3.3 – Predicting the Solubility of Salts

Strictly speaking, nothing is INSOLUBLE (really! even glass).

But, a substance can have LOW SOLUBILITY (very little dissolves into ions).

**Defn: LOW SOLUBILITY**

A substance has **low solubility** if a saturated solution of the substance is less than **0.1 M** (arbitrary value that was chosen).

Ex: equal volumes of compounds A and B are mixed. After dilution, both compounds are present as 0.1 M solutions. If a precipitate (solid) forms:

\[
A + B \rightarrow AB_{(s)}
\]

The precipitate has **low solubility**.

**How to Determine if a Precipitate Has LOW SOLUBILITY:**

- You need your data book! (See :Solubility of Common Compounds in Water”)
- We will call this the “solubility table”

**Note about alkali ions:** these are the ions of the alkali metals (Na⁺, Li⁺, K⁺…)

**Ex #1:** Is FeCO₃(s) soluble?

**Steps:**

- Find the negative ion (anion) on the table: \( \text{CO}_3^{2-} \)
- Look for the positive ion (cation) beside the anion: \( \text{Fe}^{2+} \)
- The cation will be in the group “soluble” or “low solubility”.
- If the cation appears in the “low solubility group, a PPT will form!
Ex #2: Determine the solubility of Na$_2$SO$_4$ (is it soluble?)

\[ \text{Na}_2\text{SO}_4 (s) \rightarrow 2\text{Na}^+ + \text{SO}_4^{2-} \]

Sulphate (SO$_4^{2-}$)

- All others $\leftarrow$ Na$^+$
- Soluble $\checkmark$
- Low Solubility

Ag$^+$, Ca$^{2+}$, Sr$^{2+}$, Ba$^{2+}$, Pb$^{2+}$

**Na$_2$SO$_4$ is soluble**

Ex #3: Determine the solubility of AgBr:

\[ \text{AgBr} (s) \rightarrow \text{Ag}^+ + \text{Br}^- \]

Chloride, Cl$^-$

- All others $\Leftarrow$ Na$^+$
- Soluble

Bromide, Br$^-$

- Ag$^+$, Pb$^{2+}$, Cu$^+$
- Low Solubility

Iodide, I$^-$

**AgBr has low solubility**

Determine Whether a Precipitate will form:

When 2 ions form a solution having "LOW SOLUBILITY", the mixing of these ions will cause a precipitate (solid) to form.

Ex #4: Will a precipitate form when 0.2 M solutions of CaS$_{(aq)}$ and Na$_2$SO$_4$_{(aq)} are mixed?

\[ \text{CaS}_{(aq)} + \text{Na}_2\text{SO}_4_{(aq)} \rightarrow ? \]

*if two equal volumes of 0.2 M solution are mixed, the dilution factor is 2.

The resulting solution has 0.1 M CaS and 0.1 M Na$_2$SO$_4$.

break into ions

\[ \text{CaS}_{(aq)} = \text{Ca}^{2+} + \text{S}^{2-} \]
\[ \text{Na}_2\text{SO}_4_{(aq)} = 2\text{Na}^+ + \text{SO}_4^{2-} \]

Sulphate (SO$_4^{2-}$)

- All others $\Leftarrow$ Na$^+$
- Soluble
- Low Solubility

Ag$^+$, Ca$^{2+}$, Sr$^{2+}$, Ba$^{2+}$, Pb$^{2+}$

Sulphide (S$_2^{-}$)

- Alkali ions, H$^+$, NH$_4^+$, Be$^{2+}$, Mg$^{2+}$, Ca$^{2+}$, Sr$^{2+}$, Ba$^{2+}$ $\rightarrow$ Soluble
- All others $\rightarrow$ Low Solubility

\[ \text{Na}_2\text{S} \text{ is soluble.} \]

But CaSO$_4$ makes a precipitate!
Ex # 4: Will a precipitate form when 0.2 M solutions of KI\(_{(aq)}\) and Pb(NO\(_3\))\(_2(aq)\) are mixed?

\[
0.1 \text{ M } \text{KI} = K^+ + I^-
\]
\[
0.1 \text{ M } \text{Pb(NO}_3\text{)}_2 = \text{Pb}^{2+} + 2 \text{NO}_3^-
\]

Check: 
- K\(^+\)I\(^-\) Soluble (no PPT)
- Pb\(^{2+}\)NO\(_3\)^\(^-\) Soluble (no PPT)

Some General Rules:

1. H\(^+\), alkali metal ions, NH\(_4\)^\(^+\), and NO\(_3\)^\(^-\) are always soluble in water.
   - You cannot make a precipitate with these ions containing these ions.

2. If you want to make a cation soluble in water...pair it with NO\(_3\)^\(^-\) (nitrate).

3. If you want to make an anion soluble in water...pair it with Na\(^+\) (sodium).

Making Precipitates:

Ex #1: You wish to make a AgCl precipitate. You will make 2 solutions containing soluble salts. Give the chemical formula for the soluble salts you will choose to use:

\[
(\text{working backwards}) \quad \text{AgCl(s)} \rightarrow \text{Ag}^+ + \text{Cl}^- \quad \text{PP+ cation \ anion}
\]

I will make soln's with these 2 salts:

\[
\text{Ag}^+ + \text{NO}_3^- = \text{AgNO}_3
\]
\[
\text{Na}^+ + \text{Cl}^- = \text{NaCl}
\]

Do Hebden Q's: p. 83 #21, 22 / p. 84 #24