Name: ________________

Ksp Equilibrium Test

1. Determine the maximum possible concentration of Mg^{2+} ion in p.p.m. in a solution of 0.25 M KOH.

✓ $KOH \rightarrow K^{1+} + OH^{1-}$
0.25M 0.25M ← not common ion because the source of Mg^{2+} is not stated as coming from $Mg(OH)_2$

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

✓ $Ksp = [Mg^{2+}][OH^{1-}]^2$

$[Mg^{2+}] = \frac{Ksp}{[OH^{1-}]^2}$

$[Mg^{2+}] = \frac{9.0 \times 10^{-12}}{(0.25)^2} \Rightarrow [Mg^{2+}] = 1.44 \times 10^{-10}$ M ✓

$\frac{1.44 \times 10^{-10} \text{ mol } Mg^{2+}}{1 L} \times \frac{24.31 g\ Mg^{2+}}{1 \text{ mol } Mg^{2+}} \times \frac{1000 mg}{1 g} = 3.5 \times 10^{-6}$ p.p.m. Mg^{2+}

↳ 3.5 p.p.t. Mg^{2+}

2. What mass of Ag_2S in mg is required to saturate 45000 L of water (yes that is forty five thousand litres of solution).

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

Let s represent the solubility of Ag_2S ✓

$\therefore [Ag^{+}] = 2s$ ✓

$[S^{2-}] = s$ ✓

$Ksp = [Ag^{1+}]^2[S^{2-}]$ ✓

$1.6 \times 10^{-49} = (2s)^2 s$

$4s^3 = 1.6 \times 10^{-49}$

$s = 3.42 \times 10^{-17}$ mol/L ✓✓

$45000 L \times \frac{3.42 \times 10^{-17} mol}{1 L} \times \frac{247.81 g}{1 mol} \times \frac{1000 mg}{1 g} = 3.81 \times 10^{-7}$ mg

↑ size of small pool

↳ 0.381 ng (nanograms)

↳ 381 pg (picograms)

3. Use the fact that 53.9 mg of Ag_2CrO_4 will saturate 2.50 L of solution, to determine the Ksp value for this salt. Use the table of Ksp values to check your answer.

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

✓ $\frac{53.9\ mg}{2.50\ L} \times \frac{1\ g}{1000\ mg}$ ✓ $\times \frac{1\ mol}{331.74\ g}$ ✓ $= \frac{6.50 \times 10^{-5}\ mol}{1\ L}$ ✓

$\therefore [Ag^+] = 2 \times 6.50 \times 10^{-5}\ M$ ✓

$= 1.30 \times 10^{-4}\ M$

$[CrO_4^{2-}] = 6.50 \times 10^{-5}\ M$ ✓

$K_{sp} = [Ag^{2+}]^2[CrO_4^{2-}]$ ✓

$K_{sp} = (1.30 \times 10^{-4})^2 \times 6.50 \times 10^{-5}$

$K_{sp} = 1.10 \times 10^{-12}$ ☺ ✓

4. What mass of CuCl in mg will dissolve in 750 mL of 0.66 M $CaCl_2$ solution?

✓ $CaCl_2 \rightarrow Ca^{2+} + 2Cl^{1-}$ common ion ✓

0.66 M 1.32 M

✓ $CuCl \rightleftharpoons Cu^{1+} + Cl^{1-}$

Let s represent the solubility of CuCl ✓

$[Cu^{1+}] = s$ ✓

$[Cl^{1-}] = s + 1.32$ ✓

$K_{sp} = [Cu^{1+}][Cl^{1-}]$ ✓

$3.2 \times 10^{-7} = s(s + 1.32)$

assume $s <<< 1.32$

$3.2 \times 10^{-7} = s(1.32)$

$s = 2.42 \times 10^{-7}\ mol/L$ ✓✓

$\therefore$ assumption is valid

$750\ mL \times \frac{1\ L}{1000\ mL} \times \frac{2.42 \times 10^{-7}\ mol}{1\ L} \times \frac{99.00\ g}{1\ mol} \times \frac{1000\ mg}{1\ g} = 0.0180\ mg$ CuCl

✓ ✓ ✓ ✓ ✓ ✓

5. Determine the identity and mass of precipitate that will form when 250 mL of 2.8 x10⁻⁴ M $Ca(NO_3)_2$ is mixed with 500 mL of 1.0 x 10⁻⁴ M Na_2CO_3. Express your mass answer in mg.

