Ksp Problems (SCH 4U) - ANSWERS

1. Calculate the Ksp for each of the salts whose solubility is listed below.

(a) $CaSO_4$ solubility = 5.0 x 10^{-3} mol/L

$$CaSO_4 \rightleftharpoons Ca^{2+} + SO_4^{2-}$$

$$[Ca^{2+}] = 5 \text{ x } 10^{-3} \text{ M}$$

$$[SO_4^{2-}] = 5 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Ca^{2+}][SO_4^{2-}]$$
$$K_{sp} = (5 \text{ x } 10^{-3})^2$$
$$K_{sp} = 2.5 \text{ x } 10^{-5}$$

(b) MgF_2 solubility = 2.7 x 10^{-3} mol/L

$$MgF_2 \rightleftharpoons Mg^{2+} + 2\,F^{1-}$$

$$[Mg^{2+}] = 2.7 \text{ x } 10^{-3} \text{ M}$$

$$[F^{1-}] = 2 \text{ x } (2.7 \text{ x } 10^{-3} \text{ M})$$
$$[F^{1-}] = 5.4 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Mg^{2+}][F^{1-}]^2$$
$$K_{sp} = (2.7 \text{ x } 10^{-3})(5.4 \text{ x } 10^{-3})^2$$
$$K_{sp} = 7.87 \text{ x } 10^{-8}$$

(c) $AgC_2H_3O_2$ solubility = 10.2 p.p.m.

$$AgC_2H_3O_2 \rightleftharpoons Ag^{1+} + C_2H_3O_2{}^{1-}$$

$$\frac{10.2 \text{ mg } AgC_2H_3O_2}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } AgC_2H_3O_2}{166.92 \text{ g } AgC_2H_3O_2} = 6.11 \text{ x } 10^{-5} \text{ mol/L}$$

$$[Ag^{1+}] = 6.11 \text{ x } 10^{-5} \text{ M}$$

$$[C_2H_3O_2{}^{1-}] = 6.11 \text{ x } 10^{-5} \text{ M}$$

$$K_{sp} = [Ag^{1+}][C_2H_3O_2{}^{1-}]$$
$$K_{sp} = (6.11 \text{ x } 10^{-5})^2$$
$$K_{sp} = 3.73 \text{ x } 10^{-9}$$

(d) SrF_2 solubility = 122 p.p.m.

$$SrF_2 \rightleftharpoons Sr^{2+} + 2\,F^{1-}$$

$$\frac{122 \text{ mg } SrF_2}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } SrF_2}{125.62 \text{ g } SrF_2} = 9.71 \text{ x } 10^{-4} \text{ mol/L}$$

$$[Sr^{2+}] = 9.71 \text{ x } 10^{-4} \text{ M}$$

$$[F^{1-}] = 2 \text{ x } (9.71 \text{ x } 10^{-4}) \text{ M}$$
$$[F^{1-}] = 1.94 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Sr^{2+}][F^{1-}]^2$$
$$K_{sp} = (9.71 \text{ x } 10^{-4})(1.94 \text{ x } 10^{-3})^2$$
$$K_{sp} = 3.66 \text{ x } 10^{-9}$$

2. Calculate the solubility in mol/L of each of these salts, determine the concentration of all ions and find the the concentration of each cation in p.p.m. in each of the saturated solutions

(a) AgCN Ksp = 2 X 10^{-12}

$$AgCN \rightleftharpoons Ag^{1+} + CN^{1-}$$

Let s represent the solubility of AgCN

$$[Ag^{1+}] = s$$
$$[CN^{1-}] = s$$

$$K_{sp} = [Ag^{1+}][CN^{1-}]$$
$$2 \text{ x } 10^{-12} = s^2$$
$$s = 1.41 \text{ x } 10^{-6} \text{ mol/L}$$

$$[Ag^{1+}] = 1.41 \text{ x } 10^{-6} \text{ M}$$

$$[CN^{1-}] = 1.41 \text{ x } 10^{-6} \text{ M}$$

$$\frac{1.41 \text{ x } 10^{-6} \text{ mol } Ag^{1+}}{1 \text{ L}} \text{ x } \frac{107.87 \text{ g } Ag^{1+}}{1 \text{ mol } Ag^{1+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{0.151 \text{ mg } Ag^{1+}}{1 \text{ L}}$$

