Molecular and Ionic Equations

The chemical equations used in the early part of any chemistry course are always in **molecular form**. This simply means that the formulas for all substances, including ionic compounds, are written as if those substances existed as neutral molecules, i.e., no charges are shown. Equations 1 through 4 are examples.

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)} \quad (1)$$

$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)} \quad (2)$$

$$3CuCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Cu_3(PO_4)_{2(s)} + 6NaCl_{(aq)} \quad (3)$$

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} \quad (4)$$

This is the appropriate form for reactions in the gas phase, such as Reacton 1, above, since in these cases the reactants and products are almost always present in the form of neutral molecules, but for a great number of reactions in aqueous, i.e., water, solution this form is less appropriate. The reason is that usually at least one of the substances that take part in the reaction is an **electrolyte**.

Definition: **Electrolyte** – a substance that produces ions in aqueous solution

An electrolyte always exists partially or, in many cases entirely, as *ions* in aqueous solution. Equations 2 through 4, above, all represent examples of this type of reaction. In fact, *nearly all* reactions in aqueous solution involve electrolytes. For such reactions it is more descriptive to write the chemical equation in *ionic form*. In this type of equation we write the formulas of substances that are present mainly in the form of separate ions *as* ions. Here is an example of an **ionic equation** for a reaction.

$$Ba^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow BaSO_{4(s)} \quad (5)$$

Definition: **Ionic equation** – an equation for a chemical reaction in which all substances that exist mainly as separate ions in aqueous solution are shown in that form

Note that the ions in solution are written *as* ions, while the insoluble product is written in molecular form. This is an example of a **precipitation reaction**. The insoluble product is called a **precipitate**.

Definitions: **Precipitate** – a solid product formed by the reaction of a solution with another solution or other reagent

Precipitation reaction – a chemical reaction in which at least one precipitate is formed

We will deal with precipitation reactions in more detail later.

There are actually *two* ionic equations that may be written starting from a given molecular equation. The **complete ionic equation** (usually called simply the **ionic equation**) includes all of the atoms that are present in the balanced molecular equation. The **net ionic equation** is the one that results when the **spectator ions** (if any) are eliminated from the ionic equation.

Definition: **Spectator ion** – an ion that is present in an aqueous solution in which a reaction takes place but is not affected in any way by the reaction

If there are no spectator ions present, the ionic equation and the net ionic equation will be identical.

Equation 5, above, is a net ionic equation. Net ionic equations have very general meaning. Equation 5 tells us that whenever an aqueous solution containing barium ions is mixed with an aqueous solution containing sulfate ions, a precipitate of barium sulfate will form.

Here are the ionic equations for Reactions 2 through 4, above.

Reaction 2

Ionic equation: $SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$

Net ionic equation: $SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$

Reaction 3

Ionic equation: $3Cu^{2+}_{(aq)} + 6Cl^{-}_{(aq)} + 6Na^{+}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Cu_3(PO_4)_{2(s)} + 6Na^{+}_{(aq)} + 6Cl^{-}_{(aq)}$

Net ionic equation: $3Cu^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Cu_3(PO_4)_{2(s)}$

Reaction 4

Ionic equation: $H^{+}_{(aq)} + Cl^{-}_{(aq)} + Na^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)} + H_2O_{(l)}$

Net ionic equation: $H^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H_2O_{(l)}$

Note that in the case of Reaction 2 the two equations are identical because no spectator ions are present, while in Reactions 3 and 4 both the chloride ions and the sodium ions are spectator ions, so they are eliminated in the net ionic equations.

In a later blog I will discuss the method for converting a molecular equation to ionic form.

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