

UNIT 9 - CHAPTER 15 REVIEW PROBLEMS - KEY

1. $\text{pH} = \text{pK}_a + \log \frac{[\text{In}^-]}{[\text{HIn}]} \rightarrow 7\% \text{ CONVERTED TO } \text{In}^-, \text{ SO } \frac{[7]}{[93]} \rightarrow \text{pH} = 3.00 + \log \frac{(7)}{(93)} = \boxed{1.88}$

2. $[\text{CH}_3\text{COO}^-]$ AT EQUIVALENCE POINT: $[\text{CH}_3\text{COO}^-] = \frac{\text{MOLES CH}_3\text{COOH}}{\text{TOTAL VOLUME (L)}}$

FINDING VOLUMES:

MOLES CH_3COOH : $.200\text{M} \times V_a$

MOLES KOH TO NEUTRALIZE: $.100\text{M} \times V_b$

$\rightarrow$ AT EQUIVALENCE, $\text{KOH} = \text{CH}_3\text{COOH}$, SO: $V_b = \frac{.200 V_a}{.100} \rightarrow V_b = 2V_a$

TOTAL VOLUME AT EQUIVALENCE: $V_{\text{TOTAL}} = V_a + V_b \rightarrow$ SUBSTITUTE: $V_a + 2V_a \rightarrow 3V_a = \text{TOTAL VOLUME}$

MOLARITY OF ACETATE: $\frac{.200\text{M} \cdot V_a}{3V_a} = .067\text{M}$ $K_b = 5.56 \times 10^{-10} = \frac{(x)(x)}{(2-x)} \rightarrow x = 1.05 \times 10^{-5}$

ACETATE $K_b = \frac{1 \times 10^{-14}}{1.05 \times 10^{-5}} = 9.52 \times 10^{-10} = \frac{(x)(x)}{(1-x)} \rightarrow x = 7.99 \times 10^{-6} \text{M OH}^-$
 $\text{pOH} = -\log(7.99 \times 10^{-6}) = 5.10 \rightarrow \text{pH} = 14 - 5.10 = \boxed{8.9, \text{PHENOLPHTHALEIN}}$

3. a) $\text{Ba}(\text{OH})_2$ AT EQUIVALENCE POINT: $\text{Ba}(\text{OH})_2$ IS A STRONG BASE, SO $\text{pH} = 7$ AT EQUIVALENCE, BROMOTHYMOX BLUE or PHENOL RED

3. b) $.100\text{M H}_2\text{NNH}_2$ w/ $.200\text{M HNO}_3$ $K_b \text{ H}_2\text{NNH}_2 = 1.3 \times 10^{-6}$ SO $K_a = \frac{1 \times 10^{-14}}{1.3 \times 10^{-6}} = 8 \times 10^{-9} K_a$

BEFORE ACID: $\text{H}_2\text{NNH}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{NNH}_3^+ + \text{OH}^-$

$K_b = \frac{[\text{H}_2\text{NNH}_3^+][\text{OH}^-]}{[\text{H}_2\text{NNH}_2]} \rightarrow K_b = \frac{(x)(x)}{(1-x)} \rightarrow 1 \times 10^{-6} = \frac{x^2}{.1} \rightarrow x = 3.16 \times 10^{-4}$

$\text{pOH} = -\log(3.16 \times 10^{-4}) = 3.5 \rightarrow \text{pH} = 14 - 3.5 = \boxed{10.5 \text{ BEFORE ACID}}$

AT EQUIVALENCE: ALL H_2NNH_2 CONVERTED TO H_2NNH_3^+

$[\text{H}_2\text{NNH}_3^+]$: MOLES H_2NNH_2 INITIALLY = $.100\text{M} \cdot \text{VOL (LITERS)} = .1\text{V mL}$

VOLUME HNO_3 NEEDED = $\frac{\text{MOLES H}_2\text{NNH}_2}{[\text{HNO}_3]} = \frac{.1\text{V}}{.2} = .5\text{V L}$

TOTAL VOLUME @ EQUIVALENCE: $V + .5V = 1.5\text{V (L)} \rightarrow [\text{H}_2\text{NNH}_3^+] = \frac{.1\text{V}}{1.5\text{V}} = \frac{.1}{1.5} = 0.0667\text{M}$



