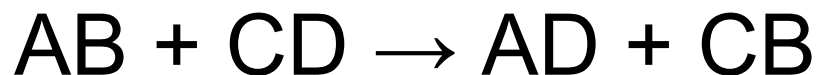


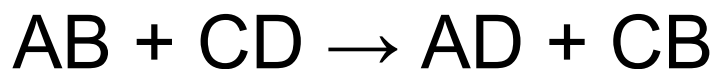
Precipitation and Double-Displacement



- Precipitation reactions belong to a general class of reactions called double-displacement reactions. Double displacement reactions have the following form. Note that the elements in two reacting compounds change partners.



Precipitation and Double-Displacement

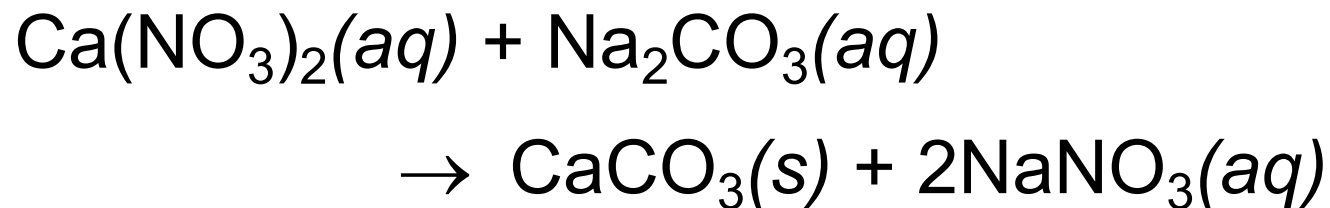


- Precipitation reactions take place between ionic compounds in solution.
- A and C represent cations, and B and D represent anions.
- The cation of the first reactant (A) combines with the anion of the second reactant (D) to form the product AD, and the cation of the second reactant (C) combines with the anion of the first reactant to form the product CB.

Precipitation Reactions



- When water solutions of calcium nitrate and sodium carbonate are combined, a reaction takes place that forms solid calcium carbonate and aqueous sodium nitrate.

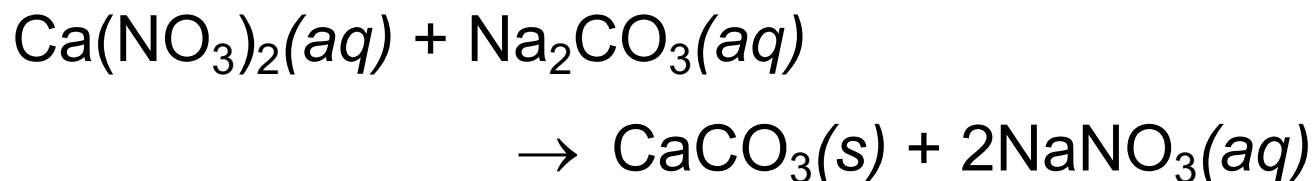


Precipitation Questions



- Describe the solution formed at the instant water solutions of two ionic compounds are mixed (before the reaction takes place).
- Describe the reaction that takes place in this mixture.
- Describe the final mixture.
- Write the complete equation for the reaction.

Precipitation Reaction



- $\text{Ca}(\text{NO}_3)_2$ and Na_2CO_3 represent ionic compounds.
- As I described in the previous lesson, when ionic compounds dissolve in water, the ions are separated, and they move throughout the liquid like any other particle in the liquid.
- Each cation is surrounded by the oxygen ends of water molecules, and each anion is surrounded by the hydrogen ends of water molecules.

Solution of $\text{Ca}(\text{NO}_3)_2$

When calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, dissolves in water, the calcium ions, Ca^{2+} , become separated from the nitrate ions, NO_3^- .

