# CHEMISTRY 12 – UNIT III – Solubility Equilibrium

**G: Solubility Equilibrium (Concept of Solubility)** *It is expected that students will be able to…*

**G1: Classifying solutions as ionic or molecular**

**1)** Write the dissolving reaction if 1.0 mol of the following particles are added to 1.0 L of water; and classify each solution as ionic or molecular:

- If IONIC (or ACID) BREAK into ions.
- If COVALENT (molecular) but NOT an ACID, then do not break into ions.
- If compound is LOW solubility then use ⇌

a) Solid hydroiodic acid: ACID ∴ break into ions
**$HI_{(s)} \rightarrow H^+_{(aq)} + I^-_{(aq)}$**

b) Solid sulphur tetrafluoride: Molecular ∴ stays together
**$SF_{4\,(s)} \rightarrow SF_{4\,(aq)}$**

c) Solid potassium phosphate: IONIC, SOLUBLE salt ∴ break into ions
**$K_3PO_{4(s)} \rightarrow 3\ K^+_{(aq)} + PO_4^{3-}{}_{(aq)}$**

d) Solid calcium phosphate: IONIC, LOW SOL ∴ break into ions BUT use EQM arrow
**$Ca_3(PO_4)_{2(s)} \rightleftharpoons 3\ Ca^{2+}_{(aq)} + 2\ PO_4^{3-}{}_{(aq)}$**

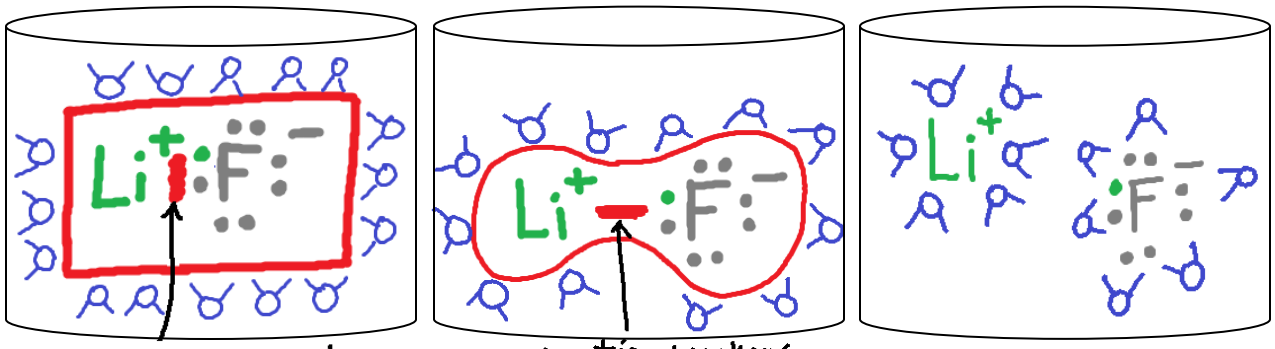
**G2: Important solution terms**

**1)** Define the following terms: **solution, solute, solvent, unsaturated, saturated, supersaturated**. You must use the salt solution, **$NaCl_{(aq)}$**, in each of your definitions.

Answer: In a NaCl **solution**, the salt ($NaCl_{(s)}$) is the **solute** which has been dissolved and the **solvent** used is water. If a small amount of NACl(s) is added, then an **Unsaturated** solution is produced (no solid present). If more and more NaCl(s) is added then a **saturated** solution is made (solid left over) which is also the MAX ION CONCENTRATION which means solubility is reached. If the saturated solution is HEATED, more ions are produced and this is called a **supersaturated** solution.

**G3: Understanding the dissolving reaction**

**1)** Sketch a pictorial transformation of an ionic compound (use lithium fluoride) being dissolved by water. Use the following 3 beakers to show the solid LiF being broken apart by the water into ions.

