

Single and Double Displacement Reactions

Objectives

- To perform and observe a variety of single and double displacement reactions
- To record observations in detail
- To identify the products formed in each of these reactions
- To write balanced chemical equations for each 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 new metallic deposit appears on the surface of a piece of metal
- Bubbles appear
- A temperature change occurs
- A color change occurs
- A precipitate (cloudy, tiny particles) appears in a solution

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

Single displacement reactions have the general form: $A + BC \rightarrow B + AC$

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 this section. As a rule, if A has a higher activity than B, a single displacement reaction will occur. However, if A has lower activity than B a reaction will not occur.

Example 1: magnesium metal + aqueous aluminum chloride

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

Reaction Equation: $3 \text{Mg}_{(s)} + 2 \text{AlCl}_{3(aq)} \rightarrow 2 \text{Al}_{(s)} + 3 \text{MgCl}_{2(aq)}$

Double Displacement Reactions

Double displacement reactions have the general form: $\mathbf{AB + CD \rightarrow AD + CB}$

Reactions that can be classified as double displacements include precipitation reactions, acid-base reactions including neutralization reactions and some 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 this section. Note that if both of the predicted products are soluble, a precipitation reaction will not occur.

Example 2: aqueous lead (II) nitrate + aqueous sodium chloride

The predicted products are lead (II) chloride (insoluble) and sodium nitrate (soluble). Since one of the predicted products is insoluble, a precipitation reaction will occur.

Reaction Equation: $\text{Pb}(\text{NO}_3)_{2(aq)} + 2 \text{NaCl}_{(aq)} \rightarrow 2 \text{NaNO}_{3(aq)} + \text{PbCl}_{2(s)}$

Neutralization Reactions

Here AB is an acid (consisting of H^+ and X^- aqueous ions) and CD 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

The predicted products are water and lithium sulfate and heat.

Reaction Equation: $\text{H}_2\text{SO}_{4(aq)} + 2\text{LiOH}_{(aq)} \rightarrow \text{Li}_2\text{SO}_{4(aq)} + 2\text{H}_2\text{O}_{(l)}$

Gas Forming Reactions

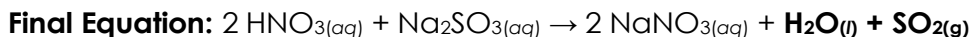
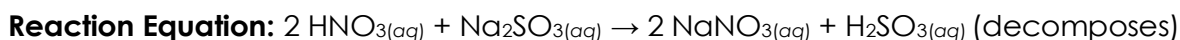
In these reactions one of the products (AD or CB) after the double displacement is in the gaseous state, such as hydrogen sulfide (H_2S) or ammonia (NH_3). One of the products could also be carbonic acid (H_2CO_3) or sulfurous acid (H_2SO_3). Both carbonic acid and sulfurous acid are unstable and will **decompose** to form carbon dioxide and sulfur dioxide gases, respectively:

Decomposition of Carbonic acid: $\text{H}_2\text{CO}_{3(aq)} \rightarrow \text{H}_2\text{O}_{(l)} + \text{CO}_{2(g)}$

Decomposition of Sulfurous Acid: $\text{H}_2\text{SO}_{3(aq)} \rightarrow \text{H}_2\text{O}_{(l)} + \text{SO}_{2(g)}$

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:



Steps for Writing Equations for Reactions in this Laboratory

1. Write the correct formulas for each reactant and place a yield arrow (\rightarrow) after the last reactant.
2. Identify the reaction type – single or double displacement.
3. 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.
4. Balance the equation (to ensure mass conservation).
5. 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 insoluble.
3. All halides are soluble except for those containing Ag^+ , Pb^{2+} , Cu^+ 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 **insoluble** (except those of the alkali metals and ammonium).
6. In addition, all acids are soluble!

ACTIVITY SERIES

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

Procedure

Safety

Be especially cautious when using the 6M HCl, 3M H₂SO₄ and 6M NaOH as they can burn your skin. Also be aware that skin discoloration will result from contact with AgNO₃. 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, 3M sulfuric acid, 6M hydrochloric acid; all other solutions are 0.1M and include silver nitrate, sodium chloride, lead (II) nitrate, iron (III) chloride, ammonium hydroxide, sodium carbonate, cobalt (II) nitrate, sodium phosphate, copper (II) sulfate, zinc nitrate, potassium nitrate, nickel (II) nitrate.

Equipment: 6 medium test tubes, 8 small test tubes, plastic test tube rack

Instructions for Performing Reactions

Reactions can be carried out in small test tubes or in well plates.

Use minimal quantities of all solutions required for good observations.

For reactions involving metals, use only one piece of each metal. Metals may be covered with a layer of oxide - use sandpaper to clean the piece of 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 in your laboratory notebook. If results are not obtained immediately, give the reaction some time. Some reactions take longer than others. **All waste is to be disposed of in the plastic container in the hood!**

1. Aqueous sodium chloride + aqueous silver nitrate
2. Zinc metal + hydrochloric acid
3. Aqueous sodium phosphate + aqueous copper(II) sulfate
4. Copper metal + aqueous silver nitrate
5. Hydrochloric acid + solid sodium bicarbonate (*just a small scoop*)
6. Aqueous nickel(II) nitrate + aqueous sodium hydroxide
7. Copper metal + aqueous zinc nitrate
8. Aqueous barium chloride + sulfuric acid
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 + sulfuric acid
14. Aqueous iron(III) chloride + aqueous ammonium hydroxide

When finished, complete the data sheet by writing the balanced equations for each reaction studied.

Set Up for Single and Double Replacement Reactions

Reagents

Four 200mL bottles of each of the following 0.1 M solutions:

- Silver Nitrate
- Sodium Chloride
- Lead (II) Nitrate
- Iron (III) Chloride
- Barium Chloride
- Sodium Carbonate
- Cobalt (II) Nitrate
- Sodium Phosphate
- Copper (II) Sulfate
- Zinc Nitrate
- Potassium Nitrate
- Nickel (II) Nitrate

Four bottles (any size from 50mL to 200mL) of each of the following solutions:

- 6M sodium hydroxide
- 3M sulfuric acid
- 3M ammonium hydroxide

Solids

- Copper metal strips (at least 32)
- Zinc metal strips (at least 32)
- Magnesium Metal strips (at least 32)
- Solid Sodium Bicarbonate (4 small jars)

Supplies

- 32 well plates
- Sandpaper squares