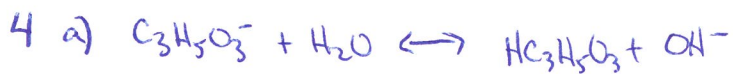
$K_a = \frac{[\text{H}^+][\text{H}_2\text{NNH}_2]}{[\text{H}_2\text{NNH}_3^+]} \rightarrow 8 \times 10^{-9} = \frac{x^2}{.0667} \rightarrow x = 2.31 \times 10^{-5}$

$\text{pH} = -\log(2.31 \times 10^{-5}) \rightarrow \boxed{4.64 \text{ @ EQUIVALENCE}}$

BEYOND EQUIVALENCE: EXCESS HNO_3 : EXCESS MOLES OF $\text{H}^+ = (.200 \times .10\text{V}) - .1\text{V} = .02\text{V}$

TOTAL VOLUME = $1.5\text{V} + .1\text{V} = 1.6\text{V L (TOTAL)}$

$[\text{H}^+] = \frac{.02\text{V}}{1.6\text{V}} = .0125\text{M} \rightarrow \text{pH} = -\log(1.25 \times 10^{-2}) \rightarrow \boxed{\text{pH} = 1.9}$



$pK_a = 3.86$

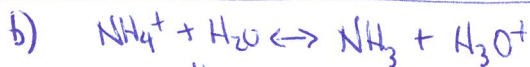
$pK_a = -\log [K_a]$

$3.86 = -\log [K_a] \rightarrow [K_a] = -3.86 \boxed{10^x} = 1.38 \times 10^{-4}$

$K_b = \frac{1 \times 10^{-14}}{1.38 \times 10^{-4}} = 7.25 \times 10^{-11}$

STRONG BASE, so $K_b = \frac{[OH^-]^1 \cdot [HC_3H_5O_3]^1}{[C_3H_5O_3^-]^1} \rightarrow 7.25 \times 10^{-11} = \frac{(x)(x)}{(1-x)} \quad x = 2.69 \times 10^{-6} (K_b)$

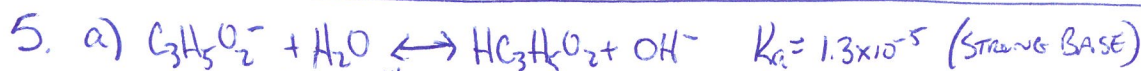
$pOH = -\log(2.69 \times 10^{-6}) \rightarrow 5.57 \quad pH = 14 - 5.57 \rightarrow \boxed{8.43}$



$K_b = 1.8 \times 10^{-5} \rightarrow K_a = \frac{1 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10}$

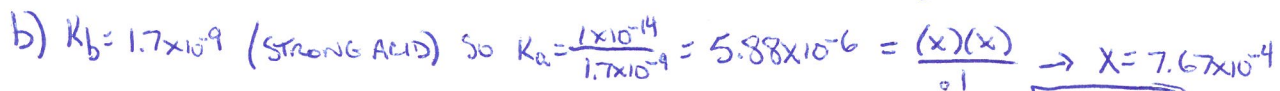
STRONG ACID, so $K_a = \frac{[NH_3]^1 \cdot [H_3O^+]^1}{[NH_4^+]^1} \rightarrow 5.56 \times 10^{-10} = \frac{(x)(x)}{(1-x)} \quad x = 7.45 \times 10^{-6} (K_a)$

$pH = -\log(7.45 \times 10^{-6}) \rightarrow \boxed{5.13}$



$K_b = \frac{1 \times 10^{-14}}{1.3 \times 10^{-5}} = 7.69 \times 10^{-10} = \frac{[HC_3H_5O_2]^1 \cdot [OH^-]^1}{[C_3H_5O_2^-]^1} \rightarrow \frac{(x)(x)}{(1-x)} = x = 8.77 \times 10^{-6}$

$pOH = -\log(8.77 \times 10^{-6}) \rightarrow 5.06 \quad pH = 14 - 5.06 = \boxed{8.94}$

