Chem 130

Chemical Reactions

This lab will provide training and practice in two important chemistry laboratory skills: making detailed qualitative observations of experiments and writing accurate chemical equations for reactions. We will be performing two major types of chemical reactions in this lab.

Precipitation Reactions: A precipitation reaction is one in which two solutions containing ions are mixed and a new compound having low solubility in water is formed and comes out of solution as a solid (precipitate.) For example, suppose a solution of $AgNO_3$ is mixed with a solution of NaCl. This reaction has the pattern of a *double displacement reaction*, which means the cations of each ionic compound trade ionic partners—the general formula of a double displacement reaction is AB + CD → AD + CB. In the example we are looking at, $Ag^+(aq)$ trades ionic partners with $Na^+(aq)$, forming AgCl and $NaNO_3$. If we look in a table of solubility rules (see your text) we find that most chloride salts are insoluble, so AgCl(*s*) will precipitate from the solution; however, most sodium and most nitrate salts are soluble, so $NaNO_3(aq)$ will remain in the solution.

A *molecular equation* is an equation in which the reactants and products are represented in their molecular forms in solution (even if their actual form is the ionic form). The molecular equation for this reaction is:

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

However, this equation does not accurately represent the states of all the reactants and products in solution. For example, $AgNO_3$, NaCl, and $NaNO_3$ are soluble in water, so their solutions actually consist of separate, solvated ions. Thus, their ionic forms should be written as follows:

$AgNO_3(aq)$ is actually $Ag^+(aq) + NO_3^-(aq)$

$NaCl(aq)$ is actually $Na^+(aq) + Cl^-(aq)$

$NaNO_3(aq)$ is actually $Na^+(aq) + NO_3^-(aq)$

A *total ionic equation* is a chemical equation in which all reactants and products are represented in their most accurate forms. Therefore, the total ionic equation describing the mixing of the two solutions in our example above is:

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

In the total ionic equation for this reaction, the $NO_3^-(aq)$ and the $Na^+(aq)$ ions are present in the reactants and are unchanged in the products. This means that they are not really involved in the reaction. Such species are called *spectator ions*. If we are interested in focusing more clearly on the reaction, we can leave out the spectator ions and write a *net ionic equation*:

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

Sometimes when two solutions containing ions are mixed, the new ion combinations are all soluble and therefore neither would precipitate. In this case we say there was no reaction because there was no net effect. For example, if you mix a solution of NaCl with a solution of KNO_3, then the products of the double displacement would be NaNO3 and KCl. When we look up the solubilities of all of the species in the solubility table, we would find that they are all soluble. Therefore, the molecular equation would be:

$$NaCl(aq) + KNO_3(aq) \longrightarrow NaNO_3(aq) + KCl(aq)$$

The total ionic equation would then be:

$$Na^+(aq) + Cl^-(aq) + K^+(aq) + NO_3^-(aq) \longrightarrow Na^+(aq) + NO_3^-(aq) + K^+(aq) + Cl^-(aq)$$

All of the ions in the reactants are present unchanged in the products; therefore, all of the ions in this reactions are spectator ions. Canceling the spectator ions removes everything from the reaction, so there is no net ionic equation and thus no reaction has occurred. The correct way to indicate this in equation form is:

$$Na^+(aq) + Cl^-(aq) + K^+(aq) + NO_3^-(aq) \longrightarrow \text{No reaction}$$

It is also, of course, possible that two solutions mixed can result in both new ion combinations being insoluble and having a double precipitation. For example, mixing a solution of $MgSO_4$ and a solution of $Ba(OH)_2$ forms $Mg(OH)_2$ and $BaSO_4$. A solubility table reveals that both products are insoluble (and that both reactants are soluble) and thus the total ionic equation is:

$$Mg^{2+}(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2OH^-(aq) \longrightarrow Mg(OH)_2(s) + BaSO_4(s)$$

Notice that this is also the net ionic equation because there are no spectator ions to cancel.

Acid-Base Reactions: In the Arrhenius definition, these reactions involve transfer of H^+ to OH^- to form water. Such reactions do not involve precipitations but do involve the formation of a new species. As with precipitation reaction, the molecular equation for an acid-base reaction has the basic pattern of a double-displacement reaction. For example, if HCl is mixed with NaOH the molecular equation is:

$$HCl(aq) + NaOH(aq) \longrightarrow HOH(l) + NaCl(aq)$$

The species HOH is just water, H_2O. Since HCl is a strong acid, when dissolved in water it really exists as hydronium ions and a negative ion.

$$HCl(aq) \text{ is actually } H_3O^+(aq) + Cl^-(aq)$$

$$NaOH(aq) \text{ is actually } Na^+(aq) + OH^-(aq)$$

The total ionic equation for this acid-base reaction then is:

$$H_3O^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \longrightarrow 2H_2O(l) + Na^+(aq) + Cl^-(aq)$$

Since $Na^+(aq)$ and $Cl^-(aq)$ are spectator ions, the net ionic equation is:

$$H_3O^+(aq) + OH^-(aq) \longrightarrow 2H_2O(l)$$

Although some acid-base reactions may be more complicated than this (for example, if the other product is a precipitate and thus no spectator ions cancel out) you will find that all strong-acid/strong-base reactions will have this portion of the net ionic equation in common—all have hydronium ions reacting with hydroxide ions to form water.

Date: ______________ CHEM 130 NAME: ____________________

Chemical Reactions

1) When a solution of lead(II) nitrate, $Pb(NO_3)_2$, is added to a solution of sodium chloride, NaCl, a precipitate forms.

   a) Predict the products that are formed (assume a double displacement reaction) and determine if either is insoluble (look at the solubility rules in your text.)

   b) Write the molecular equation for this reaction. Make sure you indicate the phase of each substance (*s*, *l*, *g*, or *aq*)

   c) Write the total ionic equation for this reaction. (Remember that the aqueous ionic substances should be represented as their ions.)

   d) What are the spectator ions in this reaction?

   e) Write the net ionic equation for this reaction.