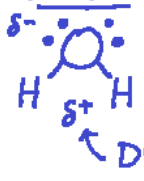



= force of attraction holding the 2 elements together (ionic bond)

Attraction weakens as water molecules are attracted to particles

Ions are produced as $H_2O$ has enough energy to break the bond BUT does not have the energy to cause the electron to go back to the metal → that is how IONS are formed (the point of this unit)

Water ($H_2O$) = polar solvent




↖ Dipole

**G4: Define Solubility**

**1)** List appropriate units that can be used to express solubility.

**Solubility must be represented as a concentration (amount / volume):**

- **Grams per litre (g/L)** or - **moles per litre (mol/L or M)**

**2)** 1.0 mol of the solid ionic compound, $AB_{(s)}$, is added to 1.0 L of water and produces a concentration of 0.034M. What can be said about the solubility of the compound? Show the reaction for this.

**$AB_{(s)} \rightleftharpoons A^+_{(aq)} + B^-_{(aq)}$**

**If concentration is less than 0.1 M when an appreciable amount is added to water, then it MUST be a LOW SOLUBILITY salt.**

**G5: Stoichiometric Calculations involving Soluble Salts**

**CHEM 11 stoichiometry solution chemistry → you will use these calculations LATER in H1 & H2 in CHEM 12 solution stoichiometry!!!**

**1)** What is the concentration of nitrate ions if 5.00g of chromium (III) nitrate is dissolved in distilled water to make a 250.0mL solution?

(5.00 g $Cr(NO_3)_3$ / 0.2500 L) (1 mol/ 238.0 g) = 0.0840 M

$Cr(NO_3)_{3(s)} \rightarrow Cr^{3+}_{(aq)} + 3\ NO_3^-{}_{(aq)}$
0.0840 M : 0.0840 M : 3(0.0840 M)
= **0.252 M**

**2)** In an experiment, a student decants a sample of saturated $MgBr_2$ solution into a beaker and evaporates the sample to dryness. He recorded the following data:

| | |
|---|---|
| Volume of saturated $MgBr_{2(aq)}$ | 25.00 mL |
| Mass of beaker | 89.05 g |
| Mass of beaker and residue | 93.47 g |

Calculate the solubility of $MgBr_2$ in moles per litre.

Mass of $MgBr_2$: 93.47 g – 89.05 g = 4.42 g

Solubility: ( 4.42 g $MgBr_2$ /0.02500L ) ( 1 mol/ 184.1 g ) = **0.960 M**

**3)** What is the concentration of sodium ions after 120.0mL of a 0.225M $Na_3N$ solution is mixed with 80.0mL of a 0.350M $Na_2CO_3$?

$Na_3N_{(aq)} \rightarrow 3\ Na^+_{(aq)} + N^{3-}_{(aq)}$
0.135 M : 3(0.135 M)
= **0.405 M**
Diluted Concentration C2 = C1V1/V2
= (0.225 M) (120.0 mL) / (200.0 mL)
= 0.135 M

$Na_2CO_{3(aq)} \rightarrow 2\ Na^+_{(aq)} + Co_3^{2-}{}_{(aq)}$
0.140 M : 2(0.140 M)
= **0.280 M**
Diluted Concentration C2 = C1V1
= (0.350 M) (80.0mL) / (200.0 mL)
= 0.140 M

Total [Na+] = 0.405 M + 0.280 M
= **0.685 M**

**G6: Precipitates and a solution reaction**

**1)** When two solutions are mixed together, what must be produced to have a reaction occur?

**A Precipitate (ppt) must form or it is simply a physical change (mixing of spectator ions)**

**2)** Describe what will happen when equal volumes of 0.2 M $K_2CO_3$ and 0.2 M $Na_3PO_4$ are mixed.

**Use table on p. 4 of data booklet after formula equation is written (or memorize that ALKALI ions are ALWAYS spectator ions! Will not form a salt with low solubility).**

**$3\ K_2CO_{3\,(aq)} + 2\ Na_3PO_{4\,(aq)} \rightarrow 2\ K_3PO_{4\,(aq)} + 3\ Na_2CO_{3\,(aq)}$ No reaction, no ppt will form**

**3)** What is the **complete ionic equation** and the **net ionic reaction** for the following mixtures?

**a)** 0.2 M $K_2CO_{3(aq)}$ and 0.2 M $Na_3PO_{4(aq)}$

**Formula equation: $3\ K_2CO_{3\,(aq)} + 2\ Na_3PO_{4\,(aq)} \rightarrow 2\ K_3PO_{4\,(aq)} + 3\ Na_2CO_{3\,(aq)}$**

**Complete Ionic: $6\ K^+ + 3\ CO_3^{2-} + 6\ Na^+ + 2\ PO_4^{3-} \rightarrow 6\ K^+ + 3\ CO_3^{2-} + 6\ Na^+ + 2\ PO_4^{3-}$**