$Ca(NO_3)_2 \rightarrow Ca^{2+} + 2NO_3^{1-}$ ✓

$Na_2CO_3 \rightarrow 2Na^{1+} + CO_3^{2-}$ ✓

$CaCO_3 \rightleftharpoons Ca^{2+} + CO_3^{2-}$ ✓ ✓

	$CaCO_3$	Ca^{2+}	CO_3^{2-}
Initial [ ]	N.A ✓	/	/
Initial amount	0	n = CV $n = 2.8\times10^{-4}\frac{mol}{L}\times 0.250L$ $n = 7\times10^{-5}$ mol ✓	n = CV $n = 1.0\times10^{-4}\frac{mol}{L}\times 0.5L$ $n = 5\times10^{-5}$ mol ✓
Final amount	x ✓	$7\times10^{-5} - x$	✓ $5\times10^{-5} - x$
Final [ ]	N.A	$\frac{7\times10^{-5} - x}{0.750}$	✓ $\frac{5\times10^{-5} - x}{0.750L}$

250 mL
500 mL
750 mL
→ 0.750L ✓

Let x represent the amount of $CaCO_3$ that forms ✓

$K_{sp} = [Ca^{2+}][CO_3^{2-}]$ ✓

$4.8\times10^{-9} = \left(\frac{7\times10^{-5} - x}{0.750}\right)\left(\frac{5\times10^{-5} - x}{0.750}\right)$

$2.7\times10^{-9} = x^2 - 1.2\times10^{-4}x + 3.5\times10^{-9}$

$0 = x^2 - 1.2\times10^{-4}x + 8\times10^{-10}$

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

$\rightarrow x = \frac{1.2\times10^{-4} \pm \sqrt{(1.2\times10^{-4})^2 - 4(1)(8\times10^{-10})}}{2(1)}$

$x = \frac{1.2\times10^{-4} \pm 1.058\times10^{-4}}{2}$

~~$x = 1.129\times10^{-4}$ mol~~ extraneous (too large)

or

$x = 7.085\times10^{-6}$ mol ✓✓

$7.085\times10^{-6}\ mol \times \frac{100.09\ g}{1\ mol} \times \frac{1000\ mg}{1\ g} = 0.709$ mg $CaCO_3$ ppte!!
✓ ✓ ✓

Bonus Question: Chloride ion is often used to test for the presence of Ag^{1+} ion through a precipitation reaction (i.e formation of AgCl precipitate). The problem is that other ions can form precipitates with chloride ion as well. Suppose you had a solution with the following composition:

$[Cu^{1+}]$ = 35 p.p.m.

$[Ag^{1+}]$ = 0.05 p.p.m.

What $[Cl^{1-}]$ will cause precipitation with Cu^{2+}? What $[Cl^{1-}]$ will cause precipitation with Ag^{1+}? What range of $[Cl^{1-}]$ will cause precipitation of one ion and not the other. What mass of NaCl would be required to initiate precipitation of the second ion for a 1L solution?

$CuCl \rightleftharpoons Cu^{2+} + Cl^{1-}$ $\quad [Cu^{2+}]: \frac{35\text{ mg Cu}}{1\text{ L}} \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{1\text{ mol}}{63.55\text{ g}} = 5.507\times10^{-4}$ M

$K_{sp} = [Cu^{2+}][Cl^{1-}]$ $\quad [Cl^{1-}] = \frac{K_{sp}}{[Cu^{2+}]}$ $\quad [Cl^{1-}] = \frac{3.2\times10^{-7}}{5.507\times10^{-4}}$ $\quad [Cl^{1-}] = 5.810\times10^{-4}$ M with start CuCl ppte ✓

$AgCl \rightleftharpoons Ag^{+} + Cl^{-}$ $\quad [Ag^{+}]: \frac{0.05\text{ mg Ag}}{1\text{ L}} \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{1\text{ mol}}{107.87\text{ g}} = 4.635\times10^{-7}$ M

$K_{sp} = [Ag^{+}][Cl^{-}]$ $\quad [Cl^{-}] = \frac{K_{sp}}{[Ag^{+}]}$ $\quad [Cl^{-}] = \frac{1.8\times10^{-10}}{4.635\times10^{-7}}$ $\quad [Cl^{1-}] = 3.883\ 10^{-4}$ M ✓

$\therefore$ $3.883\times10^{-4}\text{ M} < [Cl^{1-}] < 5.810\times10^{-4}\text{ M}$ is the range where AgCl ppte and CuCl does not! ✓

Before CuCl will ppte there is an amount of Cl^{1-} that is consummed by the formation of AgCl ppte that must be taken into account!

① Determine amount Cl^{1-} consummed by AgCl ppte when CuCl starts to form (i.e. $[Cl^{1-}] = 5.810\times10^{-4}$ M

② $[Ag^{+}] = \frac{K_{sp}}{[Cl^{1-}]}$ $\quad [Ag^{+}] = \frac{1.8\times10^{-10}}{5.810\times10^{-4}}$ $\quad [Ag^{+}] = 3.098\times10^{-7}$ M

③ $n = \frac{C}{V}$ $\quad n_{AgCl} = \frac{(4.635\times10^{-7} - 3.098\times10^{-7})\text{ M}}{1.0\text{ L}}$ $\quad n_{AgCl} = 1.537\times10^{-7}$ mol

$\therefore$ 1.537×10^{-7} mol NaCl require

④ NaCl require to reach $[Cl^{1-}] = 5.81\times10^{-4}$ M $\Rightarrow$ 5.81×10^{-4} mol for 1L

⑤ Total amount $\quad 5.810\times10^{-4} + 1.537\times10^{-7} = 5.813\times10^{-7}$ mol

⑥ Convert to mass $\quad 5.813\times10^{-7}\text{ mol} \times \frac{58.44\text{ g}}{1\text{ mol}} = 3.397\times10^{-2}$ g ↳ 33.97 mg ✓