SINGLE AND DOUBLE REPLACEMENT REACTIONS
EXPERIMENT 10

OBJECTIVE

The objective of this experiment is to observe double and single replacement reactions and to predict the activity of metals using experimental results.

EQUIPMENT AND CHEMICALS

Zinc, Copper and Lead metal strips
0.1 M Sodium carbonate [Na_2CO_3]
0.1 M Barium chloride [$BaCl_2$]
0.1 M Sodium sulfate [Na_2SO_4]
0.1 M Silver nitrate [$AgNO_3$]
0.1 M Lead (ll) nitrate [$Pb(NO_3)_2$]
0.1 M Copper (ll) nitrate [$Cu(NO_3)_2$]
0.1 M Magnesium nitrate [$Mg(NO_3)_2$]
0.1 M Zinc nitrate [$Zn(NO_3)_2$]
0.1 M Sodium chloride [$NaCl$]
0.1 M Potassium chromate [K_2CrO_4]
0.1 M Calcium chloride [$CaCl_2$]
6 M Hydrochloric acid [HCl]
6 M Sodium hydroxide [$NaOH$]
6 M Sulfuric acid [H_2SO_4]
5% Acetic acid [$HC_2H_3O_2$]
5% Sodium bicarbonate [$NaHCO_3$]
Emory cloth
Small test tubes [8]
Graduated cylinder [10 ml]
Eyedroppers
Unknowns

DISCUSSION

Chemical equations represent chemical changes (reactions) that actually occur. A chemical equation consists of two parts: 1) the reactants (starting materials), and 2) products (the resulting materials).

$$\text{Reactant A} + \text{Reactant B} \longrightarrow \text{Product A} + \text{Product B} + \text{etc......}$$

The major problem in writing a chemical equation is predicting what products will be produced in the reaction. To determine what reactions will take place, we carry out experimental work (experiments). Using the experimental data (information) obtained from the experiments, we can predict, to some extent, what chemical compounds will react with other compounds to produce products. Types of chemical equations can be classified in five types of reactions of which we will only cover three: single replacement, double replacement, and neutralization reactions.

The five types of reactions are:

- decomposition ($C \longrightarrow A + B$)
- combination ($A + B \longrightarrow C$)
- single replacement ($A + BX \longrightarrow B + AX$)
- double replacement ($ZA + BX \longrightarrow BA + ZX$)
- oxidation – reduction

SINGLE REPLACEMENT REACTIONS

In a single replacement reaction, one element reacts with a compound to produce a new compound, and displaces an element in the original compound.

$$A + BX \rightarrow B + AX$$

(single replacement reaction)

If A is a metal, it will replace the element B in the compound BS to form a new compound AX. The element B is now a free metal. The reaction will occur if A is more active than the element B. We can experimentally establish this "pecking" order. By knowing which elements are at the top of the list, we can predict whether or not a reaction will occur. The elements on the top of the list (left side) will replace any element underneath it (right side) on the list.

increasing reactivity

$\longleftarrow$

K Ca Al Fe Sn Hg Pt

For example, if Ca metal was placed in a solution of tin (ll) nitrate, the Ca would dissolve and the tin metal would come out of solution.

$$Ca + Sn(NO_3)_2 \rightarrow Sn + Ca(NO_3)_2$$

This is a typical single replacement reaction.

If the free metal is lower on the list (less reactive) than the metal attached to the anion, no reaction would occur (NR).

$$Pt + FeCl_2 \rightarrow NR$$

By setting up numerous reactions of the type, an activity series can be determined.

DOUBLE REPLACEMENT REACTIONS

In a double replacement reaction, two compounds react with each other to produce two new compounds. In this type of reaction, the metals just exchange positions.