$\therefore$ 0.152 p.p.m. Ag^{1+}

(b) $BaSO_4$ Ksp = 1.5 X 10^{-9}

$$BaSO_4 \rightleftharpoons Ba^{2+} + SO_4^{2-}$$

Let s represent the solubility of $BaSO_4$

$$[Ba^{2+}] = s$$
$$[SO_4^{2-}] = s$$

$$K_{sp} = [Ba^{2+}][SO_4^{2-}]$$
$$1.9 \text{ x } 10^{-9} = s^2$$
$$s = 3.87 \text{ x } 10^{-5} \text{ mol/L}$$

$$[Ba^{2+}] = 3.87 \text{ x } 10^{-5} \text{ M}$$

$$[SO_4^{2-}] = 3.87 \text{ x } 10^{-5} \text{ M}$$

$$\frac{3.87 \text{ x } 10^{-5} \text{ mol } Ba^{2+}}{1 \text{ L}} \text{ x } \frac{137.33 \text{ g } Ba^{2+}}{1 \text{ mol } Ba^{2+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{5.31 \text{ mg } Ba^{2+}}{1 \text{ L}}$$

$\therefore$ 5.31 p.p.m. Ba^{2+}

(c) FeS   Ksp = 3.7 X 10^{-19}

$$FeS \rightleftharpoons Fe^{2+} + S^{2-}$$

Let s represent the solubility of FeS

$$[Fe^{2+}] = s$$
$$[S^{2-}] = s$$

$$K_{sp} = [Fe^{2+}][S^{2-}]$$
$$3.7 \text{ x } 10^{-19} = s^2$$
$$s = 6.08 \text{ x } 10^{-10} \text{ mol/L}$$

$$[Fe^{2+}] = 6.08 \text{ x } 10^{-10} \text{ M}$$

$$[S^{2-}] = 6.08 \text{ x } 10^{-10} \text{ M}$$

$$\frac{6.08 \text{ x } 10^{-10} \text{ mol } Fe^{2+}}{1 \text{ L}} \text{ x } \frac{55.85 \text{ g } Fe^{2+}}{1 \text{ mol } Fe^{2+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{0.0000340 \text{ mg } Fe^{2+}}{1 \text{ L}}$$

$\therefore$ 0.0000340 p.p.m. Fe^{2+}

(d) $Mg(OH)_2$ Ksp = 9 X 10^{-12}

$$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2\,OH^{1-}$$

Let s represent the solubility of $Mg(OH)_2$

$$[Mg^{2+}] = s$$
$$[OH^{1-}] = 2s$$

$$K_{sp} = [Mg^{2+}][OH^{1-}]^2$$
$$9 \text{ x } 10^{-12} = (s)(2s)^2$$
$$9 \text{ x } 10^{-12} = (s)(4s^2)$$
$$9 \text{ x } 10^{-12} = 4s^3$$
$$s = 1.31 \text{ x } 10^{-4} \text{ mol/L}$$

$$[Mg^{2+}] = 1.31 \text{ x } 10^{-4} \text{ M}$$

$$[OH^{1-}] = 2 \text{ x } (1.31 \text{ x } 10^{-4} \text{ M})$$
$$[OH^{1-}] = (2.62 \text{ x } 10^{-4} \text{ M})$$

$$\frac{1.31 \text{ x } 10^{-4} \text{ mol } Mg^{2+}}{1 \text{ L}} \text{ x } \frac{24.31 \text{ g } Mg^{2+}}{1 \text{ mol } Mg^{2+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{3.18 \text{ mg } Mg^{2+}}{1 \text{ L}}$$

$\therefore$ 3.18 p.p.m. Mg^{2+}

(e) Ag_2S Ksp = 1.6 X 10^{-49}

$$Ag_2S \rightleftharpoons 2\,Ag^{1+} + S^{2-}$$

Let s represent the solubility of Ag_2S

$$[Ag^{1+}] = 2s$$
$$[S^{2-}] = s$$

$$K_{sp} = [Ag^{1+}]^2[S^{2-}]$$
$$1.6 \text{ x } 10^{-49} = (2s)^2(s)$$
$$1.6 \text{ x } 10^{-49} = (4s^2)(s)$$
$$1.6 \text{ x } 10^{-49} = 4s^3$$
$$s = 3.42 \text{ x } 10^{-17} \text{ mol/L}$$

