Experiment 9

Double Displacement Reactions

Pre-Lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

- Observe double displacement reactions, including precipitation, gas evolution, and acid-base reaction.
- Write and balance the molecular equation, complete ionic, and net ionic equations for double displacement reactions.

Background

In this experiment you will observe precipitation, gas evolution, and acid-base reactions. These three types of reactions can all be classified as **double displacement reactions** in which two ionic compounds swap ions and form two new ionic compounds. An example of a general double displacement reaction is shown below where the letters A and C are cations and letters B and D are anions:

$$AB + CD \rightarrow AD + CB$$

Precipitation Reactions

In a **precipitation reaction**, one of the products of the double displacement reaction is a precipitate. A **precipitate** is a solid that is formed when two aqueous solutions are mixed. The precipitate is insoluble in water, and will cause the reaction mixture to look milky, cloudy, or hazy. After enough time as passed the small solid particles will settle at the bottom of the reaction container. If the reaction mixture remains completely clear, a precipitate has not been formed.

Example 1: Precipitation Reaction

$$Cu(NO_3)_2(aq) + 2\ NaOH(aq) \rightarrow Cu(OH)_2(s) + 2\ NaNO_3(aq)$$

Gas-Evolution Reactions

In a **gas-evolution reaction**, one of the products of the double replacement reaction is a gas. Bubbles will appear in the reaction mixture. In some gas-evolution reactions the gas is produced directly by double replacement. In other gas-evolution reactions an unstable intermediate product formed by double displacement immediately decomposes into a gas. Some examples of the decomposition of unstable intermediate products are shown below:

$$H_2CO_3(aq) \rightarrow H_2O(\ell) + CO_2(g)$$

$$H_2SO_3(aq) \rightarrow H_2O(\ell) + SO_2(g)$$

When writing the equation for a gas evolution reaction the formulas of decomposition products are written instead of the unstable intermediate reaction.

Example 2: Gas Evolution Reaction

Double displacement gives H_2CO_3(aq), an unstable intermediate product H_2CO_3:

$$K_2CO_3(aq) + 2\ HNO_3(aq) \rightarrow 2\ KNO_3(aq) + H_2CO_3(aq)$$

Replace $H_2CO_3(aq)$ with $H_2O(\ell)$ and $CO_2(g)$ for the final equation:

$$K_2CO_3(aq) + 2\ HNO_3(aq) \rightarrow 2\ KNO_3(aq) + H_2O(\ell) + CO_2(g)$$

Acid-Base Reactions

In an **acid-base reaction**, an acid and a base react to form water and a salt. The H^+ from the acid and the OH^- from the base combine to form liquid water. The anion from the acid and the cation from the base make the salt. A salt is an ionic compound that usually dissolves in water. If the salt is soluble then it may look like no reaction has happened. However, heat is given off when water is formed. The increase in temperature of the reaction mixture indicates a reaction has occurred.

Example 3: Acid-Base Reaction

$$\underset{(acid)}{HNO_3(aq)} + \underset{(base)}{NaOH(aq)} \rightarrow \underset{(water)}{H_2O(\ell)} + \underset{(salt)}{NaNO_3(aq)}$$

Making Observations

In this experiment you will make twelve reaction mixtures and record your observations about each mixture. One four possibilities will result from each reaction mixture:

1. A precipitate is formed (a precipitation reaction happened)
2. Bubbles are formed (a gas-evolution reaction happened)
3. The reaction mixture gets hotter (an acid-base reaction happened)
4. Nothing happens! (no reaction has occurred)

It is important to note that some of the reaction mixtures in this experiment will **not** result in a reaction. Although it is easy to see if a precipitate or bubbles form, it is important to check any mixtures where nothing appears to happen for a temperature change as instructed in the procedure.

Predicting Products and Writing Reactions for Double Displacement Reactions

In this experiment you will predict the products of double displacement reactions using the formulas of the reactants. When the solutions of the two soluble ionic compounds react the cation from one reactant will pair with the anion from the second reactant and vice versa. An example for predicting the formulas of the products is shown at the end of this section.

If either of the two new possible compounds result in an insoluble ionic compound (a precipitate), a gas, or water, then a reaction has occurred. If both possible products are soluble ionic compounds then no reaction has occurred.

To determine if an ionic compound is soluble, use the solubility rules shown in the box below. Use the rules in order and only use the first rule that applies to the compound.

