CHEM 2
Problem Set Ch.17

Key begins on page 3.

1. Write the **solubility product expression** for the following compounds.

a) $Au(OH)_3$ K_{sp} =

b) $Zn_3(PO_4)_2$ K_{sp} =

c) Hg_2I_2 K_{sp} =

2. The molar solubility of AgSCN is 1.0×10^{-6}. **Calculate its K_{sp}.**

3. The K_{sp} for bismuth sulfide, Bi_2S_3 is 1.6×10^{-72}. Calculate its solubility in **g/L**.

4. A volume of 75.0 mL of 0.060 M NaF is mixed with 25.0 mL 0f 0.15 M $Sr(NO_3)_2$. Calculate the **concentrations in the final solution** of NO_3^{-1}, Na^+, Sr^{+2} and F^-. (K_{sp} for SrF_2 is 2.0×10^{-10})

5.Solid NaI is slowly added to a solution that is 0.010 M in Cu^{+1} and 0.010 M in Ag^{+1}. (the K_{sp}'s for CuI and AgI are 5.1×10^{-12} and 8.3×10^{-17}, respectively)

a) **Which compound will begin to precipitate first?**

b) **Calculate [Ag^+] when CuI just begins to precipitate**.

c) **What percent of Ag^+ remains in solution at this point?**

6. The Ksp of $PbBr_2$ is 8.9 x 10^{-6}. Calculate its **molar solubility** in:

a) pure water.

b) in 0.20 M KBr solution.

c) in 0.20 M $Pb(NO_3)_2$ solution.

7. Which of the following substances would be more soluble in an **acid solution** than in pure water.

a) CuI   b) $PbCl_2$ c) Bi_2S_3 d) $CaCO_3$ e) $Mg_3(PO_4)_2$

8. Write the **formation constant expressions** for the following complex ions.

a) $Zn(OH)_4^{-2}$

b) $Co(NH3)_6^{+3}$

c) HgI_4^{-2}

9. Calculate the **concentrations of Cd^{+2}, $Cd(CN)_4^{-2}$ and CN^{-1}** at equilibrium when 0.50 grams of $Cd(NO_3)_2$ dissolves in 500 mL of 0.50 M NaCN. (K_f for $Cd(CN)_4^{-2}$ is 7.1 x 10^{16})

CHEM 132

1. **Write the solubility product expression for the following compounds.**

a) $Au(OH)_3$ $K_{sp} = [Au^{+3}][OH^{-}]^3$

b) $Zn_3(PO_4)_2$ $K_{sp} = [Zn^{+2}]^3[PO_4^{-3}]^2$

c) Hg_2I_2 $K_{sp} = [Hg^{+1}]^2[I^{-1}]^2$

2. **The molar solubility of AgSCN is 1.0×10^{-6}. Calculate its K_{sp}.**

$AgSCN_{(s)} \rightleftharpoons Ag^{+}_{(aq)} + SCN^{-}_{(aq)}$

1.0×10^{-6} M 1.0×10^{-6} M

$K_{sp} = [Ag^{+}][SCN^{-}]$

$= (1.0 \times 10^{-6})(1.0 \times 10^{-6})$

$K_{sp} = 1.0 \times 10^{-12}$

3. **The K_{sp} for bismuth sulfide, Bi_2S_3 is 1.6×10^{-72}. Calculate its solubility in g/L.**

$Bi_2S_{3(s)} \rightleftharpoons 2\,Bi^{+3}_{(aq)} + 3\,S^{-2}_{(aq)}$

$K_{sp} = [Bi^{+3}]^2[S^{-2}]^3$

IF x = moles/L of soluble Bi_2S_3, THEN

$1.6 \times 10^{-72} = (2x)^2(3x)^3 = 108x^5 \longrightarrow x = \sqrt[5]{\frac{1.6 \times 10^{-72}}{108}}$