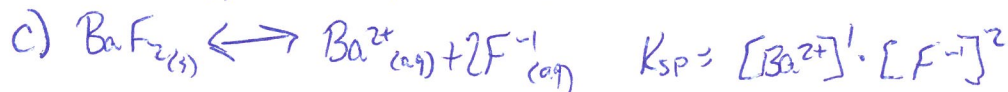
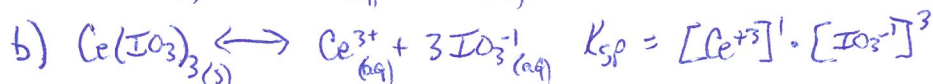
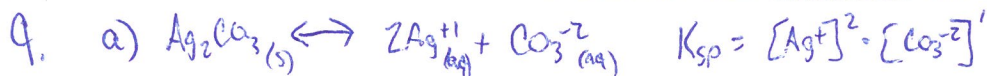
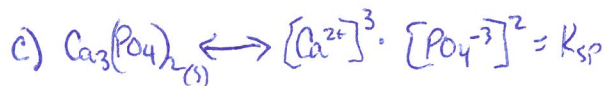
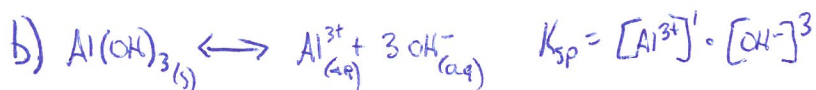
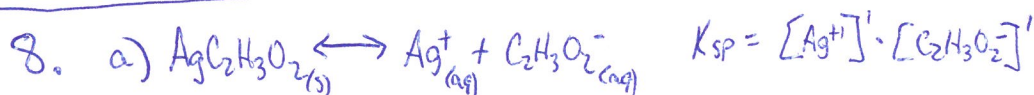


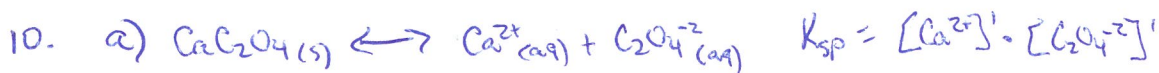
$\boxed{pH = 3.12}$

6. Bromocresol GREEN: BLUE (~5-5.4)

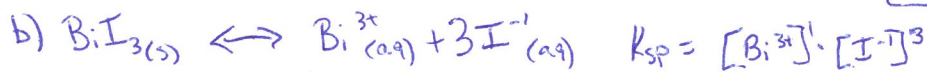
Thymol BLUE: YELLOW (~2.5-2.7)

7. $pH = 7$ THYMOL BLUE: YELLOW ; Bromothymol BLUE: GREEN; METHYL RED: YELLOW; CRYSTAL VIOLET: BLUE

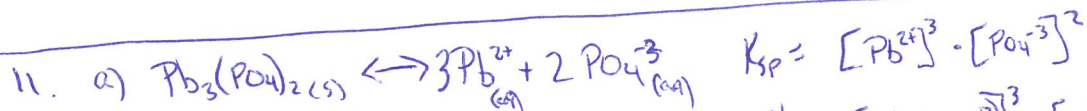




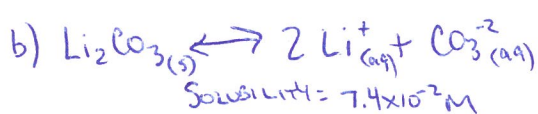
Solubility = $\frac{6.1 \times 10^{-3} \text{ g}}{1 \text{ L}} \cdot \frac{1 \text{ mol}}{128.10 \text{ g}} = \frac{4.76 \times 10^{-5} \text{ mol}}{1 \text{ L}} (M) \quad K_{sp} = [4.76 \times 10^{-5}] \cdot [4.76 \times 10^{-5}]$
 $K_{sp} = 2 \times 10^{-9}$



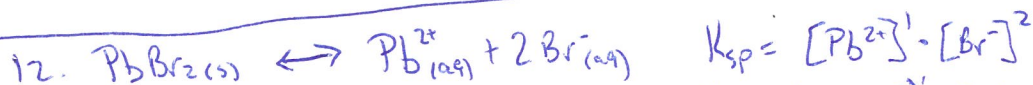
Solubility = $\frac{1.32 \times 10^{-5} \text{ mol}}{1 \text{ L}} (M) \quad K_{sp} = (1.32 \times 10^{-5}) \cdot [3(1.32 \times 10^{-5})]^3$
 $K_{sp} = 8.20 \times 10^{-19}$