$$[Ag^{1+}] = 2 \text{ x } (3.42 \text{ x } 10^{-17} \text{ M})$$
$$[Ag^{1+}] = 6.84 \text{ x } 10^{-17} \text{ M}$$

$$[S^{2-}] = 3.42 \text{ x } 10^{-17} \text{ M}$$

$$\frac{6.84 \text{ x } 10^{-17} \text{ mol } Ag^{1+}}{1 \text{ L}} \text{ x } \frac{107.87 \text{ g } Ag^{1+}}{1 \text{ mol } Ag^{1+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{7.38 \text{ x } 10^{-12} \text{ mg } Ag^{1+}}{1 \text{ L}}$$

$\therefore$ 7.38 x 10^{-12} p.p.m. Ag^{1+}

(f) CaF_2 Ksp = 4.9 X 10^{-11}

$$CaF_2 \rightleftharpoons Ca^{2+} + 2\,F^{1-}$$

Let s represent the solubility of CaF_2

$$[Ca^{2+}] = s$$
$$[F^{1-}] = 2s$$

$$K_{sp} = [Ca^{2+}][F^{1-}]^2$$
$$4.9 \text{ x } 10^{-11} = (s)(2s)^2$$
$$4.9 \text{ x } 10^{-11} = (s)(4s^2)$$
$$4.9 \text{ x } 10^{-11} = 4s^3$$
$$s = 2.31 \text{ x } 10^{-4} \text{ mol/L}$$

$$[Ca^{2+}] = 2.31 \text{ x } 10^{-4} \text{ M}$$

$$[F^{1-}] = 2 \text{ x } (2.31 \text{ x } 10^{-4} \text{ M})$$
$$[F^{1-}] = (4.61 \text{ x } 10^{-4} \text{ M})$$

$$\frac{2.31 \text{ x } 10^{-4} \text{ mol } Ca^{2+}}{1 \text{ L}} \text{ x } \frac{40.08 \text{ g } Ca^{2+}}{1 \text{ mol } Ca^{2+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{9.26 \text{ mg } Ca^{2+}}{1 \text{ L}}$$

$\therefore$ 9.26 p.p.m. Ca^{2+}

3. For each of these substances, calculate the concentration of metallic ion in p.p.m. that can remain at equilibrium in a solution having a $[OH^{-1}] = 1.0 \times 10^{-4}$ mol/L

(a) $Cu(OH)_2$ Ksp = 1.6×10^{-19}

$$Cu(OH)_2 \rightleftharpoons Cu^{2+} + 2\,OH^{1-}$$

$$[Cu^{2+}] = ?$$

$$[OH^{1-}] = 1.0 \text{ x } 10^{-4} \text{ M}$$

$$K_{sp} = [Cu^{2+}][OH^{1-}]^2$$

$$[Cu^{2+}] = \frac{K_{sp}}{[OH^{1-}]^2}$$

$$[Cu^{2+}] = \frac{1.6 \text{ x } 10^{-19}}{(1 \text{ x } 10^{-4})^2}$$

$$[Cu^{2+}] = 1.6 \text{ x } 10^{-11} \text{ M}$$

$$\frac{1.6 \text{ x } 10^{-11} \text{ mol } Cu^{2+}}{1 \text{ L}} \text{ x } \frac{63.55 \text{ g } Cu^{2+}}{1 \text{ mol } cu^{2+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{1.02 \text{ x } 10^{-6} \text{ mg } Cu^{2+}}{1 \text{ L}}$$

$$\therefore 1.02 \text{ x } 10^{-6} \text{ p.p.m. } Cu^{2+}$$

(b) $Fe(OH)_3$ Ksp = 6.0×10^{-38}

$$Fe(OH)_3 \rightleftharpoons Fe^{3+} + 3\,OH^{1-}$$

$$[Fe^{3+}] = ?$$

$$[OH^{1-}] = 1.0 \text{ x } 10^{-4} \text{ M}$$

$$K_{sp} = [Fe^{3+}][OH^{1-}]^3$$

$$[Fe^{3+}] = \frac{K_{sp}}{[OH^{1-}]^3}$$

$$[Fe^{3+}] = \frac{6.0 \text{ x } 10^{-38}}{(1 \text{ x } 10^{-4})^3}$$

$$[Fe^{3+}] = 6.0 \text{ x } 10^{-26} \text{ M}$$

$$\frac{6.0 \text{ x } 10^{-26} \text{ mol } Fe^{3+}}{1 \text{ L}} \text{ x } \frac{55.85 \text{ g } Fe^{3+}}{1 \text{ mol } Fe^{3+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{3.35 \text{ x } 10^{-21} \text{ mg } Fe^{3+}}{1 \text{ L}}$$