$x = 1.715 \times 10^{-15}$ M Bi_2S_3

$\times 514.3\ g/mol = 8.82 \times 10^{-13}$ g/L

4. **A volume of 75.0 mL of 0.060 M NaF is mixed with 25.0 mL 0f 0.15 M $Sr(NO_3)_2$. Calculate the concentrations in the final solution of NO_3^{-1}, Na^{+}, Sr^{+2} and F^{-}. (K_{sp} for SrF_2 is 2.0×10^{-10})**

(75 mL)(0.060 M NaF) = 4.5 mmol NaF

≡ 4.5 mmol Na^{+}, 4.5 mmol F^{-}

(25 mL)(0.15 M $Sr(NO_3)_2$) = 3.75 mmol $Sr(NO_3)_2$

≡ 3.75 mmol Sr^{+2}, 7.5 mol NO_3^{-} (1:2)

SINCE Na^{+}, AND NO_3^{-} ARE SPECTATORS, THEIR CONC. WON'T CHANGE .... SO

$[Na^{+}]_{FINAL} = \frac{4.5\ mmol}{100\ mL} = 0.045$ M Na^{+}

$[NO_3^{-}]_{FINAL} = \frac{7.5\ mmol}{100\ mL} = 0.075$ M NO_3^{-}

FIRST, ASSUME COMPLETE PPTION OF SrF_2

$Sr^{+2} + 2F^{-} \rightarrow SrF_{2(s)}$

	Sr^{+2}	F^{-}
INITIAL	3.75 mmol	4.5 mmol (LIMITING)
CHANGE	−2.25	
FINAL	1.5 mmol	0

ALL THE F^{-} PPTS TAKING ONLY 1/2 AS MUCH Sr^{+2} WITH IT LEAVING

$\frac{1.5\ mmol}{100\ mL} = 0.015$ M Sr^{+2} STILL IN SOLN

NOW, CALCULATE HOW MUCH SrF_2 WOULD REDISSOLVE IN THE PRESENCE OF 0.015 M Sr^{+2}

$SrF_2 \rightleftharpoons Sr^{+2} + 2F^{-}$

$(x + .015)\ (2x)$

$2.0 \times 10^{-10} = (x + .015)(2x)^2$ (IGNORE x)

$x = 5.77 \times 10^{-5}$ M

BUT $[F^{-}] = 2x = 1.15 \times 10^{-4}$ M

THE $[Sr^{+2}] \approx 0.015$ M

5. **Solid NaI is slowly added to a solution that is 0.010 M in Cu^{+1} and 0.010 M in Ag^{+1}. (the K_{sp}'s for CuI and AgI are 5.1×10^{-12} and 8.3×10^{-17}, respectively)**

a) **Which compound will begin to precipitate first?** AgI SINCE ITS K_{sp} IS SMALLER.

b) **Calculate $[Ag^{+}]$ when CuI just begins to precipitate.** FIRST CALCULATE $[I^{-}]$ AT THE POINT WHERE CuI PPT.

$5.1 \times 10^{-12} = [Cu^{+}][I^{-}]$

$= (0.010)(x)$

SO $x = 5.1 \times 10^{-10} = [I^{-}]$

NOW, HOW MUCH Ag^{+} IS ALLOWED IN SOLUTION WHEN $[I^{-}] = 5.1 \times 10^{-10}$

$8.3 \times 10^{-17} = [Ag^{+}][I^{-}]$

$= (x)(5.1 \times 10^{-10})$ $x = 1.63 \times 10^{-7} = [Ag^{+}]$

c) **What percent of Ag^{+} remains in solution at this point?**

% Ag REMAINING $= \frac{1.63 \times 10^{-7}\ M}{0.010\ M\ \text{INITIALLY}} \times 100 = 1.63 \times 10^{-3}$ %

6. **The Ksp of $PbBr_2$ is 8.9×10^{-6}. Calculate its molar solubility in:** $PbBr_2 \rightleftharpoons Pb^{+2} + 2Br^-$ (x, 2x)

a) **pure water.** $8.9 \times 10^{-6} = (x)(2x)^2 = 4x^3$

$$x = \sqrt[3]{\frac{8.9 \times 10^{-6}}{4}} = \boxed{1.31 \times 10^{-2} M}$$

SINCE $x = [Pb^{+2}]$ = sol. of $PbBr_2$.

