EXPERIMENT #12
DOUBLE-REPLACEMENT REACTIONS

Purpose:

1. To study the most common type of double-replacement reactions.

Principles:

In double-replacement reactions, two compounds are involved in a reaction, with the positive ion (cation) of one compound exchanging with the positive ion (cation) of another compound. In other words, the two positive ions exchange negative ions (anions) or partners. Double replacement reactions are also called metathesis or double-decomposition reactions.

The following general equation represents this reaction:

$$AX + BZ \rightarrow AZ + BX$$

Double-replacement reactions will generally occur if one of the following three conditions are satisfied:

1. An insoluble or slightly soluble product (precipitate) is formed.

In these reactions, upon the mixing of two clear aqueous solutions a solid will appear in solution because one of the products formed is insoluble in water. The insoluble solid that forms may initially have the appearance as a "cloudiness" or "haziness" in solution. In time the insoluble solid will settle at the bottom of the test-tube and the evidence of a reaction taking place is always referred to as the formation of a precipitate (the color of the particular precipitate is also noted).

It must be noted the whenever a solution is not absolutely clear (see-through), this is an indication that a precipitate must be present. In common practice, chemists indicate this precipitate in an equation by including an '$_{(s)}$' as a subscript to the compound.

For example a precipitate of silver chloride will be shown as: $AgCl_{(s)}$. To recognize which of the products (if any) in a reaction is the precipitate, solubility rules or tables may be consulted (See the table on the following pages).

Example:

$$Ni(NO_3)_{2(aq)} + 2NaOH_{(aq)} \rightarrow$$

The evidence of reaction is that a green precipitate forms. The two possible products are: $Ni(OH)_{2(s)}$ and $NaNO_{3(s)}$. Using the solubility table it is found that:

$Ni(OH)_2$ ..... is insoluble I
$NaNO_3$ ..... is soluble ..... S

Thus, the balanced chemical equation and the respective word equation (indicates the names of both the reactants and the products) which represents this reaction is written as follows:

$$Ni(NO_3)_{2(aq)} + 2NaOH_{(aq)} \rightarrow Ni(OH)_{2(s)} + 2NaNO_{3(aq)}$$

nickel (II) nitrate	sodium hydroxide	nickel (II) hydroxide	Sodium nitrate

2. A weakly ionized species is produced as a product. The most common species of this type is water.

In these reactions there is no visual evidence that a reaction takes place. However these reactions give off considerable amount of heat which can be detected by feeling the test-tube. It can be therefore concluded that whenever heat is given off, a weakly ionized species is formed.

In the reactions you will perform in this experiment, the detection of heat given off will indicate the format ion of water, a typical molecular compound. The most common type of reactions which belong to this category and are performed in this experiment are one type of neutralization reactions which take place between an acid and a base with the formation of salt and water:

Acid	+	Base	→	Salt	+	Water

Example:

$H_2SO_{4(aq)}$	+	$KOH_{(aq)}$	→	$KNO_{3(aq)}$	+	$H_2O_{(l)}$
Sulfuric acid		potassium hydroxide		potassium nitrate		Water

3. A gas is formed as a product.

The visual evidence for these reactions is the appearance of bubbles in the reaction mixture. The proper chemical terminology used to indicate the evolution of a gas is "effervescence", rather than bubbling, fizzing, sizzling, etc.

The most common type of reactions which belong to these category are those in which an unstable substance forms in aqueous solution which readily decomposes further producing a gas as one of its decomposition products.

Two such substances (examples) and their decomposition products are shown below:

$$H_2CO_{3(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$$

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

Note that whenever such an unstable compound is formed in a reaction and effervescence is observed, the unstable substances are written in the form of their decomposition products.

Example:

Instead of writing the following reaction in this manner,

$$K_2CrO_{3(aq)} + HNO_{3(aq)} \rightarrow KNO_{3(aq)} + H_2CO_{3(aq)}\ (unstable)$$

It is written in a manner which shows the actual products formed:

$K_2CrO_{3(aq)}$	+	$HNO_{3(aq)}$	→	$KNO_{3(aq)}$	+	$CO_{2(g)}$	+	$H_2O_{(l)}$
potassium carbonate		nitric acid		potassium nitrate		carbon dioxide		water

TABLE: SOLUBILITIES OF IONIC COMPOUNDS*

Ions	Cl^-	Br^-	I^-	OH^-	NO_3^-	SO_4^{2-}	SO_3^{2-}	CO_3^{2-}	S^{2-}	PO_4^{3-}
Na^+	S	S	S	S	S	S	S	S	S	S
K^+	S	S	S	S	S	S	S	S	S	S
Ag^+	I	I	I	-	S	P	I	I	I	I
NH_4^+	S	S	S	-	S	S	S	S	S	S
Fe^{2+}	S	S	S	I	S	S	I	I	S	I
Ni^{2+}	S	S	S	I	S	I	I	I	I	
Mg^{2+}	S	S	S	I	S	S	S	I	-	I
Ca^{2+}	S	S	S	P	S	P	P	I	I	I
Ba^{2+}	S	S	S	P	S	I	I	I	-	I
Cu^{2+}	S	-	I	I	S	S	I	I	I	
Pb^{2+}	P	P	I	I	S	I	I	I	I	
Zn^{2+}	S	S	S	I	S	S	I	I	I	I
Al^{3+}	S	S	-	I	S	S	-	I		
Fe^{3+}	S	S	-	I	S	S	-	I	I	

Legend:

S .....Soluble
I .....Insoluble
P .....Partially soluble
- .....Unstable species
(blank) .....Lack of data

Procedure

Please note that this is a qualitative experiment.

