Solubility Practice Questions

1. $V_{soln} = 0.01\ mL$ $\quad m_{CaF_2} = 0.0016\ g$

$$[CaF_2] = \frac{m}{M \cdot V}$$

$$= 0.0016\ g\ CaF_2 \times \frac{1\ mol\ CaF_2}{78.08\ g\ CaF_2} \times \frac{1}{0.00001\ L}$$

$$= 2.05\ \frac{mol\ CaF_2}{L}$$

solubility $CaF_2 = [Ca^{2+}] = \frac{1}{2}[F^-] = 2.05\ \frac{mol}{L}$

$[Ca^{2+}]_{eq'm} = 2.05\ \frac{mol}{L}$

$[F^-]_{eq'm} = 4.10\ \frac{mol}{L}$

$$K_{sp} = [Ca^{2+}][F^-]^2$$
$$= (2.05)(4.1)^2$$
$$= 34.46$$

$$CaF_{2(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$$

$\boxed{K_{sp} = 34}$

2. $$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$$

		Ag^+	Cl^-
I	/	0	0.01
C		+x	+x
E		x	0.01+x
			≈ 0.01

$[Cl^-]_I = 0.010\ \frac{mol}{L}$

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

$$1.8 \times 10^{-10} = (x)(0.01)$$

$$x = 1.8 \times 10^{-8}$$

solubility $AgCl = [Ag^+]$
$= 1.8 \times 10^{-8}\ \frac{mol}{L}$

check

$$\frac{[Cl^-]_I}{K_{sp}} = \frac{0.01}{1.8 \times 10^{-10}} > 100$$

proof

$$\frac{x}{[Cl^-]_I} \times 100\%$$

$$\frac{1.8 \times 10^{-8}}{0.01} \times 100$$

$= 1.8 \times 10^{-4}\ \%$.

assumption is valid

3. $CaSO_4(s) \rightleftharpoons Ca^{2+}(aq) + SO_4^{2-}(aq)$

I	0.01	0
C	+x	+x
E	0.01+x	x
	$\approx$ 0.01	

$[Ca^{2+}]_I = 0.0100 \frac{mol}{L}$

check

$\frac{[Ca^{2+}]_I}{K_{sp}} = \frac{0.01}{7.1\times10^{-5}} > 100$

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

$7.1\times10^{-5} = (0.01)(x)$

$x = 7.1\times10^{-3}$

proof

$\frac{x}{[Ca^{2+}]_I} \times 100\%$

$= \frac{7.1\times10^{-3}}{0.01} \times 100\%$

$= 71\%$

$\therefore$ assumption not valid.

$7.5\times10^{-5} = (0.01+x)(x)$

$7.5\times10^{-5} = 0.01x + x^2$

$0 = x^2 + 0.01x - 7.5\times10^{-5}$

$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

$= \frac{-0.01 \pm \sqrt{(0.01)^2 - 4(1)(-7.5\times10^{-5})}}{2(1)}$

$= \frac{-0.01 \pm \sqrt{4\times10^{-4}}}{2} = \frac{-0.01 \pm 0.02}{2}$

$x = -0.015$ $\quad x = 0.005$

$\therefore x = 0.005$

solubility $CaSO_4 = [SO_4^{2-}]$

$= 0.005 \frac{mol}{L}$

4. a) $Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$

		$2Ag^+$	CrO_4^{2-}
I		0	0
C		$2x$	x
E		$2x$	x

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

$1.12 \times 10^{-12} = (2x)^2(x)$

$4x^3 = 1.12 \times 10^{-12}$

$x = 6.54 \times 10^{-5}$

solubility $Ag_2CrO_4 = \frac{1}{2}[Ag^+] = [CrO_4^{2-}]$

$= 6.54 \times 10^{-5} \frac{mol}{L}$

b)

$Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$

		$2Ag^+$	CrO_4^{2-}
I		0	0.10
C		$+2x$	$+x$
E		$2x$	$0.1 + x$
			≈ 0.1

$[CrO_4^{2-}]_I = 0.1 \frac{mol}{L}$

check

$\frac{0.1}{K_{sp}} = \frac{0.1}{1.12 \times 10^{-12}} > 100$

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

$1.12 \times 10^{-12} = (2x)^2(0.1)$

$(2x)^2 = 1.12 \times 10^{-11}$

$x = 1.67 \times 10^{-6}$

proof

$\frac{x}{[CrO_4]_I} \times 100\%$

$= \frac{1.67 \times 10^{-6}}{0.1} \times 100\%$

$= 1.67 \times 10^{-3}\%$

$\therefore$ assumpt. valid

solubility $Ag_2CrO_4 = \frac{1}{2}[Ag^+]$

$= 1.67 \times 10^{-6} \frac{mol}{L}$

5. a)