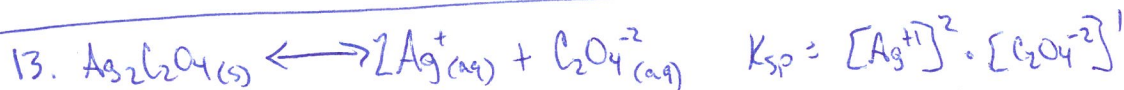
Solubility = $6.2 \times 10^{-17} \text{ M} \quad K_{sp} = [3(6.2 \times 10^{-17})]^3 \cdot [2(6.2 \times 10^{-17})]^2$
 $K_{sp} = 9.9 \times 10^{-55}$



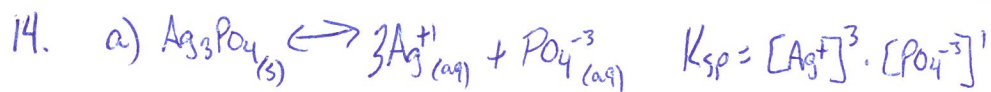
Solubility = $7.4 \times 10^{-2} \text{ M} \quad K_{sp} = [2(7.4 \times 10^{-2})]^2 \cdot [7.4 \times 10^{-2}]$
 $K_{sp} = 1.62 \times 10^{-3}$



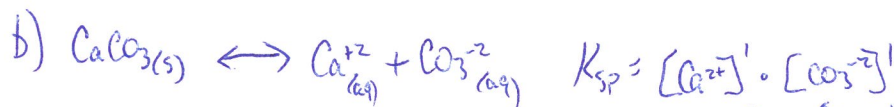
$K_{sp} = (2.14 \times 10^{-2})^1 \cdot [2(2.14 \times 10^{-2})]^2$
 $K_{sp} = 3.92 \times 10^{-5}$



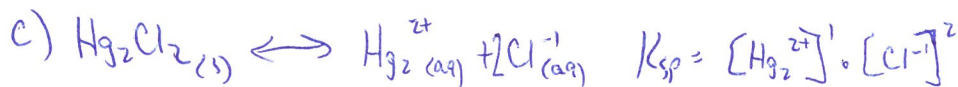
$K_{sp} = (2.2 \times 10^{-9})^2 \cdot [\frac{1}{2}(2.2 \times 10^{-9})]^1$
 $K_{sp} = 5.32 \times 10^{-12}$



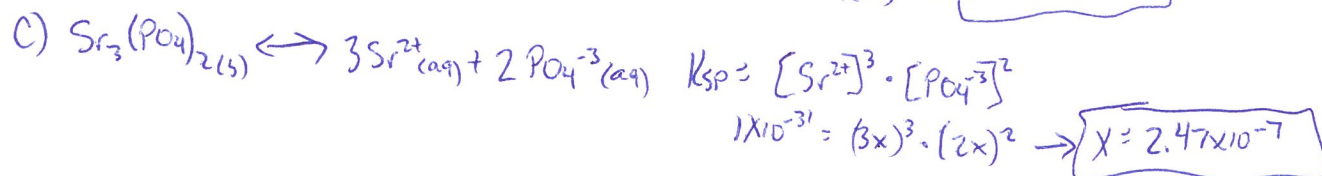
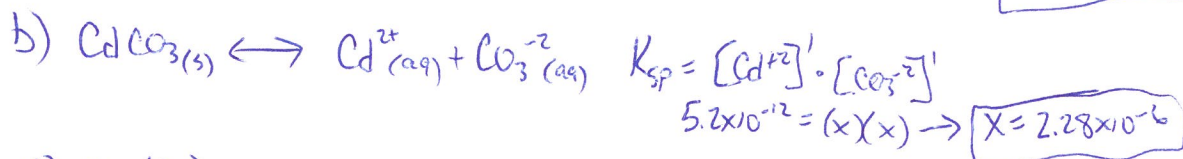
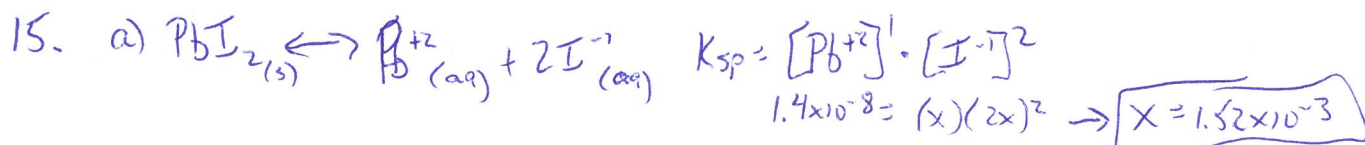
$1.8 \times 10^{-18} = (3x)^3 \cdot (x)^1 \rightarrow x = 1.6 \times 10^{-5} \text{ mol/L}$