Calcium cations, Ca^{2+} , surrounded by the oxygen ends of water molecules

Nitrate anions, NO_3^- , surrounded by the hydrogen ends of water molecules

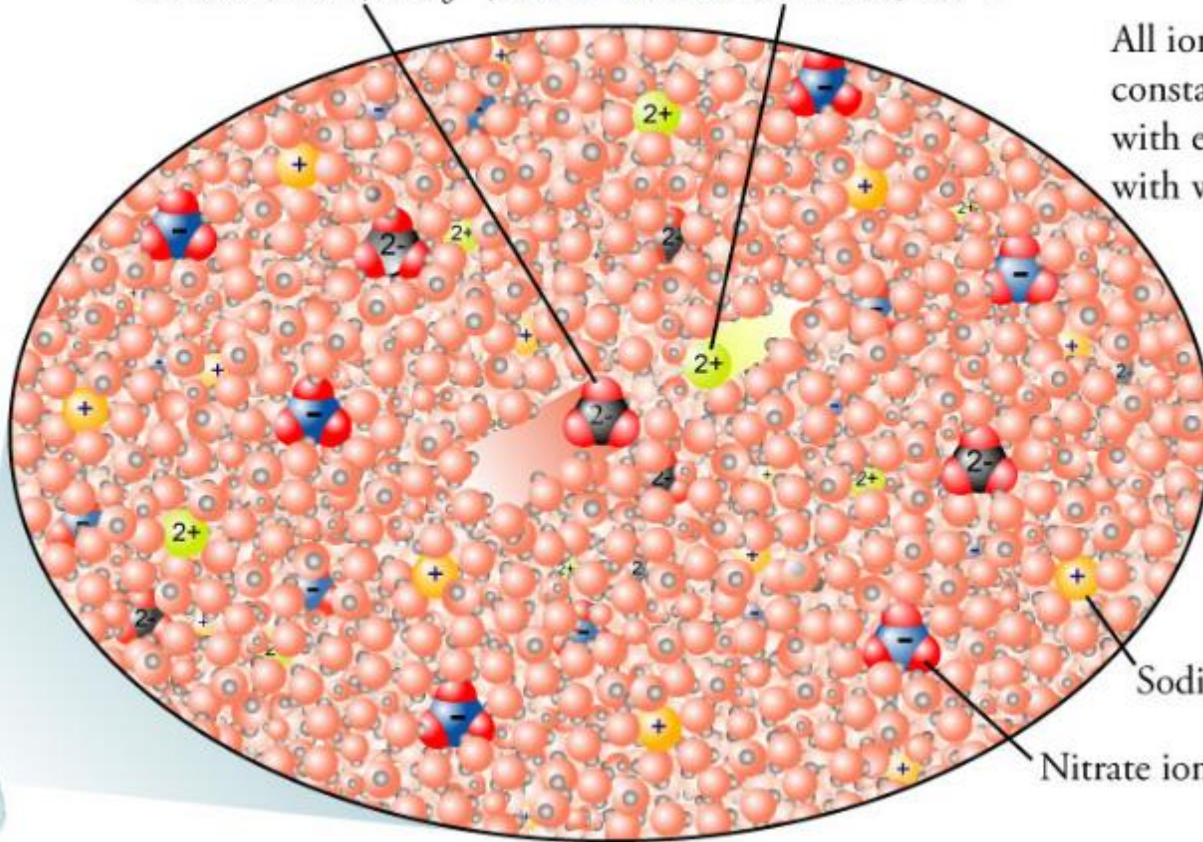


Solution of $\text{Ca}(\text{NO}_3)_2$ and Na_2CO_3 at the time of mixing, before the reaction

A sodium carbonate, Na_2CO_3 , solution is added to a calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, solution.



The precipitation reaction begins when carbonate ions, CO_3^{2-} , collide with calcium ions, Ca^{2+} .



All ions are moving constantly, colliding with each other and with water molecules.

