# Single and Double Displacement Reactions

## Objectives

The objectives of this lab are:

a) To perform and observe the results of a variety of single and double displacement reactions,
b) To become familiar with some of the observable signs of these reactions,
c) To identify the products formed in each of these reactions,
d) To write balanced chemical equations for each single and double displacement reaction studied.

## Background

During a chemical reaction both the form and composition of matter are changed. Old substances are converted to new substances, which have unique physical and chemical properties of their own. Some of the observable signs that a chemical reaction has occurred include the following:

- A metallic deposit appears
- Bubbles appear
- A temperature change occurs
- A color change occurs
- A precipitate (cloudy, tiny particles) appears

Note that there are many other observable signs for chemical reactions, but these are the ones most likely to be encountered in this lab.

**Single Displacement Reactions**

All single displacement reactions have the general form: **A + BC → B + AC**

Here, A is an element and BC is usually an aqueous ionic compound or an acid (consisting of $B^+$ and $C^-$ aqueous ions). A displaces B in BC, resulting in the formation of a new element B and a new ionic compound or acid, AC. If the new element B is a metal, it will appear as a metallic deposit. If it is a gas, it will appear as bubbles.

An *Activity Series* of elements is often used to determine if A will displace B in a single displacement reaction. An *Activity Series* is provided at the end of the Background section. As a rule, if A has a higher activity that B, a single displacement reaction will occur. However, if A has lower activity than B, a single displacement reaction will not occur.

Example 1: magnesium metal + aqueous aluminum chloride

Since Mg is more active than Al, a single displacement reaction will occur. The predicted products are aluminum metal and aqueous magnesium chloride

Reaction Equation: $3\ Mg\ (s) + 2\ AlCl_3\ (aq) \rightarrow 2\ Al\ (s) + 3\ MgCl_2\ (aq)$

**Double Displacement Reactions**

All double displacement reactions have the general form: **$AB + CD \rightarrow AD + CB$**

Reactions that can be classified as double displacements include precipitation reactions, neutralization reactions and gas forming reactions.

Precipitation Reactions

Here AB and CD are usually aqueous ionic compounds (or acids) consisting of aqueous ions ($A^+$ and $B^-$, $C^+$ and $D^-$) . When a double displacement reaction occurs, the cations and anions switch partners, resulting in the formation of two new ionic compounds AD and CB, one of which is in the solid state. This solid product is an insoluble ionic compound called a precipitate. To determine whether a product ionic compound will be soluble or insoluble, consult the *Solubility Rules* provided at the end of the Background section. Note that if both of the predicted products are soluble, a precipitation reaction will not occur.

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| Example 2: | aqueous lead(II) nitrate + aqueous potassium chloride<br>The predicted products are lead(II) chloride (insoluble) and potassium nitrate (soluble). Since one of the predicted products is insoluble, a precipitation reaction is will occur.<br>Reaction Equation: $Pb(NO_3)_2\ (aq) + 2\ KCl\ (aq) \rightarrow 2\ KNO_3\ (aq) +$ **$PbCl_2\ (s)$** |

Neutralization Reactions

Here AB is an acid (consisting of $H^+$ and $X^-$ aqueous ions) and BC is a base (consisting of $M^+$ and $OH^-$ ions). When a double displacement reaction occurs, the cations and anions switch partners, resulting in the formation of water and a new ionic compound (or salt), which is usually soluble. Neutralization reactions are exothermic, and are generally accompanied by a noticeable release of heat.

| | |
|---|---|
| Example 3: | sulfuric acid + aqueous lithium hydroxide<br>The predicted products are water and lithium sulfate.<br>Reaction Equation: $H_2SO_4\ (aq) + 2\ LiOH\ (aq) \rightarrow Li_2SO_4\ (aq) + 2\ H_2O\ (l)$ |

Gas Forming Reactions

In these reactions one of the products (AD or CB) after the double displacement is in the gaseous state. One such example is hydrogen sulfide ($H_2S$). However, one of the products could also be carbonic acid ($H_2CO_3$) or sulfurous acid ($H_2SO_3$). Both carbonic acid and sulfurous acid are unstable and will decompose to form carbon dioxide and sulfur dioxide gases, respectively:

Carbonic acid

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

Sulfurous Acid

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

Example 4: nitric acid + aqueous sodium sulfite

The predicted products are sulfurous acid and sodium nitrate. However sulfurous acid decomposes to sulfur dioxide and water:

Reaction Equation: $2\ HNO_3\ (aq) + Na_2SO_3\ (aq) \rightarrow 2\ NaNO_3\ (aq) + \mathbf{H_2SO_3\ (aq)}$

**decomposes**

Final Equation: $2\ HNO_3\ (aq) + Na_2SO_3\ (aq) \rightarrow 2\ NaNO_3\ (aq) + \mathbf{H_2O\ (l) + SO_2\ (g)}$

**Writing Equations for Reactions**

- Write the correct formulas for each reactant and place a yield arrow (→) after the last reactant.
- Identify the reaction type – single or double displacement, using the guidelines outlined thus far.
- If you determine that a reaction will occur, write the correct formula(s) of the products after the arrow. If you determine that a reaction will not occur, simply write "no reaction" after the arrow.
- Balance the equation (to ensure mass conservation).
- Be sure to include the physical states of all reactants and products in your final equation.