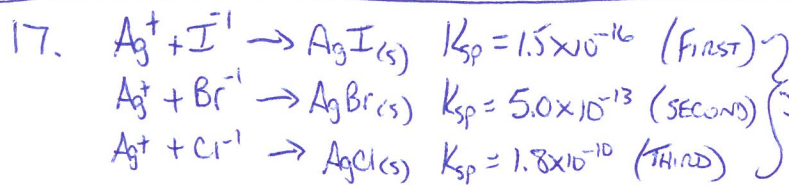
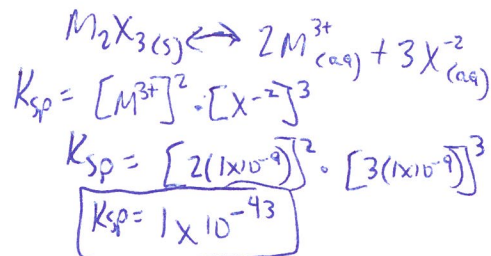
$K_{sp} = 8.7 \times 10^{-9} = (x) \cdot (x) \rightarrow x = 9.33 \times 10^{-5} \text{ mol/L}$



$1.1 \times 10^{-18} = (x)^1 \cdot (2x)^2 \rightarrow x = 1.4 \times 10^{-3}$



16. $m_{mass} = 288 g/mol$, So $\frac{3.60 \times 10^{-9} g}{288 g} \cdot \frac{1 mol}{1 mol} = \frac{1 \times 10^{-9} mol}{2} (M)$



MOLES Ag^+ : $.24M \cdot \frac{.24 mol}{1L} \cdot \frac{.200L}{1L} = .048 mol Ag^+$

*ALL 0.018 mol of I^{-} , Br^{-} , Cl^{-} REACTS w/ Ag^+ SINCE PPT OUT FIRST, BUT SINCE AgI HAS SMALLEST K_{sp} , I^{-} IS FIRST IN LINE.***

STEP 1: $.018 mol I^{-} \mid \frac{1 mol Ag^+}{1 mol I^{-}} = .018 mol Ag^+ \text{ USED} \rightarrow \frac{.048 mol}{.018 mol}$

$.030 mol Ag^+ \text{ REMAINS}$

STEP 2: $.018 mol Br^{-} \mid \frac{1 mol Ag^+}{1 mol Br^{-}} = .018 mol Ag^+ \text{ USED} \rightarrow \frac{.030 mol}{.018 mol}$

$.012 mol Ag^+ \text{ REMAINS}$

STEP 3: $.018 mol Cl^{-} \mid \frac{1 mol Ag^+}{1 mol Cl^{-}} = .018 mol Ag^+ \text{ NEEDED} \rightarrow \frac{.012 mol}{.012 mol}$

$.006 mol Cl^{-} \text{ REMAINS}$

$.012 mol Ag^+ = .012 mol AgCl \text{ FORMED} \mid \frac{143.32 g AgCl}{1 mol AgCl} = \boxed{1.72 g AgCl \text{ FORMED}}$

PART 1: How MUCH Ag^+ + Cl^{-} ??

PART 2: Ag^+ DETERMINES PRODUCT!

PART 3: FIND $[Ag^+]$ FROM K_{sp}

$1.8 \times 10^{-10} = [Ag^+]^1 \cdot [Cl^{-}]^1$

$1.8 \times 10^{-10} = [Ag^+] \cdot \left(\frac{.006 mol Cl^{-}}{.2L} \right) \rightarrow 1.8 \times 10^{-10} = (x)(.03)$