Sodium ion, Na^+

Nitrate ion, NO_3^-

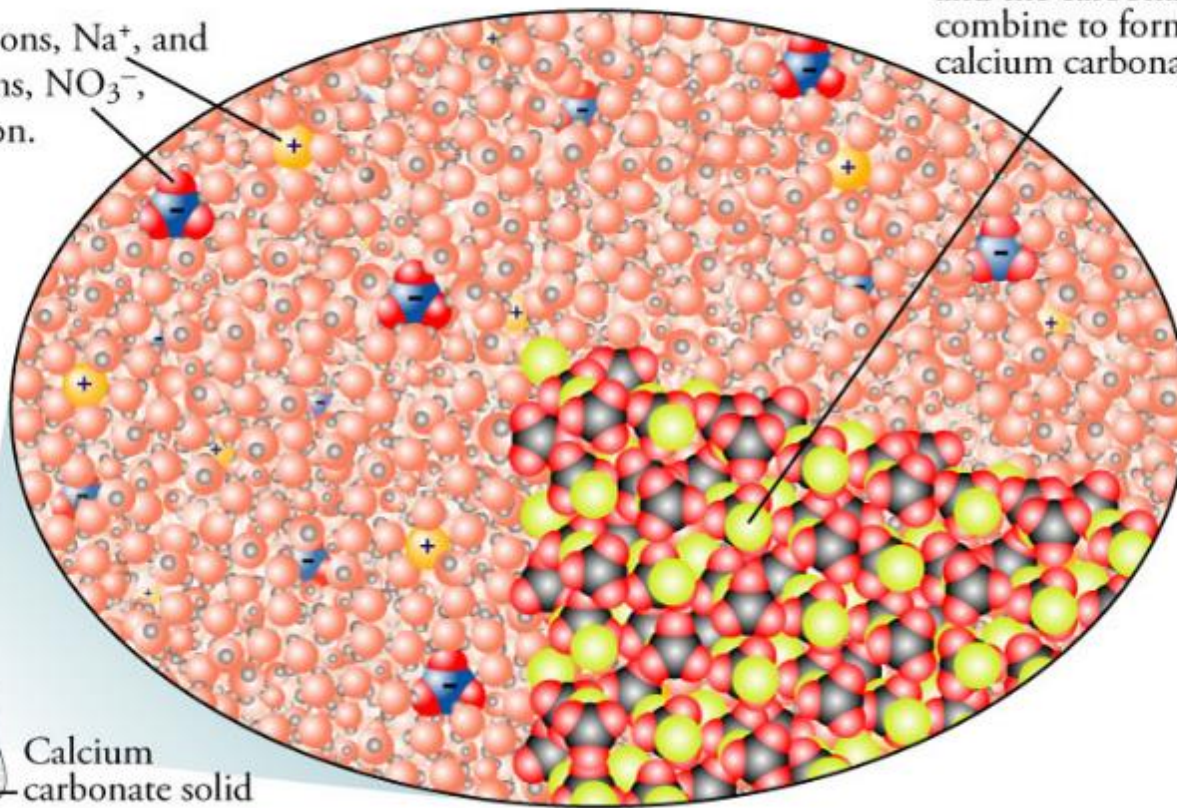
Product Mixture for the reaction of $\text{Ca}(\text{NO}_3)_2$ and Na_2CO_3

The sodium ions, Na^+ , and the nitrate ions, NO_3^- , stay in solution.

The calcium ions, Ca^{2+} , and the carbonate ions, CO_3^{2-} , combine to form solid calcium carbonate.



Calcium carbonate solid



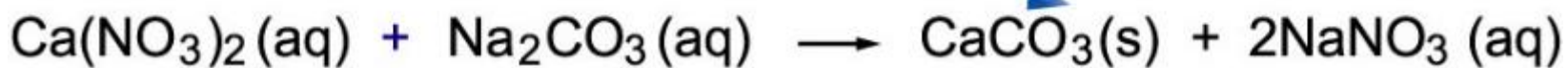
Precipitation Reactions



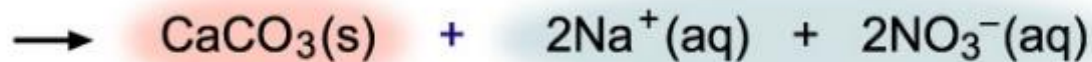
- $\text{Ca}(\text{NO}_3)_2(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq})$
 $\rightarrow \text{CaCO}_3(\text{s}) + 2\text{NaNO}_3(\text{aq})$
- The solid that comes out of solution is called a ***precipitate***.
- As the solid product forms, it emerges, or ***precipitates***, from the solution.
- In a reaction for which one product is insoluble in water and thus precipitates from the solution is called a ***precipitation reaction***.

Complete Ionic Equation

This solid precipitates from the solution. It is a precipitate.



Described as separate ions.



Solid precipitate

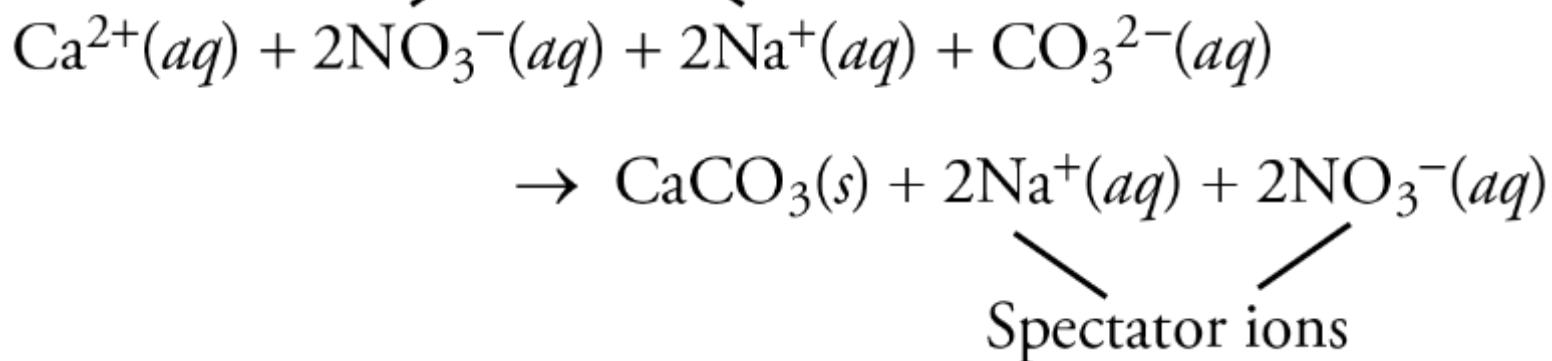
Described as separate ions.