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

(double replacement reaction)

The metal is on A replaces the metal ion B and vice versa. To determine whether a reaction takes places, some form of physical change must be observed. The most typical types of changes are:

- precipitate (solid comes out of solution)
- gas evolved (bubbles)
- change in temperature (hot or cold)
- change in colour

Sometimes reactions take place very slowly and no physical changes are rapidly observed. In this case more complicated techniques, which are out of the scope of this experiment, must be employed. Typical examples of double replacement reactions are:

$$BaCl_2 + 2AgNO_3 \longrightarrow Ba(NO_3)_2 + AgCl$$

$$HCl + ZnS \longrightarrow ZnCl_2 + H_2S$$

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O + \text{heat}$$

$$KSCN + FeCl_3 \longrightarrow FeSCN + KCl \text{ (unbalanced)}$$

(changes from yellow to deep red)

NEUTRALIZATION REACTIONS

Neutralization reactions are really double replacement reactions but are unique. Neutralization occurs when an acidic compound (contains H^+) reacts with a basic compound (OH^-) to produce a salt and water. Normally these types of reactions proceed with a change in temperature.

$$HX + BOH \longrightarrow BX + HOH$$

A typical example of this is the addition of HCl with NaOH.

$$HCl + NaOH \longrightarrow NaCl + HOH + \text{heat}$$

The salt formed is sodium chloride (NaCl) and water (HOH).

PROCEDURE

PART A - SINGLE REPLACEMENT REACTIONS

In a single replacement reaction, an element replaces another element in a compound. Evidence of reaction is a gas being evolved, a change in colour of the solution, metals being deposited on the elemental metal, or precipitates.

1. Obtain six pieces of an unknown metal from your instructor and record the unknown number on your Report Sheet.

2. Obtain six pieces of Zn metal, six pieces of Pb metal, six pieces of Cu metal, and six pieces of unknown from the chemical bench.

3. Polish each piece (including your unknown) with a piece of emory cloth. This will remove any oxides and expose the metal surfaces.

4. Label four (4) small tubes as
   (1) Zn
   (2) Pb
   (3) Cu
   (4) UNK

5. Add 5 ml of 0.1M $AgNO_3$ to each tube. Add a piece of metal to each test tube that corresponds to the label on the test tube. Allow ten minutes for each reaction. Record results on Report Sheet.

6. Label a second set of small test tubes
   (1) Zn
   (2) Pb
   (3) Cu
   (4) Unknown

7. Add 5 ml of 0.1M $Cu(NO_3)_2$ to each tube and add the metal pieces to the corresponding test tubes. Report any reactions on your Report Sheet.

8. Clean and rinse the first set of test tubes that were used in Step 4. Repeat the experiment using 5 ml of 0.1M $Pb(NO_3)_2$. Report any reactions on your Report Sheet.

9. Clean and rinse the second set of test tubes that were used in Step 6. Repeat the experiment using 5 ml of 0.1 $Mg(NO_3)_2$. Report any reactions on your Report Sheet.

10. Clean and rinse the set of test tubes used in Step 8. Repeat the experiment using 5 ml of 6M H_2SO_4. Report any reactions on your Report Sheet.

11. Clean and rinse the set of test tubes used in Step 9. Repeat the experiment using 5 ml of 0.1M $Zn(NO_3)_2$.

12. Using the data obtained from Steps 1-11, write a balanced equation for each reaction that showed evidence of a single replacement reaction. Use NR for any non-reactions.

13. Based on the data, assign an activity order to each of the metals and solutions tested.

PART B - DOUBLE REPLACEMENT REACTIONS

Double replacement reactions involve two compounds with the positive cation of one compound exchanging positions with the cation of the other compound. In order to recognize whether or not a reaction takes place, a precipitate, a change in temperature, or gas evolution must be observed.

1. Add 3 ml of 0.1M NaCl to a small test tube. Add an additional 3 ml of 0.1M $AgNO_3$ to the test tube. Observe any changes that occur and record on your Report Sheet. Remember to feel the test tube for any change in temperature.

2. Add 3 ml of 0.1M $Pb(NO_3)_2$ to a small test tube. Add an additional 3 ml of 0.1M K_2CrO_4 solution. Observe any changes and record on your Report Sheet.