$\boxed{X = 6 \times 10^{-9}}$

$$18. \text{Co(OH)}_2(s) \rightleftharpoons \text{Co}^{3+}_{(aq)} + 3 \text{OH}^{-}_{(aq)} \quad K_{sp} = [\text{Co}^{3+}] \cdot [\text{OH}^{-}]^3$$

$$2.5 \times 10^{-43} = (x) \cdot [3(x)]^3 \rightarrow \boxed{X = 9.81 \times 10^{-12}}$$

$$19. \text{Cd(OH)}_2(s) \rightleftharpoons \text{Cd}^{2+}_{(aq)} + 2 \text{OH}^{-}_{(aq)} \quad K_{sp} = [\text{Cd}^{2+}] \cdot [\text{OH}^{-}]^2$$

$$5.9 \times 10^{-11} = (x) \cdot (2x)^2 \rightarrow \boxed{X = 2.45 \times 10^{-4}}$$

$$20. a) \text{CaF}_2(s) \rightleftharpoons \text{Ca}^{2+}_{(aq)} + 2 \text{F}^{-}_{(aq)} \quad K_{sp} = [\text{Ca}^{2+}] \cdot [\text{F}^{-}]^2 \quad 4.00 \times 10^{-11} = (x)(2x)^2 \quad x = 2.15 \times 10^{-4}$$

$$\text{BaF}_2(s) \rightleftharpoons \text{Ba}^{2+}_{(aq)} + 2 \text{F}^{-}_{(aq)} \quad K_{sp} = [\text{Ba}^{2+}] \cdot [\text{F}^{-}]^2 \quad 2.45 \times 10^{-5} = (x)(2x)^2 \quad x = 1.82 \times 10^{-2}$$

$\therefore \text{CaF}_2$ Smallest

$$b) \text{Ca}_3(\text{PO}_4)_2(s) \rightleftharpoons 3 \text{Ca}^{2+}_{(aq)} + 2 \text{PO}_4^{3-}_{(aq)} \quad K_{sp} = [\text{Ca}^{2+}]^3 \cdot [\text{PO}_4^{3-}]^2 \quad 1.3 \times 10^{-32} = (3x)^3 \cdot (2x)^2$$

$$x = 1.64 \times 10^{-7}$$

$$\text{FePO}_4(s) \rightleftharpoons \text{Fe}^{3+}_{(aq)} + \text{PO}_4^{3-}_{(aq)} \quad K_{sp} = [\text{Fe}^{3+}] \cdot [\text{PO}_4^{3-}] \quad 1.0 \times 10^{-22} = (x) \cdot (x)$$

$$x = 1 \times 10^{-11}$$

$\therefore \text{FePO}_4$ Smallest

$$21. a) \text{FeC}_2\text{O}_4(s) \rightleftharpoons \text{Fe}^{2+}_{(aq)} + \text{C}_2\text{O}_4^{2-}_{(aq)} \quad K_{sp} = [\text{Fe}^{2+}] \cdot [\text{C}_2\text{O}_4^{2-}] \quad 4.0 \times 10^{-11} = (x) \cdot (x) \quad x = 6.33 \times 10^{-6}$$

$$\text{Cu(IO}_3)_2(s) \rightleftharpoons \text{Cu}^{2+}_{(aq)} + 2 \text{IO}_3^{-}_{(aq)} \quad K_{sp} = [\text{Cu}^{2+}] \cdot [\text{IO}_3^{-}]^2 \quad 1.4 \times 10^{-7} = (x) \cdot (2x)^2 \quad x = 3.27 \times 10^{-3}$$

$\therefore \text{FeC}_2\text{O}_4$ Smallest

$$b) \text{Ag}_2\text{CO}_3(s) \rightleftharpoons 2 \text{Ag}^{+}_{(aq)} + \text{CO}_3^{2-}_{(aq)} \quad K_{sp} = [\text{Ag}^{+}]^2 \cdot [\text{CO}_3^{2-}] \quad 2.1 \times 10^{-7} = (2x)^2 \cdot (x) \quad x = 1.27 \times 10^{-4}$$

$$\text{Mn(OH)}_2(s) \rightleftharpoons \text{Mn}^{2+}_{(aq)} + 2 \text{OH}^{-}_{(aq)} \quad K_{sp} = [\text{Mn}^{2+}] \cdot [\text{OH}^{-}]^2 \quad 2 \times 10^{-13} = (x) \cdot (2x)^2 \quad x = 3.68 \times 10^{-5}$$

