4.5 - Precipitate Reactions and Selective Precipitation

pg 458-464 in Health
pg 292-294 in Matter and Change

- Lead Nitrate and Potassium Iodide are ionic solids that are soluble in water.

- If a solution of $Pb(NO_3)_2$ and a solution of KI are combined, bright yellow crystals form and will eventually "settle out" on the bottom.*(Water is not a reactant, but a medium for solvating individual ions, thus does not appear in the chemical equation).*

$$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_2 + 2KNO_3$$

Use the solubility table to decide which of the products will form a solid and which will be aqueous and the write a net ionic equation to show.

PbI_2 : **has low solubility in water so will likely form a precipitate**
KNO_3 : **is soluble in water so will not form a solid**

- Showing the actual nature of the reactants and product ions involved in a reaction would be a more accurate representation.

- The reaction above could be rewritten as:

$$Pb^{2+}_{(aq)} + 2(NO_3)^-_{(aq)} + 2K^+_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2(s)} + 2K^+_{(aq)} + 2NO_3^-{}_{(aq)}$$

- The ions $K^+_{(aq)}$ and $NO_3^-{}_{(aq)}$ remain unchanged in the reaction; they are called spectator ions. To simplify the reaction representation, spectator ions may be deleted from the ionic equation.

- The resultant representation is called the net ionic equation and it only shows the reacting species.

A **precipitate** is a solid that forms when two aqueous solutions are mixed together.

They result because the compound formed is insoluble in water.

In general, precipitates form during a double replacement reaction.

- In a double replacement reaction, the reactants will both be aqueous.
- A reaction will **only** take place if at least one of the products is a solid (a precipitate).
- A solubility table will be needed to check the solubility of each product.

If a precipitate is formed, we are only interested in the ions in the reactants that form the precipitants.

The chemical equation showing only the ions that make up the precipitate is called a **net ionic equation**.

Ex) If aqueous zinc bromide and aqueous silver nitrate are mixed together, does a reaction take place? Write the net ionic equation if there is a reaction.

If no precipitate forms, then no reaction actually takes place because all the ions remain in the solution.

In this case, all the ions would be considered spectators.

Ex) Write a balanced equation for the following reactants. Then, write the net ionic equation. Identify all spectator ions.

a) copper (II) sulfate and sodium hydroxide

b) magnesium bromide and sulfuric acid

Selective precipitation (or qualitative analysis) is a method we can use to separate mixtures of ions one at a time from a mixture containing many soluble substances.

For example, imagine we mixed $Ba(NO_3)_2$, and $Pb(NO_3)_2$ together in a beaker.

Since any cation bonded to NO_3^- makes a soluble substance, NO_3^- would be considered a spectator ion when we mix these two substances together (thus, we no longer need to consider them).

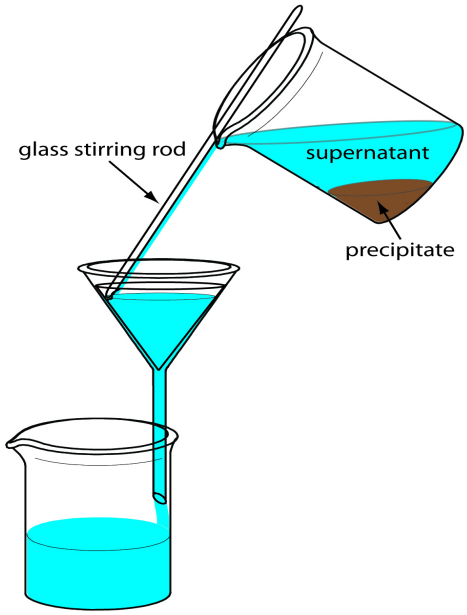
Ignoring the NO_3^- we basically have a beaker full of Ba^{2+} and Pb^{2+}

What we want to do now, is add aqueous solutions that will form a precipitate with each of the cations above **one at a time.**

When a precipitate is formed, we can filter it out of the solution because it is solid. The original beaker now has one less ion in it. This process is continued until no ions are left.

Pb^{2+} forms an insoluble precipitate with Cl^-, Br^- and I^- but Ba^{2+} does not; thus we can use substances like NaBr, NaCl, and NaI to cause the Pb^{2+} ions in our beaker drop out of it. Since the Na^+ ions are soluble with everything, it too is a spectator ion. The precipitate can then be filtered off.

Ba^{2+} ions can be precipitated by adding sulfate (Na_2SO_4), phosphate ($Na_3(PO_4)_2$), carbonate(Na_2CO_3) or sulfite ions(Na_2SO_3).



Therefore, we are basically adding anions one at a time to make precipitates with the cations in the beaker.

Ex 2) imagine we mixed $Sr(NO_3)_2$, $Cu(NO_3)_2$, and $Mg(NO_3)_2$ together in a beaker.

We can use three substances like Na $_2$S, Na_2SO_4, and NaOH one at a time to make specific cations in our beaker drop out of it.

Since the Na^+ ions are soluble with everything, it too is a spectator ion. Therefore, we are basically adding anions one at a time to make precipitates with the cations in the beaker.

The order that we add the sodium compounds is crucial because the anions may be insoluble with more than one of the cations in the beaker.

We can use a chart like the following to help us determine the correct order.

	Sr^{2+}	Cu^{2+}	Mg^{2+}
S^{2-}			
SO_4^{2-}			
OH^-			

In each box, fill in ppt if the two will form a precipitate and fill in sol if they will be soluble.

Once this chart is filled out it will be easy to determine the order, as well as each precipitate that will form.

So, what is the correct order of the substances, and what precipitate will form for each step?

2.5 – Precipitate Reactions and Selective Precipitation Assignment

Part A: Net Ionic Equations

Write the balanced and net-ionic equation for the following double replacement reactions. Note that all reactants are aqueous. All states must be shown. If a reaction does not occur you must indicate that and a balanced equation is not necessary.

1) Potassium phosphate and calcium nitrate.

2) Barium chloride and sodium sulfate.

3) Sodium acetate and silver nitrate.

4) Hydrochloric acid and copper (II) nitrate

5) Calcium iodide and potassium carbonate.

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Part B Selective Precipitation

1. An aqueous solution containing the following cations: Ca^{2+} Ag^{+} Cu^{2+} K^{+}

In order to separate them, the following solutions are available: Na_2S Na_2CO_3 NaBr

If we wish to separate the cations by causing only one cation to precipitate out of solution at a time:

a) in what order should the solutions Na_2S, Na_2CO_3, and NaBr be added?

b) identify the three precipitates that form after the addition of those solutions.

c) which one cation will remain in solution?

2. We wish to separate the cations from a mixture containing the following solutions:

$Ra(NO_3)_2$, $Mg(NO_3)_2$, and $AgNO_3$

In order to do so we are given the following separate solutions: **K_2SO_4, K_2S, and KOH**

In what order should we add the separate solutions in order to remove the cations by selective precipitation? List the precipitates that form, in the proper order.

3. You want to separate the followings cations from a solution: Be^{2+}, Sr^{2+}, and Ag^{+}. If you are given NH_4Br, Na_2SO_3, and H_2SO_4, list the order the substances must be added and the precipitates that form in each step.

4. Choose your own Solutions!

An aqueous solution contains a mixture of Ba^{2+}, Pb^{2+} and Ca^{2+}. List 3 substances that can be added in the correct order such that 1 cation will precipitate out at a time. List the precipitate that forms in each step.