$$\therefore 3.35 \text{ x } 10^{-21} \text{ p.p.m. } Fe^{3+}$$

(c) $Mg(OH)_2$ Ksp = 9.0×10^{-12}

$$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2\,OH^{1-}$$

$$[Mg^{2+}] = ?$$
$$[OH^{1-}] = 1.0 \text{ x } 10^{-4} \text{ M}$$

$$K_{sp} = [Mg^{2+}][OH^{1-}]^2$$
$$[Mg^{2+}] = \frac{K_{sp}}{[OH^{1-}]^2}$$
$$[Mg^{2+}] = \frac{9.0 \text{ x } 10^{-12}}{(1 \text{ x } 10^{-4})^2}$$
$$[Mg^{2+}] = 9.0 \text{ x } 10^{-4} \text{ M}$$

$$\frac{9.0 \text{ x } 10^{-4} \text{ mol } Mg^{2+}}{1 \text{ L}} \text{ x } \frac{24.31 \text{ g } Mg^{2+}}{1 \text{ mol cu}^{2+}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{21.9 \text{ mg } Mg^{2+}}{1 \text{ L}}$$

$\therefore$ 21.9 p.p.m. Mg^{2+}

4. Calculate the $[Ag^+]$ in mol/L (M) needed to begin precipitation of each of these anions from solutions containing a concentration of 500 p.p.m. for each anion.

Please note that for each of the following, precipitation will begin once equilibrium concentrations are achieved, therefore calculations are done as equilibrium conditions

(a) Br^{1-}

$$AgBr \rightleftharpoons Ag^{1+} + Br^{1-}$$

$$[Ag^{1+}] = ?$$
$$[Br^{1-}] = \frac{500 \text{ mg } Br^{1-}}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } Br^{1-}}{79.90 \text{ g } Br^{1-}} = 6.25 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Ag^{1+}][Br^{1-}]$$
$$[Ag^{1+}] = \frac{K_{sp}}{[Br^{1-}]}$$
$$[Ag^{1+}] = \frac{7.7 \text{ x } 10^{-13}}{6.25 \text{ x } 10^{-3}}$$
$$[Ag^{1+}] = 1.23 \text{ x } 10^{-10} \text{ M}$$

(b) S^{2-}

$$Ag_2S \rightleftharpoons 2\,Ag^{1+} + S^{2-}$$

$$[Ag^{1+}] = ?$$

$$[S^{2-}] = \frac{500 \text{ mg } S^{2-}}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } S^{2-}}{32.07 \text{ g } S^{2-}} = 1.56 \text{ x } 10^{-2} \text{ M}$$

$$K_{sp} = [Ag^{1+}]^2[S^{2-}]$$

$$[Ag^{1+}] = \sqrt{\frac{K_{sp}}{[S^{2-}]}}$$

$$[Ag^{1+}] = \sqrt{\frac{1.6 \text{ x } 10^{-49}}{1.56 \text{ x } 10^{-2}}}$$

$$[Ag^{1+}] = 3.20 \text{ x } 10^{-24} \text{ M}$$

(c) $BrO_3{}^{1-}$

$$AgBr \rightleftharpoons Ag^{1+} + BrO_3{}^{1-}$$

$$[Ag^{1+}] = ?$$

$$[BrO_3{}^{1-}] = \frac{500 \text{ mg } BrO_3{}^{1-}}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } BrO_3{}^{1-}}{127.91 \text{ g } BrO_3{}^{1-}} = 3.91 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Ag^{1+}][BrO_3{}^{1-}]$$