Solubility Rules

1. A salt is soluble if it contains NH_4^+, Li^+, Na^+, K^+, NO_3^-, or $C_2H_3O_2^-$
2. A salt is soluble if it contains Cl^-, Br^-, or I^- *unless* it also contains Ag^+ or Pb^{2+}
3. A salt is soluble if it contains SO_4^{2-} *unless* it also contains Ba^{2+}, Pb^{2+}, Ca^{2+}, or Sr^{2+}
4. Strong acids such as HCl, HBr, HI, HNO_3, and H_2SO_4 are soluble.
5. If none of the rules above apply, the compound is insoluble or does not dissociate into ions.

Example 4: Predicting the Products of a Double Replacement Reaction

Predict the formulas of the products formed when solutions of $Pb(NO_3)_2$ and KI are mixed.

Step 1: Determine the ions that each reactant forms when it dissolved in water.

$Pb(NO_3)_2$ makes Pb^{2+} and NO_3^-

KI makes K^+ and I^-

Step 2: Exchange ions so that the cation with one reactant is paired with the anion from the other. Balance charges of combined ions to get the formula of each product.

Pb^{2+} and I^- form PbI_2

K^+ and NO_3^- form KNO_3

Step 3: Determine the solubility of each product in water using the solubility rules.

PbI_2 is insoluble according to Rule 2 of the solubility rules

KNO_3 is soluble according to Rule 1 of the solubility rules

There are three different ways to write a balanced chemical equation to describe a double displacement reaction: the molecular equation, the complete ionic equation, and the net ionic equation.

In the **molecular equation** all the reactants and products are represented as neutral chemical compounds.

In the **complete ionic equation**, all the reactants and products are written as they are actually exist in solution. Soluble ionic compounds (compounds with(aq) written after the formula) are written as ions. Any solids, liquids, or gases in the molecular equation are not changed. **Spectator ions** are ions that appear on both sides of the arrow in the complete ionic equation.

In the **net ionic equation**, the spectator ions have been removed from the complete ionic equation and only the chemical species that participate in the formation of the solid, liquid, or gas are shown.

Example 5: Predicting the Products of a Double Replacement Reaction

Write the molecular, complete ionic, and net ionic equation for the that occurs when solutions of $Pb(NO_3)_2$ and KI are mixed.

Predict the possible products by swapping the cation and anion partners for the reactants and check if an insoluble compound, a gas, or water is formed. We have already determined the products for this reaction in Example 4.

The products are $PbI_2(s)$ and $KNO_3(aq)$.

Molecular Equation: If one of the products is insoluble, a gas, or water, write the formulas and states of all reactants and products and balance the equation. If both the products are both soluble then no reaction has happened; write NO REACTION next to the arrow on the product side.

Molecular Equation:
$Pb(NO_3)_2(aq) + 2\ KI(aq) \rightarrow PbI_2(s) + 2\ KNO_3(aq)$

Complete Ionic Equation: All aqueous compounds must be written as ions in solution. Be sure to include the correct charge on all ions. Include the physical state for all chemical species.

Complete Ionic Equation:
$Pb^{2+}(aq) + \underline{2\ NO_3^-(aq)} + \underline{2\ K^+(aq)} + 2\ I^-(aq) \rightarrow PbI_2(s) + \underline{2\ K^+(aq)} + \underline{2\ NO_3^-(aq)}$

Net Ionic Equation: Rewrite the complete ionic equation *without the spectator ions*. The spectator ions have been underlined in the complete ionic equation above.

Net Ionic Equation:
$Pb^{2+}(aq) + 2\ I^-(aq) \rightarrow PbI_2(s)$

Procedure

Safety and Waste Disposal

- Wear your goggles at all times.
- Avoid contact with all solutions. Many are irritants and some can cause chemical burns. If a solution gets on your skin, immediately rinse the affected area with water for several minutes and have your partner inform your instructor.
- All reactions must be disposed of in the hazardous waste jug for this experiment. Keep a temporary waste beaker at your station to collect completed reactions. At the end of the experiment, empty your temporary waste beaker into the hazardous waste jug in the fumehood.

1. Get a spot plate from the instructor's desk. Take out the 400-mL beaker from your drawer and use a pencil to label it as your temporary waste container on the large white marking spot.

For the first eleven (11) reaction mixtures:

2. Combine three drops of each of the two solutions listed in the reaction in one well on the spot plate. Observe what happens and record your observations on your report sheet.

