Precipitations Reactions

There are many common types of reactions that occur in aqueous solutions. The precipitation reaction is one of them, which *results in the formation of precipitate (insoluble product).* Therefore, the ***precipitate*** *is the insoluble solid that forms during the chemical reaction and separates out in solution*. For example, when an aqueous solution of silver nitrate ($AgNO_3$) is added to the aqueous solution of sodium chloride (NaCl), a white precipitate of silver chloride (AgCl) is formed that is indicated by the following chemical reaction.

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

Sodium chloride (NaCl) remains in solution meaning that exits as a sodium ion (Na^+) and a chloride ion (Cl^-). This type of equation is called **molar equation** because it is written in terms of molecular formulas. This type of representation is useful in two ways (a) to identify the reagents, and (b) to carry out the experiment in the laboratory because this identifies reagents to be used. However, the molecular equation is a gross representation of the chemical reaction on a macroscopic level, and it does not give any accurate picture of the chemical reaction at a microscopic level.

Ionic compounds dissociate into ions when dissolved in water (aqueous solution). To be more realistic, the chemical equation should show the dissociated ions of the compounds. After all, only ions, not compounds, are involved in the reaction. Now, we can rewrite the above equation in terms of ions for all the compounds except AgCl because it is the resulting solid that cannot be broken up into ions.

$$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$$

This equation is known as the **total ionic equation** that is written in terms of ions with proper charges except the solid. The examination of the above total ionic equation reveals that some ions, like Na^+ and NO_3^-, did not participate in the reaction because they exist on both sides of the equation. These ions are labeled as spectator ions**.** ***Spectator ions*** *do not participate in the chemical reaction,* but they are simply staying there to watch the reaction, just like, you going to the ball game and watching the game. You do not participate in the game, but you watch the game; you are a spectator not a player. Therefore, we do not need the specter ions and they can be cancelled out on both sides.

$$Ag^+(aq) + \cancel{NO_3^-}(aq) + \cancel{Na^+}(aq) + Cl^-(aq) \rightarrow AgCl(s) + \cancel{Na^+}(aq) + \cancel{NO_3^-}(aq)$$

Now we can rewrite the above equation by excluding the spectator ions.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

which is known as the **net ionic equation,** which shows only the species (ions) responsible for the reaction.

The chemical reaction in the above equation is the formation of silver chloride solid. In this process, only the silver ion and the chloride ion react together to produce sliver chloride solid.

The above concept can also be applied to other chemical reactions where the pure liquid and the gas are formed. Consider the following examples.

When acid and base react together, they form water as a pure liquid and a soluble salt. For example, the reaction between the hydrochloric acid and sodium hydroxide is given below.

$$HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq)$$

This is a **molecular equation**. When the pure liquid like water is formed it remains intact in solution without further breaking up into ions. The **total ionic equation** for this reaction is,

$$H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$$

As you can see, this reaction has two spectator ions (Na^+, Cl^-) because they appear on both sides of the equation, hence they can be cancelled.

$$H^+(aq) + \cancel{Cl^-}(aq) + \cancel{Na^+}(aq) + OH^-(aq) \rightarrow H_2O(l) + \cancel{Na^+}(aq) + \cancel{Cl^-}(aq)$$

The **net ionic equation** eliminating the spectator ions assumes

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

which indicates the formation of water from hydrogen ion and hydroxide ion.

The reaction between the potassium sulfide (K_2S) and hydrochloric acid (HCl(aq)) involves the formation of hydrogen sulfide (H_2S) gas and soluble potassium chloride (KCl) salt. The **molecular equation** for this reaction is

$$K_2S(aq) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2S(g)$$

This equation can be converted into **total ionic equation** by writing the ions for each compound except H_2S because it is in the form of gas (remember that when the gas is formed, it cannot be broken down into ions just like precipitate and pure liquid). Thus,

$$2K^+(aq) + S^{2-}(aq) + 2H^+(aq) + 2Cl^-(aq) \rightarrow 2K^+(aq) + 2Cl^-(aq) + H_2S(g)$$

Cancelling the spectator ions leaves the **net ionic equation** as,

$$S^{2-}(aq) + 2H^+(aq) \rightarrow H_2S(g)$$

Things to Remember

- You should know how to break up the compounds into ions – monatomic or polyatomic.
- You should also know the proper charges on the ions, whether monatomic or polyatomic.
- If the solid, the pure liquid or the gas is formed in the reaction, do not break that into ions- leave that chemical formula the way it is.