Spectator Ions

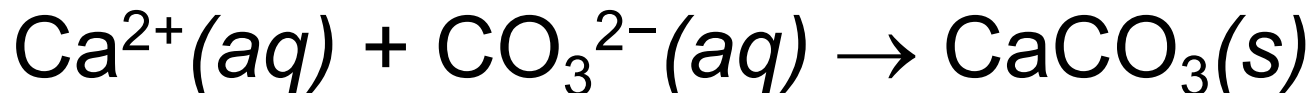
- Ions that are important for delivering other ions into solution but that are not actively involved in the reaction are called ***spectator ions***.
- Spectator ions can be recognized because they are separate and surrounded by water molecules both before and after the reaction.

Net Ionic Equations

Spectator ions are eliminated.



- An equation written without spectator ions is called a ***net ionic equation***.



Animation



- Precipitation reaction animation

https://preparatorychemistry.com/precipitation_Canvas.html

Writing Precipitation Equations

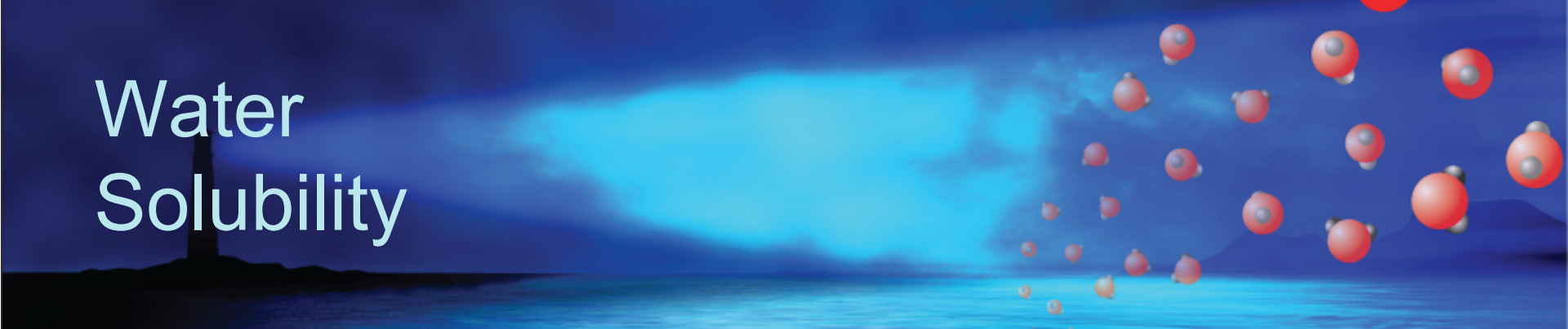


- **Step 1:** Determine the formulas for the possible products using the general double-displacement equation.



- **Step 2:** Predict whether either of the possible products is water insoluble. If either possible product is insoluble, a precipitation reaction takes place, and you may continue with step 3. If neither is insoluble, write “No reaction”.

Water Solubility



- Ionic compounds with the following ions are soluble.
 - NH_4^+ , group 1 metal ions, NO_3^- , and $\text{C}_2\text{H}_3\text{O}_2^-$
- Ionic compounds with the following ions are usually soluble.
 - Cl^- , Br^- , I^- except with Ag^+ and Pb^{2+}
 - SO_4^{2-} except with Ba^{2+} and Pb^{2+}
- Ionic compounds with the following ions are insoluble.
 - CO_3^{2-} , PO_4^{3-} , and OH^- except with NH_4^+ and group 1 metal cations
 - S^{2-} except with NH_4^+ and group 1 and 2 metal cations

Writing Precipitation Equations (cont)

- **Step 3:** Follow these steps to write the complete equation.
 - Write the formulas for the reactants separated by a “+”.
 - Separate the formulas for the reactants and products with a single arrow.
 - Write the formulas for the products separated by a “+”.
 - Write the physical state for each formula.
 - The insoluble product will be followed by (s).
 - Water-soluble ionic compounds will be followed by (aq).
 - Balance the equation.