**Solubility Rules and Activity Series**

SOLUBILITY RULES

1. Alkali metal compounds, acetates, nitrates, and ammonium compounds are all soluble.
2. Hydroxides of alkali metals and $NH_4^+$, $Ca^{2+}$, $Sr^{2+}$, and $Ba^{2+}$ are soluble. All others are **in**soluble.
3. All halides (chlorides etc.) are soluble except for those containing $Ag^+$, $Pb^{2+}$, and $Hg_2^{2+}$.
4. Most sulfates are soluble , except for $BaSO_4$, $SrSO_4$, $Ag_2SO_4$, $PbSO_4$, and $CaSO_4$.
5. Most phosphates, carbonates, chromates and sulfides are **in**soluble (except those of the alkali metals and ammonium).
6. In addition, acids in general are soluble

ACTIVITY SERIES

| | |
|---|---|
| highest activity | Li |
| | K |
| | Ca |
| | Na |
| | Mg |
| | Al |
| | Zn |
| | $Cr \rightarrow Cr^{3+}$ |
| | $Fe \rightarrow Fe^{2+}$ |
| | Cd |
| | $Ni \rightarrow Ni^{2+}$ |
| | $Sn \rightarrow Sn^{2+}$ |
| | $Pb \rightarrow Pb^{2+}$ |
| | $H_2$ |
| | $Cu \rightarrow Cu^{2+}$ |
| | Ag |
| | $Hg \rightarrow Hg^{2+}$ |
| lowest activity | $Au \rightarrow Au^{3+}$ |

## Procedure

### Safety

Be especially cautious when using the 6M HCl and 6M NaOH as they can burn your skin. Also be aware that skin discoloration will result from contact with $AgNO_3$ . If you feel any tingling sensations or see any color changes on your skin, flush with water immediately for a minimum of 15 minutes. Inform your instructor of any chemical contact as soon as possible.

### Materials and Equipment

Solids: Copper metal, zinc metal, magnesium metal, solid sodium bicarbonate
Solutions: 6M sodium hydroxide, 6M hydrochloric acid, 6M ammonium hydroxide, 5% acetic acid; all other solutions are 0.1M and include silver nitrate, barium chloride, sodium sulfate, potassium chloride, lead(II) nitrate, iron(III) chloride, sodium carbonate, cobalt(II) nitrate, sodium phosphate, zinc nitrate, copper(II) sulfate, sodium chloride, potassium nitrate, nickel(II) nitrate.
Equipment: 6 large test tubes, 8 small test tubes, plastic test tube rack (or large beaker)

### Instructions for Performing Reactions

- For the reactions involving solid reactants (#2, 4, 5, 7, 11, 13), use the large test tubes. For reactions involving solutions only, use small test tubes. Always use clean test tubes that have been rinsed with ***distilled water***. The test tubes do not have to be dry.
- Use approximately 3-mL quantities of all solutions. A good estimate is to use two full dropper squirts of each chemical.
- For reactions involving metals, use just 1-2 pieces of each metal. Place the metal in the test tube first, and then add the solution. The metal should be completely immersed in the solution used.
- Perform the following reactions and record your observations for each on the report form. Note that some reactions take longer than others. Thus, if results are not obtained immediately, give the reaction some time. ***All waste is to be disposed of in the plastic container in the hood*!**

1. Aqueous barium chloride + aqueous sodium sulfate
2. Zinc metal + hydrochloric acid
3. Aqueous sodium phosphate + aqueous copper(II) sulfate
4. Copper metal + aqueous silver nitrate
5. *Solid* sodium bicarbonate + acetic acid
6. Aqueous nickel(II) nitrate + aqueous sodium hydroxide
7. Copper metal + aqueous zinc nitrate
8. Aqueous potassium chloride + aqueous silver nitrate
9. Hydrochloric acid + aqueous sodium hydroxide
10. Aqueous sodium carbonate + aqueous cobalt(II) nitrate
11. Zinc metal + aqueous lead(II) nitrate
12. Aqueous sodium chloride + aqueous potassium nitrate
13. Magnesium metal + acetic acid
14. Aqueous iron(III) chloride + aqueous ammonium hydroxide

Click on the entries 1-14 to go to the videos showing the reaction (if any)

- When finished, complete your lab report by writing the balanced equations for each reaction studied.