$$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$$

$$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$$

$$[Ag^+] = [AgNO_3] \times \text{mol ratio} \times \frac{V_{AgNO_3}}{V_T}$$

$$= 0.010 \frac{\text{mol } AgNO_3}{L} \times \frac{1 \text{ mol } Ag^+}{1 \text{ mol } AgNO_3} \times \frac{25.0 \text{ mL}}{50.0 \text{ mL}}$$

$$= 0.005 \frac{\text{mol}}{L} Ag^+$$

$$[Cl^-] = [KCl] \times \text{mol ratio} \times \frac{V_{KCl}}{V_T}$$

$$= 0.0050 \frac{\text{mol KCl}}{L} \times \frac{1 \text{ mol } Cl^-}{1 \text{ mol KCl}} \times \frac{25.0 \text{ mL}}{50.0 \text{ mL}}$$

$$= 0.0025 \frac{\text{mol } Cl^-}{L}$$

$$Q_{sp} = [Ag^+][Cl^-]$$

$$= (0.005)(0.0025)$$

$$= 1.25 \times 10^{-5}$$

$$Q_{sp} > K_{sp}$$

$$1.25 \times 10^{-5} \qquad 1.8 \times 10^{-10}$$

$\therefore$ ppt will form

(E)

b) $Ca(NO_3)_{2\,(aq)} + 2KOH_{(aq)} \rightarrow Ca(OH)_{2\,(aq)} + 2KNO_{3\,(aq)}$

→ no ppt formed

c) $Pb(NO_3)_{2\,(aq)} + 2NaCl_{(aq)} \rightarrow PbCl_{2\,(s)} + 2NaNO_{3\,(aq)}$

$PbCl_{2\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$ $\quad K_{sp} = 1.2 \times 10^{-12}$

$[Pb^{2+}] = [Pb(NO_3)_2] \times \text{mol ratio} \times \frac{V}{V_T}$

$= 0.010 \frac{\text{mol } Pb(NO_3)_2}{L} \times \frac{1 \text{mol } Pb^{2+}}{1 \text{mol } Pb(NO_3)_2} \times \frac{x}{2x}$

$= 0.005 \frac{\text{mol } Pb^{2+}}{L}$

$Q_{sp} = [Pb^{2+}][Cl^-]^2$

$= (0.005)(0.005)^2$

$= 1.25 \times 10^{-7}$

$Q_{sp} < K_{sp}$

∴ no ppt

$[Cl^-] = [NaCl] \times \text{mol ratio} \times \frac{V}{V_T}$

$= 0.010 \frac{\text{mol NaCl}}{L} \times \frac{1 \text{mol } Cl^-}{1 \text{mol NaCl}} \times \frac{x}{2x}$

$= 0.005 \frac{\text{mol } Cl^-}{L}$

6. $PbCl_{2\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$ $\quad K_{sp} = 1.2 \times 10^{-5}$

$[Cl^-] = [NaCl] \times \text{mol ratio}$

$= 0.010 \frac{\text{mol } Cl^-}{L}$

$[Pb^{2+}] = \frac{m_{Pb(NO_3)_2}}{M_{Pb(NO_3)_2} V} \times \text{mol ratio}$

$= 5.00\text{g } Pb(NO_3)_2 \times \frac{1 \text{mol } Pb(NO_3)_2}{331.20\text{g } Pb(NO_3)_2} \times \frac{1}{1.0\text{L}} \times \frac{1 \text{mol } Pb^{2+}}{1 \text{mol } Pb(NO_3)_2}$

$= 0.0151 \frac{\text{mol } Pb^{2+}}{}$

$Q_{sp} = [Pb^{2+}][Cl^-]^2$

$= (0.0151)(0.01)^2$

$= 1.51 \times 10^{-6}$

$Q_{sp} < K_{sp}$

∴ no ppt

7. $Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$

$K_{sp} =$

$[OH^-] = [NaOH] \times \text{mol ratio} \times \frac{V_{NaOH}}{V_T}$

$= 0.010 \frac{mol\ NaOH}{L} \times \frac{1\ mol\ OH^-}{1\ mol\ NaOH} \times \frac{0.010\ L}{1.01\ L}$

$= 9.90 \times 10^{-5} \frac{mol\ OH^-}{L}$

$[Cu^{2+}] = [CuCl_2] \times \text{mol ratio} \times \frac{V_{CuCl_2}}{V_T}$

$= 0.010 \frac{mol\ CuCl_2}{L} \times \frac{1\ mol\ Cu^{2+}}{1\ mol\ CuCl_2} \times \frac{1.0\ L}{1.01\ L}$