$\therefore \text{Mn(OH)}_2$ Smallest

22. a) $\text{Fe}(\text{OH})_3(s) \rightleftharpoons \text{Fe}^{3+}_{(aq)} + 3\text{OH}^{-1}_{(aq)}$ $K_{sp} = [\text{Fe}^{3+}]^1 \cdot [\text{OH}^{-}]^3$ $4 \times 10^{-38} = (x)(3x)^3$
 $x = 4.29 \times 10^{-10} \text{ M in H}_2\text{O}$

b) $\text{pH} = 5.0$, so $\text{pOH} = 14 - 5 \rightarrow 9$; $[\text{OH}^{-}] = 1 \times 10^{-9} \text{ M}$
 $4 \times 10^{-38} = [\text{Fe}^{3+}]^1 \cdot [1 \times 10^{-9}]^3 \rightarrow [\text{Fe}^{3+}] = \frac{4 \times 10^{-38}}{(1 \times 10^{-9})^3} \rightarrow x = 4 \times 10^{-11} \text{ M}$

c) $\text{pH} = 11.0$, so $\text{pOH} = 14 - 11 \rightarrow 3$; $[\text{OH}^{-}] = 1 \times 10^{-3} \text{ M}$
 $4 \times 10^{-38} = [\text{Fe}^{3+}]^1 \cdot [1 \times 10^{-3}]^3 \rightarrow [\text{Fe}^{3+}] = \frac{4 \times 10^{-38}}{(1 \times 10^{-3})^3} \rightarrow x = 4 \times 10^{-29} \text{ M}$

23. a) $\text{Ag}_2\text{SO}_4(s) \rightleftharpoons 2\text{Ag}^{+1}_{(aq)} + \text{SO}_4^{-2}_{(aq)}$ $K_{sp} = [\text{Ag}^{+}]^2 \cdot [\text{SO}_4^{-2}]^1$ $1.2 \times 10^{-5} = (2x)^2 \cdot (x)^1$
 $x = 1.44 \times 10^{-2} \text{ M in H}_2\text{O}$

b) $.10 \text{ M AgNO}_3 + \text{Ag}_2\text{SO}_4$ $K_{sp} = [.10 + 2x]^2 \cdot [x]^1 \rightarrow 1.25 \times 10^{-5} = (.10 + 2x)^2 (x) \rightarrow x = 1.25 \times 10^{-3}$

c) $.20 \text{ M K}_2\text{SO}_4 + \text{Ag}_2\text{SO}_4$ $K_{sp} = [2x]^2 \cdot [.20 + x]^1 \rightarrow 1.25 \times 10^{-5} = (4x^2)(.2) \rightarrow x = 3.95 \times 10^{-3}$

24. $\text{Ca}_3(\text{PO}_4)_2(s) \rightleftharpoons 3\text{Ca}^{+2}_{(aq)} + 2\text{PO}_4^{-3}_{(aq)}$ $K_{sp} = [\text{Ca}^{+2}]^3 \cdot [\text{PO}_4^{-2}]^2$
 $1.3 \times 10^{-32} = (3x)^3 \cdot (2x)^2 \rightarrow x = 2.29 \times 10^{-11}$

25. $\text{Ce}(\text{IO}_3)_3(s) \rightleftharpoons \text{Ce}^{3+}_{(aq)} + 3\text{IO}_3^{-1}_{(aq)}$ $K_{sp} = (x) \cdot (3x)^3 \rightarrow 4.4 \times 10^{-8} = (x)(.2 + 3x)^3$
 $4.4 \times 10^{-8} = (x)(.008)$
 $x = 5.5 \times 10^{-6}$

26. $\text{ZnS}(s) \rightleftharpoons \text{Zn}^{2+}_{(aq)} + \text{S}^{-2}_{(aq)}$ $K_{sp} = [\text{Zn}^{2+}]^1 \cdot [\text{S}^{-2}]^1$ $K_{sp} = (.05 + x)^1 \cdot (x)^1$
 $2.5 \times 10^{-22} = (.05)(x)$
 $x = 5 \times 10^{-21} \text{ M}$

$5 \times 10^{-21} \text{ mol ZnS}$	$\times 3\text{L}$	$\frac{97.4 \text{ g ZnS}}{1 \text{ mol ZnS}}$	$=$	$1.46 \times 10^{-19} \text{ g ZnS}$
1 L		$\frac{97.4 \text{ g ZnS}}{1 \text{ mol}}$		