C12 - 3.0 - Solubility

Assume $25^{o}C^{*}$

Solution : A homogeneous mixture of two or more substances.
(Saturated when solvent dissolved maximum solute.)

Solvent : Able to dissolve other substances.
Solute : Minor component in a solution.

Electrolyte - A substance which dissolves to give it an electrically conducting solution containing ions.

$$HCl_{(g)} \rightarrow H^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Ionic Solution - Contains ions.
Ionic Compounds - Metal/Non-metal likely ionic in solution.

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

A compound of polyatomic ions will be ionic in solution.

$$(NH_4)_2Cr_2O_{7(s)} \rightarrow 2NH^{+}_{4(aq)} + Cr_2O^{2-}_{7(aq)}$$

Non-Electrolyte - A substance which dissolves to give it a non-conducting solution containing only neutral molecules.

$$Br_{2(l)} \rightarrow Br_{2(aq)}$$

Molecular Solution - Contains only neutral molecules.

Molecular/Covalent Compounds - Non-metals/Non-metals, especially organic compounds, generally form molecular solutions.

$$ClO_{2(l)} \rightarrow ClO_{2(aq)}$$

Solubility - Maximum amount of substance which can dissolve in a given amount of solvent at given temperature. (C12 - The $[\,]_{eq}$) (Negligible Solubility - Dissolves an extremely small extent.)
(Low Solubility - If a saturated solution of a substance is less than 0.1M.)

Saturated - Solution has dissolved maximum amount. (C12 - Dissolved substance in Eq with some of the undissolved substance.) (Supersaturation - Concentrated solution contains more than when saturated.)

$$AgBrO_{3(s)} \rightarrow Ag^{+}_{(aq)} + BrO_3^{-1}{}_{(aq)}$$

Dissolving

$\boxed{\text{Eventually}}$

$$AgBrO_{3(s)} \rightleftharpoons Ag^{+}_{(aq)} + BrO_3^{-1}{}_{(aq)}$$

$$Ag^{+}_{(aq)} + BrO_3^{-1}{}_{(aq)} \rightarrow AgBrO_{3(s)}$$

Recrystallization

$1\ mol\ Na_3PO_{4(s)}\ disolved\ and\ diluted\ to\ a\ 1L\ volume.$

$$Na_3PO_{4(s)} \rightarrow 3Na^{+}_{(aq)} + PO^{3-}_{4(aq)} \quad \boxed{\text{Mole Ratio - 1 : 3 : 1}} \quad [Na^{+}_{(aq)}] = \frac{3mol}{1L} = 3M \quad [PO^{3-}_{4(aq)}] = \frac{1mol}{1L} = 1M$$

If two ions from a compound have "low solubility," mixing of the two ions will cause a precipitate to form.

$0.2M\ CaS$ & $0.2M\ Na_2SO_4\ solutions\ are\ mixed.$

$$CaS \rightarrow Ca^{2+} + S^{2-}$$

Examine Cross Combinations

$$Na_2SO_4 \rightarrow Na^{+} + SO_4^{2-}$$

$Na^{+} + S^{2-}\ ; Soluble$ See Table

$Ca^{2+} + SO_4^{2-}\ ; Low\ solubility$ $CaSO_4\ precipitate\ will\ form.$

Qualitative Analysis - Experimental procedures to determine which elements or ions are present in a substance.

Assume aqueous solution contains either or both $Ag^{+}\ or\ Sr_2^{2+}$.

Possible Reactions

		Cl^{-}	SO_4^{2-}	S^{2-}	OH^{-}	PO_4^{3-}
Originals*	Ag^{+}	ppt	ppt	ppt	ppt	ppt
	Sr^{2+}	----	ppt	----	----	ppt

ppt : Precipitate, ---- : No

Basically start with the addition that ppt's by most originals with that doesn't precipitate others. Repeat.

If only $SO_4^{2-}\ or\ PO_4^{3-}$ is added its undetermined which is present.

To test for Ag^{+} and/or Sr^{2+} steps :
Precipitate all Ag^{+} with sufficient $Cl^{-}, S^{2-}\ or\ OH^{-}$.
1) Take 1 mL solution, add a few drops ie. $1\ M\ NaCl, Na_2S\ or\ NaOH$.
-If precipitate forms Ag^{+} is present. (If not absent). Filter off/discard any precipitate.
2) To solution in step 1, add a few drops of $1\ M\ Na_2SO_4\ or\ Na_3PO_4$.
-If precipitate forms Sr^{2+} is present. (If not absent)

C12 - 3.0 - Predicting a Precipitate Solubility

Find the $[Mg^{2+}]$ in a saturatedsolution of $Mg(OH)_2$

$Mg(OH)_{2(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2(OH)^{1-}_{(aq)}$ Solubility Product Expression

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

Larger K_{sp} ;
More soluble salt.