$= 9.90 \times 10^{-3} \frac{mol\ Cu^{2+}}{L}$

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

$= (9.90 \times 10^{-3})(9.90 \times 10^{-5})^2$

$= 9.70 \times 10^{-11}$

8. $Ca(OH)_2(aq) + MgCO_3(aq) \rightarrow CaCO_3(s) + Mg(OH)_2(s)$

$[Ca(OH)_2] = \frac{m}{MV} = 56\ g\ Ca(OH)_2 \times \frac{1\ mol\ Ca(OH)_2}{74.10\ g\ Ca(OH)_2} \times \frac{1}{520\ L}$

$= 0.00145 \frac{mol\ Ca(OH)_2}{L}$

$\therefore [Ca^{2+}] = 0.00145 \frac{mol\ Ca^{2+}}{L}$

$[OH^-] = 0.00290 \frac{mol\ OH^-}{L}$

$[MgCO_3] = \frac{m}{MV} = 45g \times \frac{1\ mol\ MgCO_3}{84.32\ g\ MgCO_3} \times \frac{1}{520\ L}$

$= 0.00103 \frac{mol\ MgCO_3}{L}$

$\therefore [Mg^{2+}] = 0.00103 \frac{mol\ Mg}{L}$

$[CO_3^{2-}] = 0.00103 \frac{mol\ CO_3^{2-}}{L}$

$CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3^{2-}(aq)$

$K_{sp} = 5.0 \times 10^{-9}$

$Q_{sp} = [Ca^{2+}][CO_3^{2-}]$

$= (0.00145)(0.00103)$

$= 1.49 \times 10^{-6}$

$Q_{sp} > K_{sp}$

$\therefore CaCO_3$ will ppt

$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$

$K_{sp} = 5.6 \times 10^{-12}$

$Q_{sp} = [Mg^{2+}][OH^-]^2$

$= (0.00103)(0.00290)^2$

$= 8.66 \times 10^{-9}$

$Q_{sp} > K_{sp}$

$\therefore Mg(OH)_2$ will ppt

Exp. 1

$PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$

$Pb^{2+}_{(aq)} + Zn_{(s)} \rightarrow Pb_{(s)} + Zn^{2+}_{(aq)}$

$m_{Zn} = 0.094\,g$

$V = 100\,mL$

a) $n_{Zn} = \frac{m}{M} = 0.094\,g\,Zn \times \frac{1\,mol\,Zn}{65.38\,g\,Zn} = 0.00144\,mol\,Zn$

b) $n_{Pb^{2+}} = n_{Zn} \times \text{mol ratio}$

$= 0.00144\,mol\,Zn \times \frac{1\,mol\,Pb^{2+}}{1\,mol\,Zn}$

$= 0.00144\,mol\,Pb^{2+}$

$[Pb^{2+}] = \frac{0.00144\,mol\,Pb^{2+}}{0.1\,L} = 0.0144\,\frac{mol\,Pb^{2+}}{L}$

c) solubility $PbCl_2 = [Pb^{2+}] = \frac{1}{2}[Cl^-]$

$\frac{1}{2}[Cl^-] = [Pb^{2+}] = 0.0144\,\frac{mol\,Pb^{2+}}{L}$

$[Cl^-] = 0.0288\,\frac{mol\,Cl^-}{L}$

$K_{sp} = [Pb^{2+}][Cl^-]^2$

$= (0.0144)(0.0288)^2$

$= 1.2 \times 10^{-5}$

Exp 2

$$AgCH_3COO_{(s)} \rightleftharpoons Ag^+_{(aq)} + CH_3COO^-_{(aq)}$$

$$2Ag^+_{(aq)} + Cu_{(s)} \rightleftharpoons 2Ag_{(s)} + Cu^{2+}_{(aq)}$$

$m_{Cu} = 0.16g$

$V = 100\ mL$

a) $$n_{Cu} = \frac{m}{M} = 0.16\ g\ Cu \times \frac{1\ mol\ Cu}{63.55\ g\ Cu}$$

$$= 0.00252\ mol\ Cu$$

b) $$n_{Ag^+} = n_{Cu} \times \text{mol ratio}$$

$$= 0.00252\ mol\ Cu \times \frac{2\ mol\ Ag^+}{1\ mol\ Cu}$$

$$= 0.00504\ mol\ Ag^+$$

c) $$[Ag^+] = \frac{n}{V} = \frac{0.00504\ mol\ Ag^+}{0.1\ L}$$

$$= 0.0504\ \frac{mol\ Ag^+}{L}$$

solubility $AgC_2H_3O_2 = [Ag^+] = [C_2H_3O_2^-]$

$$[Ag^+] = [C_2H_3O_2^-] = 0.0504\ \frac{mol}{L}$$

$$K_{sp} = [Ag^+][C_2H_3O_2^-]$$

$$= (0.0504)(0.0504)$$

$$K_{sp} = 2.5 \times 10^{-3}$$