# Precipitation reactions
# General Information:

A **precipitation reaction** is a reaction between two ionic compounds to form two new compounds.
A **precipitate** (abbreviated ppt) is a solid that will form in the bottom of a reaction vessel after a reaction has occurred if one of the compounds is insoluble. The reaction that occurs is a double replacement (double displacement) reaction. When this reaction happens, there *cannot* be more than one precipitate.

In a precipitate reaction, the acid will give off H+ ions when dissolved in water. The base will give off OH- ions when dissolved in water.

Double Replacement reactions occur in the form **AB + CD → AD + CB** where A and C are cations and B and D are anions.

**Make sure to indicate whether each substance is aqueous (aq), solid (s), gas (g), or liquid (l).** An arrow pointing downwards may also be used to indicate a precipitate (solid).

Precipitation Reactions can be written in three forms: (see below for examples)

- **Molecular form** (shows molecules)
- **Complete ionic** (shows all ions with only the precipitate as a molecule)
- **Net Ionic** (all spectator ions removed; includes only those which the precipitate includes)

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## Solubility:

- When something is considered **soluble**, that means that the attraction between the polar water molecules and also the attraction between ions is stronger than the attraction between the two ions. If this is the case, a precipitate will not form and the ions will remain in solution.
- When something is considered **insoluble**, that means that the attraction between the two ions is stronger than the reaction between the polar water molecules and the two ions separately. If this is the case, a precipitate will form.
- A solubility chart should be used to determine solubility. Here is an example of a solubility chart. Many charts display the same information in different ways. This chart displays ions that are insoluble as having "low solubility".
- Solubility depends on the nature of the solubility of solute and nature of the solubility of Solvents
  Solubility of solute depends on the temperature, particle size and the nature of the solvent.
  If it is a solubility of a gas pressure will also affect the solubility.

## Table F
### Solubility Guidelines for Aqueous Solutions

| Ions That Form *Soluble* Compounds | Exceptions |
|---|---|
| Group 1 ions ($Li^+$, $Na^+$, etc.) | |
| ammonium ($NH_4^+$) | |
| nitrate ($NO_3^-$) | |
| acetate ($C_2H_3O_2^-$ or $CH_3COO^-$) | |
| hydrogen carbonate ($HCO_3^-$) | |
| chlorate ($ClO_3^-$) | |
| perchlorate ($ClO_4^-$) | |
| halides ($Cl^-$, $Br^-$, $I^-$) | when combined with $Ag^+$, $Pb^{2+}$, and $Hg_2^{2+}$ |
| sulfates ($SO_4^{2-}$) | when combined with $Ag^+$, $Ca^{2+}$, $Sr^{2+}$, $Ba^{2+}$, and $Pb^{2+}$ |

| Ions That Form *Insoluble* Compounds | Exceptions |
|---|---|
| carbonate ($CO_3^{2-}$) | when combined with Group 1 ions or ammonium ($NH_4^+$) |
| chromate ($CrO_4^{2-}$) | when combined with Group 1 ions, $Ca^{2+}$, $Mg^{2+}$, or ammonium ($NH_4^+$) |
| phosphate ($PO_4^{3-}$) | when combined with Group 1 ions or ammonium ($NH_4^+$) |
| sulfide ($S^{2-}$) | when combined with Group 1 ions or ammonium ($NH_4^+$) |
| hydroxide ($OH^-$) | when combined with Group 1 ions, $Ca^{2+}$, $Ba^{2+}$, $Sr^{2+}$, or ammonium ($NH_4^+$) |