Solubility Product Constant
$K_{sp} = [A^+]^a[B^-]^b$
$AB_{b\,(s)} \rightleftharpoons aA^{\#+}_{(aq)} + bB^{\#-}_{(aq)}$

$let\ x = [Mg(OH)_2]_{dissolved}$

$x \rightleftharpoons x + 2x$ $\boxed{\text{Mole Ratio 1 : 1 : 2}}$

$K_{sp} = [x][2x]^2$ See Table
$5.6 \times 10^{-12} = 4x^3$ Divide both sides
$1.4 \times 12^{-12} = x^3$ Cube root* Both sides
$x = 1.12 \times 10^{-4}$

$[Mg^{2+}] = 1.12 \times 10^{-4}\ M$

Note:
Use "Solubility of Common Ions in Water" Table to predict whether a compound has low solubility.
Use "Solubility Product Constants at 25^oC" Table (K_{sp}) to compare relative solublities.

Solubility - Amount of substance required to make a saturated solution $\frac{g}{L}$.
Molar Solubility - Molar concentration of a saturated solution $\frac{mol}{L}$. $\boxed{\text{Solubility} \neq \text{Solubility Constant}}$
Solubility Product - K_{sp} value obtained when concentration of ions in a solution are multiplied together.

$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^{-1}_{(aq)}$ $K_{sp} = [Ag^+][Cl^{-1}] = 1.8 \times 10^{-10}$ $Q = [Ag^+]_{start}[Cl^{-1}]_{start}$ Ion Product (Trial)

The Product of Ion Concentrations : Q =which actually exist in solution ("what we have.")

K_{sp} = required to establish a solubilty Eq (What we need to form a saturated solution.")

Precipitate :	$Q < K_{sp}$ Cannot Form	$Q = K_{sp}$ Barely saturated solution formed	$Q > K_{sp}$ Will Form

$5.0\ mL\ 6.0 \times 10^{-5}\ M\ Ag^+$ $10.\ mL\ 4.2 \times 10^{-6}\ M\ Cl^-$

$$[Ag^+]_{diluted} = 6.0 \times 10^{-5}\ M \times \frac{5.0\ mL}{15\ mL} = 2.0 \times 10^{-5}\ M$$

$\boxed{c_1v_1 = c_2v_2}$ $5\ mL + 10\ mL = 15\ mL$

$$[Cl^-]_{diluted} = 4.2 \times 10^{-6}\ M \times \frac{10.\ mL}{15\ mL} = 2.8 \times 10^{-6}\ M$$

$Q = [Ag^+]_{dil}[Cl^{-1}]_{dil}$
$= (2.0 \times 10^{-5})(2.8 \times 10^{-6})$
$= 5.6 \times 10^{-11}$

$5.6 \times 10^{-11} < K_{sp} = 1.8 \times 10^{-10}$

Precipitate will not form.

$25.0\ mL\ 4.5 \times 10^{-3}\ M\ Pb(NO_3)_2$ $35.0\ mL\ 2.8 \times 10^{-3}\ M\ MgI_2$

$Pb(NO_3)_{2(aq)} + MgI_{2(aq)} \rightleftharpoons PbI_{2\,(s)} + Mg(NO_3)_{2(aq)}$

$PbI_{2\,(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2I^{-1}_{(aq)}$ $K_{sp} = [Pb^{2+}][I^{-1}]$

$$[Pb(NO_3)_2]_{dil} = 4.5 \times 10^{-3}\ M \times \frac{25.0\ mL}{60.0\ mL} = 1.88 \times 10^{-3}\ M$$

$$[MgI_2]_{dil} = 2.8 \times 10^{-3}\ M \times \frac{35.\ mL}{60\ mL} = 1.63 \times 10^{-3}\ M$$

$Q = [Pb^{2+}]_{dil}[I^-]_{dil}$
$= (1.88 \times 10^{-2})(3.26 \times 10^{-3})$
$= 2.00 \times 10^{-8}$

$2.00 \times 10^{-8} < K_{sp} = 8.5 \times 10^{-9}$

Precipitate will form.

$Pb(NO_3)_{2(s)} \rightarrow Pb^{2+}_{(aq)} + 2NO^{-1}_{3(aq)}$ $MgI_{2(aq)} \rightarrow Mg^{2+}_{(aq)} + 2I^{+}_{(aq)}$

1.88×10^{-3} 1.88×10^{-3} 3.76×10^{-3} $\boxed{\text{Molarity}}$ 1.63×10^{-3} 1.63×10^{-3} 3.26×10^{-3}