

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 $AB + CD \rightarrow AD + CB$ 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)

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	Ions That Form Insoluble Compounds	Exceptions
Group 1 ions (Li ⁺ , Na ⁺ , etc.)		carbonate (CO ₃ ²⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
ammonium (NH ₄ ⁺)		chromate (CrO ₄ ²⁻)	when combined with Group 1 ions, Ca ²⁺ , Mg ²⁺ , or ammonium (NH ₄ ⁺)
nitrate (NO ₃ ⁻)		phosphate (PO ₄ ³⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
acetate (C ₂ H ₃ O ₂ ⁻ or CH ₃ COO ⁻)		sulfide (S ²⁻)	when combined with Group 1 ions or ammonium (NH ₄ ⁺)
hydrogen carbonate (HCO ₃ ⁻)		hydroxide (OH ⁻)	when combined with Group 1 ions, Ca ²⁺ , Ba ²⁺ , Sr ²⁺ , or ammonium (NH ₄ ⁺)
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⁺		

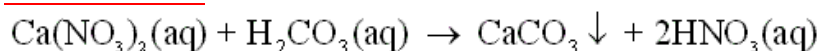
Ion	General Solubility Rule
NO ₃ ⁻	All nitrates are soluble
C ₂ H ₃ O ₂ ⁻	All acetates are soluble (AgC ₂ H ₃ O ₂ only moderately)
Cl ⁻ , Br ⁻ , I ⁻	All chlorides, bromides and iodides are soluble except Ag ⁺ , Pb ²⁺ and Hg ₂ ²⁺ . (PbCl ₂ is slightly soluble in cold water and moderatel soluble in hot 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 precipitate 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.

Predicting Products for Precipitation Reactions:

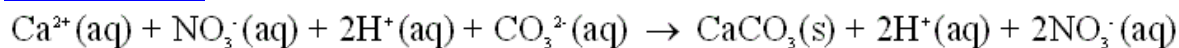
1. Take the first cation and pair it with the opposite anion.
2. Take the second cation and pair it with the opposite anion.
3. Look at a solubility chart to determine whether or not a precipitate will form and if so, what it is.
4. Balance the equation.

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

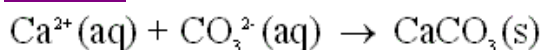
Molecular form:



Complete ionic:



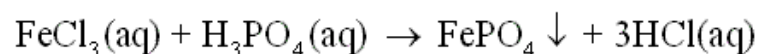
Net Ionic:



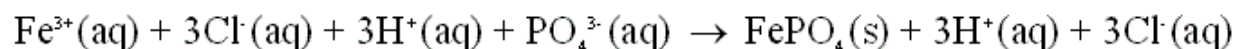
As seen above, CaCO₃ is the precipitate.

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

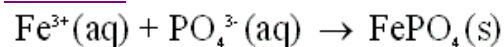
Molecular form:



Complete ionic:



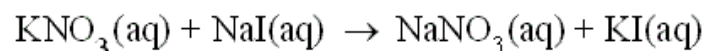
Net Ionic:



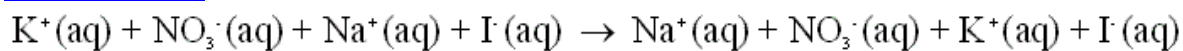
As seen above, FePO₄ is the precipitate.

3. Reaction between potassium nitrate and sodium iodide:

Molecular form:



Complete ionic:



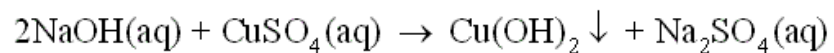
Net Ionic: None because **no precipitate forms** and nothing can be removed as spectators.

No precipitate forms and all species remain in aqueous solution due to all species being soluble

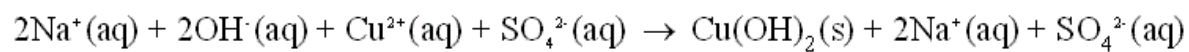
according to a solubility chart.

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

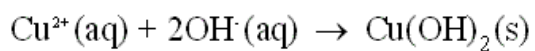
Molecular form:



Complete ionic:



Net Ionic:



As seen above, $\text{Cu}(\text{OH})_2$ is the precipitate