SOLUBILITY REVIEW
ANSWER KEY

① $PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$

② $AlCl_{3(s)} \rightarrow Al^{3+}_{(aq)} + 3Cl^-_{(aq)}$

$\quad 0.25M \qquad \underline{0.25M} \qquad \underline{0.75M}$

③ SOLUBILITY: THE EQUILIBRIUM CONCENTRATION OF A SUBSTANCE IN SOLUTION AT A GIVEN TEMPERATURE.

④ SATURATED SOLUTION: A SOLUTION IN WHICH THERE IS THE MAXIMUM AMOUNT OF SOLUTE IN SOLUTION SO THAT THE RATE OF DISSOLVING EQUALS THE RATE OF RECRYSTALLIZATION.

⑤ 0.1M NaCl IS A BETTER CONDUCTOR AS NaCl DISSOCIATES INTO IONS, AND IT IS THE PRESENCE OF IONS THAT INCREASES CONDUCTION.

$NaCl \rightarrow Na^+ + Cl^-$

$0.1M \qquad 0.1M \quad 0.1M = 0.2M$ TOTAL IONS.

CH_3OH IS A MOLECULAR COMPOUND AND DOES NOT PRODUCE IONS IN SOLUTION

6) A 0.1M $MgCl_2$ SOLUTION CANNOT BE SATURATED BECAUSE $MgCl_2$ IS A 'SOLUBLE' MPOUND (SEE TABLE), MEANING IT CAN PRODUCE A SOLUTION > 0.1M.

7) $$\frac{6.78g\ CaBr_2}{} \left| \frac{1\ mol\ CaBr_2}{199.9g\ CaBr_2} \right. = 0.033917\ mol\ CaBr_2$$

$$[CaBr_2] = \frac{0.033917mol}{0.2500L} = 0.13567M$$

$CaBr_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Br^-_{(aq)}$

$0.13567 \qquad 0.136M \qquad 0.271M$

$\underline{[Br^-] = 0.271M}$

8) $$[Al_2(SO_4)_3] = \frac{0.050mol}{0.5000L} = 0.10M$$

$Al_2(SO_4)_{3(s)} \rightarrow 2Al^{3+}_{(aq)} + 3SO_4^{2-}{}_{(aq)}$

$0.10M \qquad 0.20M \qquad 0.30M$

$\underline{[Al^{3+}] = 0.20M}$, $\underline{[SO_4^{2-}] = 0.30M}$

9) ⓘ Add $Sr(NO_3)_{2(aq)}$ and the ppt $SrSO_4$ forms. Filter. – SO_4^{2-} separated

Add $Ba(NO_3)_{2(aq)}$ and the ppt $Ba(OH)_2$ forms. Filter – OH^- separated

(iii) Add $AgNO_{3(aq)}$ and the ppt AgI forms. – I^- separated.] – OPTIONAL STEP

⑩ F: $Ca(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \longrightarrow 2NaNO_{3(aq)} + CaSO_{4(s)}$

C: $Ca^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow 2Na^+_{(aq)} + 2NO_3^-{}_{(aq)} + CaSO_{4(s)}$

N: $Ca^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow CaSO_{4(s)}$

⑪ $$\frac{1.84g\ AgCH_3COO \mid 1mol\ AgCH_3COO}{\mid 166.9g} = 0.011025mol \qquad [AgCH_3COO] = \frac{0.011025mol}{0.2500L} = 0.0441M$$

$$\underset{0.0441M}{AgCH_3COO_{(s)}} \rightleftharpoons \underset{0.0441M}{Ag^+_{(aq)}} + \underset{0.0441M}{CH_3COO^-_{(aq)}}$$

$$K_{sp} = [Ag^+][CH_3COO^-] = (0.0441)^2 = \underline{1.94\times10^{-3}}$$

⑫ $$\underset{0.038M}{Pb(IO_3)_2} \rightleftharpoons \underset{0.038M}{Pb^{2+}_{(aq)}} + \underset{0.076}{2IO_3^-{}_{(aq)}}$$

$$K_{sp} = [Pb^{2+}][IO_3^-]^2 = (0.038)(0.076)^2 = \underline{2.2\times10^{-4}}$$

⑬ $$\underset{\boxed{7.071\times10^{-5}}}{CaCO_{3(s)}} \rightleftharpoons \underset{7.071\times10^{-5}M}{Ca^{2+}_{(aq)}} + \underset{7.071\times10^{-5}}{CO_3^{2-}{}_{(aq)}}$$

use stoich 1:1

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

$5.0\times10^{-9} = [Ca^{2+}][CO_3^{2-}]$

Let $x = [Ca^{2+}]_{eq} = [CO_3^{2-}]_{eq}$.