| Ion | General Solubility Rule |
|---|---|
| $NO_3^-$ | All nitrates are soluble |
| $C_2H_3O_2^-$ | All acetates are soluble ($AgC_2H_3O_2$ only moderately) |
| $Cl^-$, $Br^-$, $I^-$ | All chlorides, bromides and iodides are soluble except $Ag^+$, $Pb^+$ and $Hg_2^{2+}$. ($PbCl_2$ is slightly soluble in cold water and moderatel soluble in hot water.) |
| $SO_4^{2-}$ | All sulfates are soluble except those of $Ba^{2+}$, $Pb^{2+}$, $Ca^{2+}$ and $Sr^{2+}$ |
| $CO_3^{2-}$ and $PO_4^{3-}$ | All carbonates and phosphates are insoluble except those of $Na^+$, $K^+$ and $NH_4^+$. (Many acid phosphates are soluble). |
| $OH^-$ | All hydroxides are insoluble except those of $Na^+$ and $K^+$. Hydroxides of $Ba^{2+}$ and $Ca^{2+}$ are slightly soluble. |
| $S^{2-}$ | All sulfides are insoluble except those of $Na^+$, $K^+$, $NH_4^+$ and those of the alkaline earths: $Mg^{2+}$, $Ca^{2+}$, $Sr^{2+}$ and $Ba^{2+}$. (Sulfides of $Al^{3+}$ and $Cr^{3+}$ hydrolyze and precipiate as the corresponding hydroxides. |
| $Na^+$, $K^+$ and $NH_4^+$ | All salts of sodium ion, potassium ion and ammonium ion are soluble except several uncommon ones. |

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# Predicting Products for Precipitation Reactions:

1. Take the first cation and pair it with the opposite anion.
2. Take the second cation and pair it with the opposite anion.
3. Look at a solubility chart to determine whether or not a precipitate will form and if so, what it is.
4. Balance the equation.

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## 1. Reaction between calcium nitrate and carbonic acid: (species exist largely undissociated in solution)

***Molecular form:***

$$Ca(NO_3)_2(aq) + H_2CO_3(aq) \rightarrow CaCO_3 \downarrow + 2HNO_3(aq)$$

***Complete ionic:***

$$Ca^{2+}(aq) + NO_3^-(aq) + 2H^+(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s) + 2H^+(aq) + 2NO_3^-(aq)$$

***Net Ionic:***

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

As seen above, CaCO3 is the precipitate.

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## 2. Reaction between iron(III) chloride and phosphoric acid:

***Molecular form:***

$$FeCl_3(aq) + H_3PO_4(aq) \rightarrow FePO_4 \downarrow + 3HCl(aq)$$

***Complete ionic:***

$$Fe^{3+}(aq) + 3Cl^-(aq) + 3H^+(aq) + PO_4^{3-}(aq) \rightarrow FePO_4(s) + 3H^+(aq) + 3Cl^-(aq)$$

***Net Ionic:***

$$Fe^{3+}(aq) + PO_4^{3-}(aq) \rightarrow FePO_4(s)$$

As seen above, FePO4 is the precipitate.

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## 3. Reaction between potassium nitrate and sodium iodide:

***Molecular form:***

$$KNO_3(aq) + NaI(aq) \rightarrow NaNO_3(aq) + KI(aq)$$

***Complete ionic:***

$$K^+(aq) + NO_3^-(aq) + Na^+(aq) + I^-(aq) \rightarrow Na^+(aq) + NO_3^-(aq) + K^+(aq) + I^-(aq)$$

***Net Ionic:*** None because **no precipitate forms** and nothing can be removed as spectators.

No precipitate forms and all species remain in aqueous solution due to all species being soluble according to a solubility chart.

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## 4. Reaction between sodium hydroxide and copper(II) sulfate:

***Molecular form:***

$$2NaOH(aq) + CuSO_4(aq) \rightarrow Cu(OH)_2\downarrow + Na_2SO_4(aq)$$

***Complete ionic:***

$$2Na^+(aq) + 2OH^-(aq) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Cu(OH)_2(s) + 2Na^+(aq) + SO_4^{2-}(aq)$$

***Net Ionic:***

$$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$$

As seen above, Cu(OH)2 is the precipitate