b) **in 0.20 M KBr solution.**

$PbBr_2 \rightleftharpoons Pb^{+2} + 2Br^-$
(x) (2x + 0.2)

$8.9 \times 10^{-6} = (x)(2x + 0.20)^2 \approx (x)(0.20)^2$ (IGNORE 2x)

so $x = \frac{8.9 \times 10^{-6}}{(0.20)^2} = \boxed{2.25 \times 10^{-4} M}$

c) **in 0.20 M $Pb(NO_3)_2$ solution.**

$PbBr_2 \rightleftharpoons Pb^{+2} + 2Br^-$
(x + 0.20) (2x)

$8.9 \times 10^{-6} = (x + 0.20)(2x)^2 \approx 0.80x^2$ (IGNORE x)

$x = \sqrt{\frac{8.9 \times 10^{-6}}{0.80}} = \boxed{3.16 \times 10^{-3} M}$

7. **Which of the following substances would be more soluble in an acid solution than in pure water.**

a) CuI	b) $PbCl_2$	c) Bi_2S_3	d) $CaCO_3$	e) $Mg_3(PO_4)_2$
NO	NO	yes	yes	yes
CONJ. OF STRONG ACID	CONJ. OF STRONG ACID	CONJ. OF WEAK ACID	CONJ. OF WEAK ACID	CONJ. OF WEAK ACID.

8. **Write the formation constant expressions for the following complex ions.**

a) $Zn(OH)_4^{-2}$ $K_f = \frac{[Zn(OH)_4^{-2}]}{[Zn^{+2}][OH^-]^4}$

b) $Co(NH3)_6^{+3}$ $K_f = \frac{[Co(NH_3)_6^{+3}]}{[Co^{+3}][NH_3]^6}$

c) HgI_4^{-2} $K_f = \frac{[HgI_4^{-2}]}{[Hg^{+2}][I^-]^4}$

9. **Calculate the concentrations of Cd^{+2}, $Cd(CN)_4^{-2}$ and CN^{-1} at equilibrium when 0.50 grams of $Cd(NO_3)_2$ dissolves in 500 mL of 0.50 M NaCN. (K_f for $Cd(CN)_4^{-2}$ is 7.1×10^{16})**

$0.50\,g\ Cd(NO_3)_2 \left(\frac{1\ mol}{236.4\,g}\right) = 2.115 \times 10^{-3}\ mol\ Cd(NO_3)_2 \equiv 2.115 \times 10^{-3}\ mol\ Cd^{+2}$

$(.500\,L)(0.5\,M\ NaCN) = 0.25\ mol\ NaCN \equiv 0.25\ mol\ CN^-$

FIRST ASSUME COMPLETE COMPLEX FORMATION

$Cd^{+2} + 4CN^- \rightarrow Cd(CN)_4^{+2}$

INIT. 2.115×10^{-3} (LIMIT) | 0.25 |
 | $-4(2.115 \times 10^{-3})$ | $+2.115 \times 10^{-3}$ mol CREATED
FINAL 0 | 0.24154 mol REMAINING | ÷ 0.500 L → .00423 M
 | ÷ 0.500 L → 0.483 M |

NOW LOOK AT IT AS A DISSOCIATION.

$K_d = \frac{1}{7.1 \times 10^{16}} = 1.41 \times 10^{-17} = \frac{[Cd^{+2}][CN^-]^4}{[Cd(CN)_4^{+2}]} = \frac{(x)(4x + 0.483)^4}{(.00423 - x)}$ (IGNORE)

$[CN^-] \approx 0.483 M$

$[Cd(CN)_4^{+2}] \approx .00423 M$

$x = 1.10 \times 10^{-18} M = [Cd^{+2}]$