$$[Ag^{1+}] = \frac{K_{sp}}{[BrO_3{}^{1-}]}$$

$$[Ag^{1+}] = \frac{6.0 \text{ x } 10^{-5}}{3.91 \text{ x } 10^{-3}}$$

$$[Ag^{1+}] = 1.53 \text{ x } 10^{-2} \text{ M}$$

(d) CrO_4^{2-}

$$Ag_2CrO_4 \rightleftharpoons 2\,Ag^{1+} + CrO_4^{2-}$$

$$[Ag^{1+}] = ?$$

$$[CrO_4^{2-}] = \frac{500 \text{ mg } CrO_4^{2-}}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } CrO_4^{2-}}{116.00 \text{ g } CrO_4^{2-}} = 4.31 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Ag^{1+}]^2[CrO_4^{2-}]$$

$$[Ag^{1+}] = \sqrt{\frac{K_{sp}}{[CrO_4^{2-}]}}$$

$$[Ag^{1+}] = \sqrt{\frac{1.1 \text{ x } 10^{-12}}{4.31 \text{ x } 10^{-3}}}$$

$$[Ag^{1+}] = 1.60 \text{ x } 10^{-5} \text{ M}$$

(e) IO_3^{1-}

$$AgIO_3 \rightleftharpoons Ag^{1+} + IO_3^{1-}$$

$$[Ag^{1+}] = ?$$

$$[IO_3^{1-}] = \frac{500 \text{ mg } IO_3^{1-}}{1 \text{ L}} \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol } IO_3^{1-}}{174.90 \text{ g } IO_3^{1-}} = 2.86 \text{ x } 10^{-3} \text{ M}$$

$$K_{sp} = [Ag^{1+}][IO_3^{1-}]$$

$$[Ag^{1+}] = \frac{K_{sp}}{[IO_3^{1-}]}$$

$$[Ag^{1+}] = \frac{3.1 \text{ x } 10^{-8}}{2.86 \text{ x } 10^{-3}}$$

$$[Ag^{1+}] = 1.08 \text{ x } 10^{-5} \text{ M}$$

5. How many mg of TlI can dissolve in 500 mL of:

(a) water

$$TlI \rightleftharpoons Tl^{1+} + I^{1-}$$

Let s represent the solubility of TlI

$$[Tl^{1+}] = s$$
$$[I^{1-}] = s$$

$$K_{sp} = [Tl^{1+}][I^{1-}]$$
$$8.9 \text{ x } 10^{-8} = s^2$$
$$s = 2.98 \text{ x } 10^{-4} \text{ mol/L}$$

$$500 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{2.98 \text{ x } 10^{-4} \text{ mol TlI}}{1 \text{ L}} \text{ x } \frac{331.27 \text{ g TlI}}{1 \text{ mol TlI}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = 49.4 \text{ mg TlI}$$

(b) 0.1 mol/L $TlNO_3$

$$\underset{0.1\text{ M}}{TlNO_3} \longrightarrow \underset{0.1\text{ M}}{Tl^{1+}} + NO_3{}^{1-}$$

$$TlI \rightleftharpoons Tl^{1+} + I^{1-}$$

Let s represent the solubility of TlI

$$[Tl^{1+}] = s + 0.1$$
$$[I^{1-}] = s$$

$$K_{sp} = [Tl^{1+}][I^{1-}] \; *$$
$$8.9 \text{ x } 10^{-8} = (s + 0.1)(s)$$
$$\text{assume } s <<< 0.1$$
$$\therefore (s + 0.1) \simeq 0.1$$
$$8.9 \text{ x } 10^{-8} \simeq (0.1)(s)$$
$$s \simeq 8.9 \text{ x } 10^{-7} \text{ mol/L}$$
$$\because 8.9 \text{ x } 10^{-7} <<< 0.1 \quad \therefore \text{ the assumption is valid}$$

$$500 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{8.9 \text{ x } 10^{-7} \text{ mol TlI}}{1 \text{ L}} \text{ x } \frac{331.27 \text{ g TlI}}{1 \text{ mol TlI}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = 0.147 \text{ mg TlI}$$

for exact solution see next page *

The exact solution requires using the quadratic formula starting from the Ksp expression. Please note the * above.

$$K_{sp} = [Tl^{1+}][I^{1-}] \; *$$
$$8.9 \text{ x } 10^{-8} = (s)(s + 0.1)$$
$$8.9 \text{ x } 10^{-8} = s^2 + 0.1s$$
$$0 = s^2 + 0.1s - 8.9 \text{ x } 10^{-8}$$
$$s = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$s = \frac{-0.1 \pm \sqrt{(0.1)b^2 - 4(1)(-8.9 \text{ x } 10^{-8})}}{2(1)}$$

$$s = \frac{-0.1 \pm 0.10000178}{2}$$ Be careful. These digits matter!!

$$s = \underset{\text{extraneous}}{-0.1 \text{ mol/L}} \text{ or } s = 8.89992 \text{ x } 10^{-7} \text{ mol/L}$$

This result is only slightly different that the result obtained using the assumption. The error generated through the assumption is only 0.0009 %. Assumptions are used to make the math easier. Checking the assumption validates its use. As a general rule, a 10 % error is acceptable!