**Net Ionic: None – no ppt forms**

**b)** 0.2 M $Na_2S_{(aq)}$ and 0.2 M $CuCl_{2(aq)}$

**Formula equation: $Na_2S_{(aq)} + CuCl_{2(aq)} \rightarrow 2\ NaCl_{(aq)} + CuS_{(s)}$**

**Complete Ionic: $2\ Na^+ + S^{2-} + Cu^{2+} + 2\ Cl^- \rightarrow 2\ Na^+ + 2\ Cl^- + CuS_{(s)}$**

**Net Ionic: $S^{2-} + Cu^{2+} \rightarrow CuS_{(s)}$**

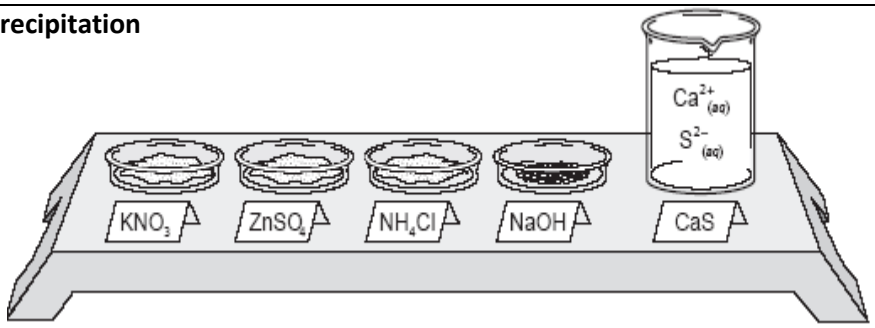
**4)** For each of the mixtures in **3)** write a list of spectator ions for each.

a) All: $K^+$ / $CO_3^{2-}$ / $Na^+$ / $PO_4^{3-}$

b) $Na^+$ / $Cl^-$

**G7: Separation of ions using precipitation**

**1)** Consider the following:




Which two solid samples could be added to the calcium sulphide solution in order to remove first one ion then the other ion from the solution. Indicate the order in which to add them and determine what will be formed in each case.

**Work: S = soluble LS = low solubility --- = 2 cations (or anions) will not react**

| **Ions to use for ppt →** / **Ions to separate↓** | **$K^+$** | **$NO_3^-$** | **$Zn^{2+}$** | **$SO_4^{2-}$** | **$NH_4^+$** | **$Cl^-$** | **$Na^+$** | **$OH^-$** |
|---|---|---|---|---|---|---|---|---|
| **$Ca^{2+}$** | --- | S | --- | LS | --- | S | --- | LS |
| **$S^{2-}$** | S | --- | LS | --- | S | --- | S | --- |

***Note: if you memorize the top 4 rows of the table on p. 4 of data booklet you will save a lot of time! You can eliminate 4 ions of the possible 8 by memorizing the table because $K^+$, $Na^+$ and $NH_4^+$ are soluble with any anion and $NO_3^-$ is soluble with any cation.**

**Answer:**

**Step 1: add $NaOH_{(s)}$ – it will dissolve and react with $Ca^{2+}$**

**Complete ionic: $2\ Na^+ + 2\ OH^- + Ca^{2+} + S^{2-} \rightarrow Ca(OH)_{2(s)} + S^{2-} + 2\ Na^+$**

**Net ionic: $Ca^{2+} + 2\ OH^- \rightarrow Ca(OH)_{2(s)}$**

**Step 2: Add $ZnSO_{4(s)}$ – it will dissolve and react with $S^{2-}$**

**Complete ionic: $Zn^{2+} + SO_4^{2-} + S^{2-}\ (+ 2\ Na^+) \rightarrow ZnS_{(s)} + SO_4^{2-}\ (+ 2\ Na^+)$**

**Net ionic: $Zn^{2+} + S^{2-} \rightarrow ZnS_{(s)}$**

**Be careful about the order you add the salts… If you add $ZnSO_4$ first, then you will form 2 ppt's and they will not be separated!**