3 Add 3 ml of 0.1M $CaCl_2$ to a small test tube. Add an additional 3 ml of 0.1M Na_2CO_3. Record any observations on your Report Sheet.

4. Add 3 ml of 0.1M $BaCl_2$ to the small test tube. Add an additional 3 ml of 0.1M Na_2 SO_4 and record any observations on your Report Sheet.

5. Add 3 ml of 5% $NaHCO_3$ to the small test tube. Add 3 ml of 5% acetic acid, and record any observations on your Report Sheet.

6. Add 3 ml of 6M HCl to a small test tube, and, dropwise, add an additional 3 ml of 6M NaOH. Record any observations of your Report Sheet.

7. What types of reactions did you observe in Part B?

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NAME ________________________
DATE ________________________
SECTION ______________________

SINGLE AND DOUBLE REPLACEMENT REACTIONS
REPORT SHEET
EXPERIMENT 10

SINGLE REPLACEMENT REACTIONS

1. If any evidence of a reaction occurs, place an "R" in the appropriate box. If no evidence of reaction was observed, place a "NR" in the appropriate box.

	Metal			
Compound	Zn	Pb	Cu	Unk
Ag NO_3				
$Cu(NO_3)_2$				
$Pb(NO_3)_2$				
$Mg(NO_3)_2$				
H_2SO_4				
$Zn(NO_3)_2$				

2. Using the above information write and balance an equation for each reaction that took place. If no reaction occurred, write "NR". Refer to Appendix l for valences and charges.

a) $Zn + AgNO_3 \longrightarrow$

b) $Pb + AgNO_3 \longrightarrow$

c) $Cu + AgNO_3 \longrightarrow$

d) $Zn + Cu(NO_3)_2 \longrightarrow$

e) $Pb + Cu(NO_3)_2 \longrightarrow$

f) $Zn + Pb(NO_3)_2 \longrightarrow$

g) Cu + $Pb(NO_3)_2$ $\longrightarrow$

h) Zn + $Mg(NO_3)_2$ $\longrightarrow$

i) Pb + $Mg(NO_3)_2$ $\longrightarrow$

j) Cu + $Mg(NO_3)_2$ $\longrightarrow$

k) Zn + H_2SO_4 $\longrightarrow$

l) Pb + H_2SO_4 $\longrightarrow$

m) Cu + H_2SO_4 $\longrightarrow$

n) Pb + $Zn(NO_3)_2$ $\longrightarrow$

o) Cu + $Zn(NO_3)_2$ $\longrightarrow$

3. Based on the above information, assign an activity order to each of the metals with the most active metal as number 1.

______	______	______	______	______	______
1	2	3	4	5	6

4. Where would your unknown be located in the above activity series?

DOUBLE REPLACEMENT REACTION

1. a) Describe what happens when the $AgNO_3$ solution was added to the NaCl solution?

   b) What evidence of reaction was observed?

   c) Write a balanced equation for the above reaction.

2. a) Describe what happens when the $Pb(NO_3)_2$ solution was added to the K_2CrO_4 solution.

b) What evidence of reaction was observed?

c) Write a balanced equation for the above reaction.

3. a) Describe what happens when the $CaCl_2$ solution is added to the Na_2CO_3 solution.

b) What evidence of reaction was observed?

c) Write a balanced equation for the above reaction.

4. a) Describe what happens when the $BaCl_2$ solution is added to the Na_2SO_4 solution.

b) What evidence of reaction was observed?

c) Write a balanced equation for the above reaction.

5. a) Describe what happens when the acetic acid solution is added to the sodium bicarbonate solution.

b) What evidence of reaction was observed?

c) Write a balanced equation for the above reaction.

6. a) Describe what happens when sodium hydroxide solution is added to the hydrochloric acid solution.

b) What evidence of reaction was observed?

c) Write a balanced equation for the above reaction.

7. What three types of observations indicate a reaction has taken place in Part B?

a)

b)

c)