Precipitation Reactions

Precipitation Reactions occur when cations and anions of aqueous solutions combine to form an insoluble ionic solid, called a**precipitate**. Whether or not such a reaction occurs can be determined by using the **solubility rules** for common ionic solids. Since not all aqueous reactions form precipitates, one must consult the solubility rules before determining the state of the products and writing a **net ionic equation.** Being able to predict these reactions allows scientists to calculate what ions are present in a solution, and allows industries to form chemicals by extracting certain elements from these reactions.

Properties of Precipitates

Precipitates are insoluble ionic solid products of a reaction, in which certain cations and anions combine in an aqueous solution. The determining factors of the formation of a precipitate can vary. Some reactions depend on temperature, such as solutions used for buffers, while others are dependent only on solution concentration. The solids produced in precipitate reactions are crystalline solids. This solid can be suspended throughout the liquid or fall to the bottom of the solution. The fluid that remains is called the supernatant liquid. The two parts (precipitate and supernate) can be separated by various methods, such as filtration, centrifuging, or decanting.

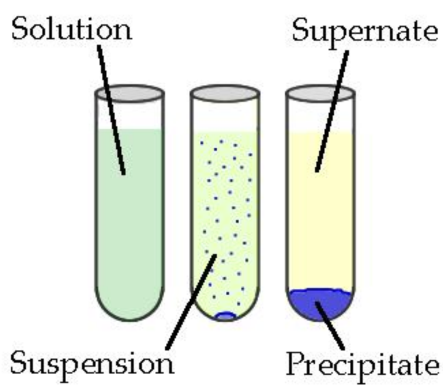

Figure 1: Above is a diagram of the formation of a precipitate in solution.

Precipitation and Double Replacement Reactions

In order to use these solubility rules, one first must understand the way that ions react. Most precipitation reactions that occur are single replacement reactions or double replacement reactions. A double replacement reaction occurs when two ionic reactants dissociate and bond with the respective anion or cation from the other reactant. The ions replace each other based on their charges as either a cation or an anion. This can be thought of as "switching partners," that is, the two reactants "lose" their partner and form a bond with a different partner:

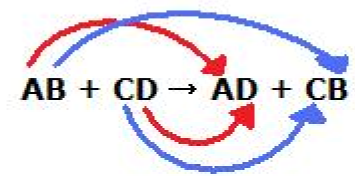

Figure 2: A double replacement reaction

A double replacement reaction is specifically classified as a **precipitation reaction** when the chemical equation in question occurs in aqueous solution and one of the of the products formed is insoluble. An example of a precipitation reaction is as follows:

$$\mathbf{CdSO_4(\textit{aq}) + K_2S(\textit{aq}) \rightarrow CdS(\textit{s}) + K_2SO_4(\textit{aq})}$$

As you can see, both of the reactants are aqueous and the one of the products is solid. Because the reactants are ionic and they are aqueous, i.e. in water, means that these reactants will dissociate and thus are **soluble**. However, there are six solubility guidelines that help us predict which molecules are insoluble in water. These molecules will form a solid precipitate in solution.

Solubility Rules

Whether or not a reaction will form a precipitate is dictated by the solubility rules. These rules provide us with the guidelines that tell which ions form solids and which remain in their ionic form in aqueous solution. The rules are to be followed from the top down, meaning that if something is insoluble (or soluble) due to rule 1, it has precedence over a higher-numbered rule, for example rule 4.

1. **Salts formed with group 1 cations and NH_4^+ cations are soluble. There are some exceptions for certain Li^+ salts.**
2. **Acetates ($C_2H_3O_2^-$), nitrates (NO_3^-), and perchlorates (ClO_4^-) are soluble.**
3. **Bromides, chlorides, and iodides are soluble**
4. **Sulfates (SO_4^{2-}) are soluble with the exception of sulfates formed with Ca^{2+}, Sr^{2+}, and Ba^{2+}.**
5. **Salts containing silver, lead, and mercury (I) are insoluble.**
6. **Carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), sulfides, oxides, and hydroxides (OH^-) are insoluble. Sulfides formed with group 2 cations and hydroxides formed with calcium, strontium, and barium are exceptions to the rule.**

If the rules state that an ion is soluble, then it will remain in its aqueous ion form. If an ion is insoluble based on the solubility rules, then it will form a solid with an ion from the other reactant in an equation. If all the ions in a reaction are shown to be soluble, then no precipitation reaction occurs.

Net Ionic Equations

To understand the definition of a **net ionic equation**, let's look back on the equation for the double replacement reaction. Because this particular reaction is a precipitation reaction, we can assign states of matter to each variable pair.

$$\mathbf{AB(\mathit{aq}) + CD(\mathit{aq}) \rightarrow AD(\mathit{aq}) + CB(\mathit{s})}$$

The first step to writing a net ionic equation is to separate the soluble (aqueous) reactants and products into their respective cations and anions. Precipitates, as we know, do not dissociate in water, so do not separate the solid into its ions. The resulting equation would look like this:

$$\mathbf{A^{+}(\mathit{aq}) + B^{-}(\mathit{aq}) + C^{+}(\mathit{aq}) + D^{-}(\mathit{aq}) \rightarrow A^{+}(\mathit{aq}) + D^{-}(\mathit{aq}) + CB(\mathit{s})}$$

In the equation above, **A^+** and **D^-** ions are present on both sides of the equation. These are called **spectator ions** because they remain unchanged throughout the reaction. Since they go through the equation unchanged, they can be eliminated to show the **net ionic equation**:

$$\mathbf{C^{+}(aq) + B^{-}(aq) \rightarrow CB\ (s)}$$

The net ionic equation only shows the precipitation reaction. A net ionic equation must be balanced on both sides not only in terms of atoms of elements but also in terms of electric charge. Precipitation reactions are usually represented solely by their net ionic equation. If all products are aqueous, a net ionic equation cannot be written because all ions are cancelled out as spectator ions. Therefore, **no precipitation reaction occurs.**

Applications

Precipitation reactions are useful for finding out whether or not a certain element is present in a solution. If one knows that a precipitate is formed when a chemical reacts to form a precipitate with lead, for example, one could test for lead in water sources by seeing if a precipitate forms. In addition, precipitation reactions can be used to extract elements, such as magnesium from seawater. Precipitation reactions even occur in our bodies between antibodies and antigens, however the environment in which this occurs is still being studied.

Source: http://chemwiki.ucdavis.edu/Inorganic_Chemistry/Reactions_in_Aqueous_Solutions/Precipitation_Reactions