(c) mol/L KI

$$\underset{0.02 \text{ M}}{KI} \longrightarrow K^{1+} + \underset{0.02 \text{ M}}{I^{1-}}$$

$$TlI \rightleftharpoons Tl^{1+} + I^{1-}$$

Let s represent the solubility of TlI

$$[Tl^{1+}] = s$$
$$[I^{1-}] = s + 0.02$$

$$K_{sp} = [Tl^{1+}][I^{1-}]$$
$$8.9 \text{ x } 10^{-8} = (s)(s + 0.02)$$
$$\text{assume } s <<< 0.02$$
$$\therefore (s + 0.02) \simeq 0.02$$
$$8.9 \text{ x } 10^{-8} \simeq (s)(0.02)$$
$$s \simeq 4.45 \text{ x } 10^{-6} \text{ mol/L}$$
$$\because 4.45 \text{ x } 10^{-6} <<< 0.02 \quad \therefore \text{ the assumption is valid}$$

$$500 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{4.45 \text{ x } 10^{-6} \text{ mol TlI}}{1 \text{ L}} \text{ x } \frac{331.27 \text{ g TlI}}{1 \text{ mol TlI}} \text{ x } \frac{1000 \text{ mg}}{1 \text{ g}} = 0.737 \text{ mg TlI}$$

6. These questions require a comparison of the "solubility product constant" to the "solubility product". If:

$K_{sp} > [A^+][B^-]$ unsaturated, more can dissolve
$K_{sp} = [A^+][B^-]$ saturated, at equilibrium
$K_{sp} < [A^+][B^-]$ supersaturated, ppte is imminent

(a)

$$AgNO_3 \longrightarrow Ag^{1+} + NO_3^{\ 1-}$$
$$Na_2SO_4 \longrightarrow 2\,Na^{1+} + SO_4^{\ 2-}$$

$$Ag_2SO_4 \rightleftharpoons 2\,Ag^{1+} + SO_4^{\ 2-} \qquad K_{sp} = 1.2 \text{ x } 10^{-5}$$

For $[Ag^{1+}]$:

$$10.0 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{0.01 \text{ mol}}{1 \text{ L}} = 1 \text{ x } 10^{-4} \text{ mol } Ag^{1+}$$

$$[Ag^{1+}] = \frac{n}{V}$$

$$[Ag^{1+}] = \frac{1 \text{ x } 10^{-4} \text{ mol } Ag^{1+}}{0.020 \text{ L}}$$

$$[Ag^{1+}] = 0.005 \text{ M}$$

For $[SO4^2-]$:

$$10.0 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{0.10 \text{ mol}}{1 \text{ L}} = 1 \text{ x } 10^{-3} \text{ mol } SO_4^{\ 2-}$$

$$[SO_4^{\ 2-}] = \frac{n}{V}$$

$$[SO_4^{\ 2-}] = \frac{1 \text{ x } 10^{-3} \text{ mol } SO_4^{\ 2-}}{0.020 \text{ L}}$$

$$[SO_4^{\ 2-}] = 0.05 \text{ M}$$

$$K_{sp} = [Ag^{1+}][SO_4^{\ 2-}]$$
$$[Ag^{1+}][SO_4^{\ 2-}] = (0.005)(0.05)$$
$$[Ag^{1+}][SO_4^{\ 2-}] = 2.5 \text{ x } 10^{-4}$$
$$K_{sp} = 1.2 \text{ x } 10^{-5}$$
$$K_{sp} < [Ag^{1+}][SO_4^{\ 2-}]$$

$\therefore$ therefore precipitate forms

(b) $MgCl_2 \longrightarrow Mg^{2+} + 2\,Cl^{1-}$

$Na_2C_2O_4 \longrightarrow 2\,Na^{1+} + C_2O_4{}^{2-}$

$MgC_2O_4 \rightleftharpoons Mg^{2+} + C_2O_4{}^{2-}$ $\quad K_{sp} = 8.6 \text{ x } 10^{-5}$