    Examples of observations:

    - Precipitate formed (include the color of the precipitate)
    - Bubbles formed
    - Heat was produced
    - No changes observed

3. When you run out of wells on your spot plate, empty and rinse the spot plate into your waste beaker using a small amount of water from your wash bottle.

4. *If you did not observe any changes for a reaction,* repeat the reaction in a small test tube. Use about 1 mL of each solution this time and immediately feel the outside of the test tube to determine if there has been a temperature change. Record your observations on your report sheet.

Reaction mixture 12 must be made a fume hood:

5. Place about 0.5 g of solid sodium sulfite into a small test tube. *In a fume hood,* add about 2 mL of 6M HCl one drop at a time into the test tube containing the solid sodium sulfite. Record your observations.

6. Rinse the completed reactions from the spot plate and test tubes into your temporary waste beaker using a small amount of water from your wash bottle.

7. Wash the spot plate with soap and water, dry it, and return it to the instructor's desk.

8. Empty your temporary waste beaker into the large hazardous waste jug in the fumehood. Wash your waste beaker and test tubes and return them to your drawer.

9. On your report sheet, write the molecular equation (ME), complete ionic equation (CIE), and net ionic equation (NIE) for each reaction.

Experiment 9—Report Sheet

Name _____ **Date** _____

Partner's Name _____ **Lab: M T W R at** _____

1. Reaction Observations: _____

_____

ME: _____ $NaCl(aq)$ + _____ $KNO_3(aq)$ → _____

CIE: _____

NIE: _____

2. Reaction Observations: _____

_____

ME: _____ $NaCl(aq)$ + _____ $AgNO_3(aq)$ → _____

CIE: _____

NIE: _____

3. Reaction Observations: _____

_____

ME: _____ $Na_2CO_3(aq)$ + _____ $HCl(aq)$ → _____

CIE: _____

NIE: _____

4. Reaction Observations: _____

_____

ME: _____ $NaOH(aq)$ + _____ $HCl(aq)$ → _____

CIE: _____

NIE: _____

5. Reaction Observations: _____

_____

ME: _____ $BaCl_2(aq)$ + _____ $H_2SO_4(aq)$ → _____

CIE: _____

NIE: _____

6. Reaction Observations: _____

_____

ME: _____ $NH_4OH(aq)$ + _____ $H_2SO_4(aq)$ → _____

CIE: _____

NIE: _____

7. Reaction Observations: _____

_____

ME: _____ $CuSO_4(aq)$ + _____ $Zn(NO_3)_2(aq)$ → _____

CIE: _____

NIE: _____

8. Reaction Observations: _____

_____

ME: _____ $Na_2CO_3(aq)$ + _____ $CaCl_2(aq)$ → _____

CIE: _____

NIE: _____

9. Reaction Observations: _____

_____

ME: _____ $CuSO_4(aq)$ + _____ $NH_4Cl(aq)$ → _____

CIE: _____

NIE: _____

10. Reaction Observations: _____

_____

ME: _____ $NaOH(aq)$ + _____ $HNO_3(aq)$ → _____

CIE: _____

NIE: _____

11. Reaction Observations: _____

_____

ME: _____ $FeCl_3(aq)$ + _____ $NH_4OH(aq)$ → _____

CIE: _____

NIE: _____

THE FOLLOWING REACTION MUST BE DONE IN A FUMEHOOD!

12. Reaction Observations: _____

_____

ME: _____ $Na_2SO_3(aq)$ + _____ $HCl(aq)$ → _____

CIE: _____

NIE: _____

Name: _____

Pre-Lab Assignment for Double Displacement Reactions

1. Complete the double displacement reaction below by determining the formulas of the products, balancing the overall reaction, and indicating the solid that forms.

   Complete Molecular Equation:

   _____ $AgNO_3(aq)$ + _____ $CoCl_2(aq)$ → _____

2. Using your answer for question 1, write the ionic equation and net ionic equation for the above reaction.

   Complete Ionic Equation:

   Net Ionic Equation:

3. Complete the following acid- base reaction and write the ionic and net ionic equation for the reaction:

   Complete Molecular Equation:

   _____ $NaOH(aq)$ + _____ $H_3PO_3(aq)$ → _____

   Complete Ionic Equation:

   Net Ionic Equation:

4. Give three types of observations that indicate a chemical reaction has occurred.

   a. _____

   b. _____

   c. _____