- ✓ Each part of the experiment (except number 12) consists of mixing equal volumes of two solutions in a depression of a spot-plate.

- ✓ Add equal amounts of both reactants into the spot plate depression. Depending upon the type of dropper used, this could be a few as three and as many as twenty drops of each solution.
- ✓ Record your observation at the time of mixing.
    - Precipitate
    - Gas evolved
    - Heat evolved
    - Color change (none of the reactions in this experiment will have a color change)
    - No reaction
- ✓ Where there is no visible evidence of reaction (no precipitate formed, and no effervescence observed), determine if heat is evolved by immersing the bulb of the thermometer into the react ion mixture and carefully noting any increase in temperature (exothermic reaction).
- ✓ In each case where a reaction has occurred, complete and balance the equation properly and indicate the state designations.
- ✓ Underneath the chemical equations write the word equation, giving the proper names for all reactants and if there was a reaction the names of the products.
- ✓ Where there is no evidence of reaction, write the words "No Reaction" as the right hand side of the equation.

1. Mix **sodium chloride** (0.1 M) and **potassium nitrate** (0.1 M) solutions.
2. Mix **sodium chloride** (0.1 M) and **silver nitrate** (0.2 M) solutions.
3. Mix **sodium carbonate** 0.1 M and dilute **hydrochloric acid** (6 M) solutions.
4. Mix 10% **sodium hydroxide** and dilute **hydrochloric acid** (6 M) solutions.
5. Mix **barium chloride** (0.1 M) and dilute **sulfuric acid** (3 M) solutions.
6. Mix dilute **ammonium hydroxide** (6 M) and dilute **sulfuric acid** (3 M) solutions.
7. Mix **copper (II) sulfate** (0.1 M) and **zinc nitrate** (0.1 M) solutions.
8. Mix **sodium carbonate** (0.1 M) and **calcium chloride** (0.1 M) solutions.
9. Mix **copper (II) sulfate** (0.1 M) and **ammonium chloride** (0.1 M) solutions.
10. Mix 10% **sodium hydroxide** and dilute **nitric acid** (3 M) solutions.
11. Mix **iron (III) chloride** (0.1 M) and **ammonium hydroxide** (6 M) solutions.

DO THIS IN THE HOOD

12. Place a few crystals of solid **sodium sulfite** into the depression of a spot-plate. Add drop wise a few drops of dilute **hydrochloric acid** solution (6M) until a reaction is observed.

EXPERIMENT #12

Double Replacement Reactions

Name:_____

Date:_____

Partner:_____

Evidence of a Reaction	Equations ✓ Balanced chemical equation with state designations ✓ Word equation with correct names for both reactants and products
1. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $NaCl_{(aq)} + KNO_{3(aq)} \rightarrow$ *Word Equation*
2. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow$ *Word Equation*
3. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $Na_2CO_{3(aq)} + HCl_{(aq)} \rightarrow$ *Word Equation*
4. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $NaOH_{(aq)} + HCl_{(aq)} \rightarrow$ *Word Equation*
5. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $BaCl_{2(aq)} + H_2SO_{4(aq)} \rightarrow$ *Word Equation*

6. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $NH_4OH_{(aq)} + H_2SO_{4(aq)} \rightarrow$ *Word Equation*
7. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $CuSO_{4(aq)} + Zn(NO_3)_{2\ (aq)} \rightarrow$ *Word Equation*
8. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $Na_2CO_{3(aq)} + CaCl_{2(aq)} \rightarrow$ *Word Equation*
9. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $CuSO_{4(aq)} + NH_4Cl_{(aq)} \rightarrow$ *Word Equation*
10. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $NaOH_{(aq)} + HNO_{3(aq)} \rightarrow$ *Word Equation*
11. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $FeCl_{3(aq)} + NH_4OH_{(aq)} \rightarrow$ *Word Equation*
12. ☐ Precipitate ☐ Gas evolved ☐ Heat evolved ☐ Color Change ☐ No reaction	*Chemical Equation* $Na_2SO_{3(s)} + HCl_{(aq)} \rightarrow$ *Word Equation*

Note: *None of these reactions should have a color change. Color change is available only to remind you that color change is also an indication that a reaction takes place.*