For $[Mg^{2+}]$:

$$1 \text{ mg MgCl}_2 \text{ x } \frac{1 \text{ g}}{1000 \text{ mg}} \text{ x } \frac{1 \text{ mol MgCl}_2}{95.21 \text{ g MgCl}_2} \text{ x } \frac{1 \text{ mol Mg}^{2+}}{1 \text{ mol MgCl}_2} = 1.050 \text{ x } 10^{-5} \text{ mol Mg}^{2+}$$

$$[Mg^{2+}] = \frac{n}{V}$$

$$[Mg^{2+}] = \frac{1.050 \text{ x } 10^{-5} \text{ mol Mg}^{2+}}{1 \text{ L}^*}$$

$$[Mg^{2+}] = 1.050 \text{ x } 10^{-5} \text{ M}$$

* assume the 1 mg addition of $MgCl_2$ has a neglible effect on volume

For $[C_2O_4{}^{2-}]$:

$$1 \text{ L x } \frac{0.01 \text{ mol Na}_2\text{C}_2\text{O}_4}{1 \text{ L}} \text{ x } \frac{1 \text{ mol C}_2\text{O}_4}{1 \text{ mol Na}_2\text{C}_2\text{O}_4} = 0.01 \text{ mol C}_2\text{O}_4{}^{2-}$$

$$[C_2O_4{}^{2-}] = \frac{n}{V}$$

$$[C_2O_4{}^{2-}] = \frac{0.01 \text{ mol C}_2\text{O}_4{}^{2-}}{1 \text{ L}}$$

$$[C_2O_4{}^{2-}] = 0.01 \text{ M}$$

$K_{sp} = [Mg^{2+}][C_2O_4{}^{2-}]$

$[Mg^{2+}][C_2O_4{}^{2-}] = (1.050 \text{ x } 10^{-5})(0.01)$

$[Mg^{2+}][C_2O_4{}^{2-}] = 1.050 \text{ x } 10^{-7}$

$K_{sp} = 8.6 \text{ x } 10^{-5}$

$K_{sp} > [Mg^{2+}][C_2O_4{}^{2-}]$

$\therefore$ therefore no precipitate forms

(c) $Ca(NO_3)_2 \longrightarrow Ca^{2+} + 2\,NO_3{}^{1-}$

$HF \longrightarrow H^{1+} + F^{1-}$

$Ag_2SO_4 \rightleftharpoons 2\,Ag^{1+} + SO_4{}^{2-}$ $\qquad K_{sp} = 1.2 \text{ x } 10^{-5}$

For $[Ag^{1+}]$:

$$10.0 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{0.01 \text{ mol}}{1 \text{ L}} = 1 \text{ x } 10^{-4} \text{ mol } Ag^{1+}$$

$$[Ag^{1+}] = \frac{n}{V}$$

$$[Ag^{1+}] = \frac{1 \text{ x } 10^{-4} \text{ mol } Ag^{1+}}{0.020 \text{ L}}$$

$$[Ag^{1+}] = 0.005 \text{ M}$$

For $[SO_4{}^{2-}]$:

$$10.0 \text{ mL x } \frac{1 \text{ L}}{1000 \text{ mL}} \text{ x } \frac{0.01 \text{ mol}}{1 \text{ L}} = 1 \text{ x } 10^{-4} \text{ mol } SO_4{}^{2-}$$

$$[SO_4{}^{2-}] = \frac{n}{V}$$

$$[SO_4{}^{2-}] = \frac{1 \text{ x } 10^{-4} \text{ mol } SO_4{}^{2-}}{0.020 \text{ L}}$$

$$[SO_4{}^{2-}] = 0.005 \text{ M}$$

$K_{sp} = [Ag^{1+}][SO_4{}^{2-}]$

$[Ag^{1+}][SO_4{}^{2-}] = (0.005)^2$

$[Ag^{1+}][SO_4{}^{2-}] = 2.5 \text{ x } 10^{-5}$

$K_{sp} = 1.2 \text{ x } 10^{-5}$

$K_{sp} < [Ag^{1+}][SO_4{}^{2-}]$

$\therefore$ no precipitate forms

(d) dddddddd

(e) xxxxxxxx