Example 1 – Step 1

- Predict whether a precipitate will form when water solutions of silver nitrate, $\text{AgNO}_3(\text{aq})$, and sodium phosphate, $\text{Na}_3\text{PO}_4(\text{aq})$, are mixed. If there is a precipitation reaction, write the complete equation that describes the reaction.
- **Step 1:** Determine the formulas for the possible products using the general double-displacement equation.



Example 1 – Step 1


- Divide AgNO_3 (AB) and Na_3PO_4 (CD) into ions represented by A, B, C, and D, which are Ag^+ , NO_3^- , Na^+ , and PO_4^{3-} .
 - You need to have memorized the formulas, including charges, for the nitrate and phosphate ions.
 - Because the nitrate ion is minus one, and because there's only one Ag for each NO_3^- , the charge on Ag must be +1.
 - Because Na is in Group 1 on the periodic table, its charge must be +1.
 - Note that the three plus one sodium ions for each one phosphate ion reminds you that phosphate ions must have a -3 charge.

Example 1 – Step 1



- If A is Ag^+ and D is PO_4^{3-} , AD is Ag_3PO_4 .
- If C is Na^+ and B is NO_3^- , CB is NaNO_3 .

Practice Predicting Water Solubility



- There is a tool on the textbook's website that will help you to practice predicting ionic solubility in water.

https://preparatorychemistry.com/ionic_solubility_Canvas.html

Example 1 – Step 2

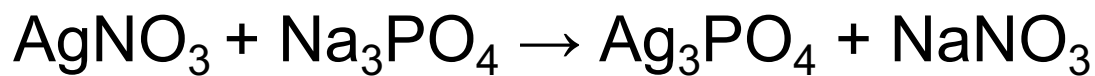
- **Step 2:** Predict whether either of the possible products (Ag_3PO_4 and NaNO_3) is water-insoluble.
- Compounds that contain the phosphate ion are insoluble in water except with group 1 metallic ions and ammonium ions.
- Silver is not in group 1 and its not ammonium, so Ag_3PO_4 is insoluble.
- Ionic compound containing group 1 metals, such as sodium, and with nitrate ions are water soluble, so NaNO_3 is soluble.
- Because Ag_3PO_4 is insoluble, we know that there is a precipitation reaction, so we go on to Step 3.

Example 1 – Step 3

- **Step 3:** Follow these steps to write the complete equation.
 - Write the formulas for the reactants separated by a “+”.
$$\text{AgNO}_3 + \text{Na}_3\text{PO}_4$$
 - Separate the formulas for the reactants and products with a single arrow.
$$\text{AgNO}_3 + \text{Na}_3\text{PO}_4 \rightarrow$$
 - Write the formulas for the products separated by a “+”.
$$\text{AgNO}_3 + \text{Na}_3\text{PO}_4 \rightarrow \text{Ag}_3\text{PO}_4 + \text{NaNO}_3$$

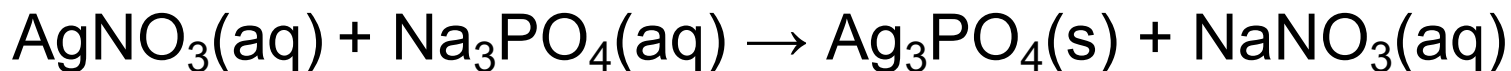
Example 1 – Step 3 (cont.)

- **Step 3 (cont.):** Follow these steps to write the complete equation.

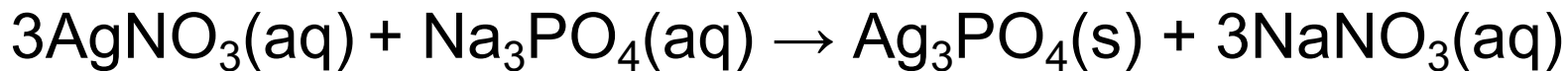


– Write the physical state for each formula.

- The insoluble product will be followed by (s).
- Water-soluble ionic compounds will be followed by (aq).



– Balance the equation.



Skills to Master (1)



- Convert between names and symbols for the common elements.
- Identify whether an element is a metal or a nonmetal.
- Determine the charges on many of the monatomic ions.
- Convert between the name and formula for polyatomic ions.

Skills to Master (2)



- Convert between the name and formula for ionic compounds.
- Balance chemical equations.
- Predict the products of double displacement reactions.
- Predict ionic solubility.