$5.0\times10^{-9} = x^2$

$\sqrt{5.0\times10^{-9}} = \sqrt{x^2}$

$7.071\times10^{-5} = x$

$[CaCO_3] = \underline{7.1\times10^{-5}}M$

⑭ $$\underset{\boxed{6.503\times10^{-5}}}{Ag_2CrO_{4(s)}} \rightleftharpoons 2Ag^+_{(aq)} + \underset{6.503\times10^{-5}M}{CrO_4^{2-}{}_{(aq)}}$$

stoich 1:1

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

$1.1\times10^{-12} = [Ag^+]^2[CrO_4^{2-}]$

Let $x = [CrO_4^{2-}]_{eq}$, then

$2x = [Ag^+]$

$1.1\times10^{-12} = (2x)^2(x)$

$1.1\times10^{-12} = 4x^2(x)$

$1.1\times10^{-12} = 4x^3$

$x = \sqrt[3]{\frac{1.1\times10^{-12}}{4}}$

$x = 6.503\times10^{-5}$

Solubility in mol/L = 6.503×10^{-5}

in g/L (change moles to grams): $$\frac{6.503\times10^{-5}mol\ Ag_2CrO_4 \mid 331.8g\ Ag_2CrO_4}{\mid 1mol\ Ag_2CrO_4} = 2.2\times10^{-2}$$

$\underline{\underline{2.2\times10^{-2}\ g/L}}$

⑮ FIND SOLUBILITY OF $CaSO_4$ FIRST:

$$\underset{\boxed{8.426\times10^{-3}M}}{CaSO_{4(s)}} \rightleftharpoons \underset{8.426\times10^{-3}M}{Ca^{2+}_{(aq)}} + \underset{8.426\times10^{-3}M}{SO_{4\,(aq)}^{2-}}$$

Stoich 1:1

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

$7.1\times10^{-5} = [Ca^{2+}][SO_4^{2-}]$

Let $x = [Ca^{2+}] = [SO_4^{2-}]$

$\sqrt{7.1\times10^{-5}} = \sqrt{x^2}$

$x = 8.426\times10^{-3}$

moles $CaSO_4$ that could dissolve in 50.0L : $(8.426\times10^{-3}M)(50.0L) = 0.4213\,mol$

MASS $CaSO_4$: $\dfrac{0.4213\,mol\ CaSO_4}{} \left|\dfrac{136.2\,g\ CaSO_4}{1\,mol\ CaSO_4}\right. = 57.38\,g$

57g of $CaSO_4$ can dissolve in 50.0L water.

⑯ $Ca(NO_3)_{2\,(aq)} + Na_2SO_{4\,(aq)} \longrightarrow 2NaNO_{3\,(aq)} + CaSO_{4\,(s)}$

← POSSIBLE PPT.

$[Ca(NO_3)_2]_f = \dfrac{(0.054M)(0.0300L)}{0.0900L}$

$= 0.018M$

$[Na_2SO_4]_f = \dfrac{(8.1\times10^{-4}M)(0.0600L)}{0.0900L}$

$= 5.4\times10^{-4}M$

$\underset{0.018M}{Ca(NO_3)_2} \rightarrow \underset{\boxed{0.018M}}{\boxed{Ca^{2+}}} + 2NO_3^-$

$\underset{5.4\times10^{-4}M}{Na_2SO_4} \rightarrow 2Na^+ + \underset{\boxed{5.4\times10^{-4}M}}{\boxed{SO_4^{2-}}}$

$CaSO_{4(s)} \rightleftharpoons Ca^{2+}_{(aq)} + SO_{4\,(aq)}^{2-}$

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

K_{sp} from table $= 7.1\times10^{-5}$

TRIAL K_{sp}: $(0.018)(5.4\times10^{-4})$

$= 9.7\times10^{-6}$

TRIAL $K_{sp} < K_{sp}$ ∴ A PPT WILL NOT FORM

⑰ $Cu(NO_3)_{2\,(aq)} + 2NaIO_{3\,(aq)} \longrightarrow 2NaNO_{3\,(aq)} + Cu(IO_3)_{2\,(s)}$

← POSSIBLE PPT.

$[Cu(NO_3)_2]_f = \dfrac{(1.00\times10^{-2}M)(0.0900L)}{0.1000L}$

$= 9.0\times10^{-3}M$

$[NaIO_3]_f = \dfrac{(1.00\times10^{-2}M)(0.0100L)}{0.1000L} = 1.0\times10^{-3}M$

$\underset{0\times10^{-3}M}{Cu(NO_3)_2} \rightarrow \underset{\boxed{9.0\times10^{-3}M}}{\boxed{Cu^{2+}}} + 2NO_3^-$

$\underset{1.0\times10^{-3}M}{NaIO_3} \rightarrow Na^+ + \underset{\boxed{1.0\times10^{-3}M}}{\boxed{IO_3^-}}$

