$] / [NH$_3$]$^2$

**Step 4** – The conc. of Ag(NH$_3$)$_2^+$ obtained in step 3 is same as that of AgCl(s).

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**HIGHLIGHT #2: Precipitation & Qualitative Analysis**

**PRACTICE PROBLEM 3:**
A solution is prepared by mixing 100.0 mL of 1.0 x 10$^{-2}$ M Pb(NO$_3$)$_2$ and 100.0 mL of 1.0 x 10$^{-3}$ M NaF. Will PbF$_2$(s) (k$_{sp}$ = 4 x 10$^{-8}$) precipitate?

**HOW TO SOLVE:**

**Step 1** - Same as Step 2 in question 1; Pb$^{2+} + 2F^- \rightarrow$ PbF$_2$(s)

**Step 2** – Find the initial concentration of each ion in step 1, taking note of dilution. Use M$_1$V$_1$ = M$_2$V$_2$.

**Step 3** – Write the reaction quotient (Q) expression (same as K$_{sp}$ but in this case only initial concentrations are used and not equilibrium concentration) and substitute values obtained from step 2 to find Q.

**Step 4** – Compare Q and the given K$_{sp}$. Q < K$_{sp}$ means no PbF$_2$ precipitate is formed.

**THINGS YOU MAY STRUGGLE WITH**

1. Not knowing the difference between solubility and solubility product constant.
2. Comparing K$_{sp}$ values for salts with different total number of ions to determine the relative solubilities of the salts.
3. Forgetting to include the concentration of common ion present as initial concentration when trying to get the solubility of a salt present in a solution with a common ion.
4. In calculating the equilibrium concentration after precipitation occurs, failure to only use the excess ion present after precipitation as the initial concentration in the ICE method.
5. Not including the effect of dilution when mixing solution to get precipitates.
6. To get the formation constant expression for a complex ion formation, students sometimes forget to put the complex as a product and leave it as a reactant.

That’s all this week! Please reach out if you have any questions and don’t forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring.

PRACTICE PROBLEM ANSWERS

1. $1.4 \times 10^{-8}$
2. $4.7 \times 10^{-2}$ mol/L
3. No, it will not precipitate