$Cu(IO_3)_{2\,(s)} \rightleftharpoons Cu^{2+}_{(aq)} + 2IO_{3\,(aq)}^-$

$K_{sp} = [Cu^{2+}][IO_3^-]^2$

FROM TABLE $= 6.9\times10^{-8}$

TRIAL $K_{sp} = (9.0\times10^{-3})(1.0\times10^{-3})^2$

$= 9.0\times10^{-9}$

TRIAL $K_{sp} < K_{sp}$ ∴ A PPT WILL NOT FORM

⑱ ppt is $PbBr_2$

$$PbBr_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Br^-_{(aq)}$$

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

K_{sp} from table $= 6.6\times10^{-6}$ $[Pb^{2+}] = 0.10M$

$$6.6\times10^{-6} = (0.10)[Br^-]^2$$

$$[Br^-] = \sqrt{\frac{6.6\times10^{-6}}{0.10}}$$

$$= \underline{8.12}4\times10^{-3}M$$

$$\text{Moles } Br^- = \underline{8.12}4\times10^{-3}M \times 0.500L$$

$$= \underline{\underline{4.1\times10^{-3}}}$$

⑲ $$PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

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

K_{sp} from table $= 1.2\times10^{-5}$ $[Cl^-] = 0.100M$

$$1.2\times10^{-5} = [Pb^{2+}][0.100]^2$$

$$[Pb^{2+}] = 1.2\times10^{-3}M$$

$$Pb(NO_3)_2 \rightarrow Pb^{2+} + 2NO_3^-$$

$$\boxed{1.2\times10^{-3}M} \quad 1.2\times10^{-3}M$$

$$\text{moles } Pb(NO_3)_2 = 1.2\times10^{-3}M \times 0.100L \Leftarrow$$

$$= 1.2\times10^{-4}\text{ mol}$$

$$\text{mass } Pb(NO_3)_2 = \frac{1.2\times10^{-4}\text{mol}}{} \left| \frac{331.2g\ Pb(NO_3)_2}{1\text{ mol } Pb(NO_3)_2} \right. = 0.03\underline{9}74$$

$$= \underline{\underline{0.040g}}$$

⑳ $$MgCO_{3(s)} \rightleftharpoons Mg^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

- adding $Ca(NO_3)_{2(s)}$ produces $Ca^{2+}_{(aq)}$ and $NO_3^-{}_{(aq)}$ ions
- $Ca^{2+}_{(aq)}$ is low solubility with $CO_3^{2-}{}_{(aq)}$, so they will react to form $CaCO_{3(s)}$
- thus, $[CO_3^{2-}]$ decreases, so a shift right occurs and more solid $MgCO_3$ dissolves, increasing the solubility of $MgCO_3$.

㉑ $$Ag_2C_2O_{4(s)} \rightleftharpoons 2Ag^+_{(aq)} + C_2O_4^{2-}{}_{(aq)}$$

- adding K_2CrO_4 produces $K^+_{(aq)}$ and $CrO_4^{2-}{}_{(aq)}$ ions
- $CrO_4^{2-}{}_{(aq)}$ is low solubility with $Ag^+_{(aq)}$, so a ppt of $Ag_2CrO_{4(s)}$ forms, causing a shift right and therefore more $Ag_2C_2O_4$ dissolves, increasing its solubility
- adding $AgNO_3$ produces $Ag^+_{(aq)}$ and $NO_3^-{}_{(aq)}$ ions.
- this increases $[Ag^+]$, causing a shift left so more $Ag_2C_2O_{4(s)}$ ppts, thereby decreasing its solubility.

∴ $Ag_2C_2O_4$ is least soluble in a solution of $AgNO_{3(aq)}$.

㉒ⓐ $CaSO_{4(s)} \rightleftharpoons Ca^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$

ⓑ Add a salt that would have an ion which precipitates with either Ca^{2+} or SO_4^{2-}.
e.g. add $Sr(NO_3)_2$

$$\underset{\xrightarrow[\text{shift right.}]{}}{CaSO_{4(s)} \rightleftharpoons Ca^{2+}_{(aq)}} + \underset{\underset{Sr^{2+}_{(aq)}}{+}}{\underset{\downarrow}{SO_4^{2-}{}_{(aq)}}}$$

Thus, $[SO_4^{2-}]$ decreases and the equil shifts right, causing more solid $CaSO_4$ to dissolve

㉓ Find $\overset{\text{max}}{\wedge}$ $[Ag^+]$ before ppt forms for each situation.

AgCl:

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

$Ksp = [Ag^+][Cl^-]$

$1.8\times10^{-10} = [Ag^+][0.10]$

$[Ag^+] = 1.8\times10^{-9}M$

Ag_2CO_3:

$Ag_2CO_{3(s)} \rightleftharpoons 2Ag^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

$Ksp = [Ag^+]^2[CO_3^{2-}]$

$8.5\times10^{-12} = [Ag^+]^2(0.10)$

$[Ag^+] = \sqrt{\frac{8.5\times10^{-12}}{0.10}}$

$[Ag^+] = 9.2\times10^{-6}M$

AgCl will form a ppt first as it will take less Ag^+ before saturation.
Therefore, a <u>WHITE</u> ppt will form first.

㉔

$$\begin{array}{r} 93.47g \\ -89.05g \\ \hline 4.42g\ MgBr_2 \end{array}$$

$$\frac{4.42g\ MgBr_2}{} \bigg| \frac{1\ mol\ MgBr_2}{184.1g\ MgBr_2} = 0.02401 mol$$

$$[MgBr_2] = \frac{0.02401\ mol}{0.02500L} = 0.960M$$

The solubility of $MgBr_2$ is <u>0.960M</u>