Experiment 11 CHEMICAL REACTIONS

Chem 110 Lab

I. INTRODUCTION

A. COMBINATION REACTIONS

In a combination reaction, two or more substances, elements and/or compounds, combine to form a single product.

1. Combination of a METAL and a NONMETAL to produce a BINARY IONIC COMPOUND.

   $2\ Mg(s) + O_2(g) \longrightarrow 2\ MgO(s)$

2. Combination of TWO NONMETALS to produce a BINARY MOLECULAR COMPOUND.

   $S(s) + O_2(g) \longrightarrow SO_2(g)$

3. Combination of METAL OXIDE and NONMETAL OXIDE.

   a. Combination of a METAL OXIDE and WATER to produce a METAL HYDROXIDE.

      $Na_2O(s) + H_2O(l) \longrightarrow 2\ NaOH(aq)$

   b. Combination of a METAL OXIDE and CO_2 to produce a METAL CARBONATE.

      $K_2O(s) + CO_2(g) \longrightarrow K_2CO_3(s)$

   c. Combination of a METAL OXIDE and SO_2 to produce a METAL SULFITE.

      $Cs_2O(s) + SO_2(g) \longrightarrow Cs_2SO_3(s)$

4. Combination of NONMETAL OXIDE and WATER to produce an ACID. (Whenever a nonmetal oxide reacts with water and acid is produced.)

   a. Combination of CO_2 and H_2O to produce H_2CO_3

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

   b. Combination of SO_2 and H_2O to produce H_2SO_3

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

B. DECOMPOSITION REACTIONS

In a decomposition reaction a single compound reacts to produce two or more products.

1. Decomposition of a BINARY COMPOUND to produce TWO ELEMENTS

   $2\ NaCl(s) \xrightarrow{\Delta} 2\ Na(s) + Cl_2(g)$

2. Decomposition of a TERNARY COMPOUND

   a. Decomposition of CARBONATES to produce OXIDES and CO_2

      (1) Decomposition of a METAL CARBONATE to produce a METAL OXIDE and CO_2

      $BaCO_3(s) \xrightarrow{\Delta} BaO(s) + CO_2(g)$

      (2) Decomposition of H_2CO_3 to produce H_2O and CO_2

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

   b. Decomposition of SULFITES to produce OXIDES and SO_2

      (1) Decomposition of a METAL SULFITE to produce a METAL OXIDE and CO_2

      $Na_2SO_3(s) \longrightarrow Na_2O(s) + SO_2(g)$

      (2) Decomposition of H_2SO_3 to produce H_2O and SO_2

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

C. SINGLE REPLACEMENT REACTIONS

In a single replacement reaction an element reacts with a compound. The element displaces an element from the compound and takes its place.

1. METALS REPLACE METALS AND HYDROGEN

$$Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$$

$$Zn(s) + 2\,HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

2. NONMETALS REPLACE NONMETALS

$$Cl_2(aq) + 2\,NaBr(aq) \longrightarrow Br_2(aq) + 2\,NaCl(aq)$$

3. Activities of Metals

A single replacement reaction will occur only if the element reacting is more "active" than the element it is replacing. If the element reacting is a metal, it replaces a metal (or hydrogen) in the compound. However, the reaction will occur only if a more active metal is replacing a less active metal—that is—the following reaction will occur only if Zn is more active than Cu:

$$Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$$

Because zinc does replace copper, it is said to be more active than copper. Since copper is less active than zinc, copper could not replace zinc—that is—the following reaction would not occur.

$$Cu(s) + ZnSO_4(aq) \rightarrow Zn(s) + CuSO_4(aq)$$ ⌫ This reaction would <u>not</u> occur

An ACTIVITY SERIES is a list of metals in order of their activities. In the case of the example above, Zn would be listed above Cu.

In the case of single replacement reactions, hydrogen acts like a metal. Only the <u>most</u> active metals will replace hydrogen from water at room temperature.

$$M(s) + H_2O(l) \rightarrow MOH(aq) + H_2(g)$$

metal — metal hydroxide — hydrogen

Metals that do not react with water that's at room temperature may react with hot water. A metal that reacts with hot but not cold room (temperature) water is less active than the one that reacts with cold water.

D. DOUBLE REPLACEMENT REACTIONS

In a double replacement reaction two compounds react to form two compounds. In the reaction the two compounds "switch last names".

$$AgNO_3(aq) + KCl(aq) \longrightarrow AgCl(s) + KNO_3(aq)$$

silver nitrate — potassium chloride — silver chloride — potassium nitrate

A double replacement reaction will occur only if one of the products of the reaction is one of the following:

1. Insoluble ionic compound
2. Insoluble gas
3. Weak acid or weak base
4. Water

For example, the following two reactions would occur because in the first a weak acid is formed and in the second, an insoluble ionic compound is formed:

$$HNO_3(aq) + KC_2H_3O_2(aq) \longrightarrow KNO_3(aq) + HC_2H_3O_2(aq)$$

$$AgNO_3(aq) + KCl(aq) \longrightarrow AgCl(s) + KNO_3(aq)$$

However, the following reaction does not occur because both products are soluble ionic compounds:

$$NaCl(aq) + LiOH(aq) \longrightarrow NaOH(aq) + LiCl(aq)$$

E. COMBUSTION REACTIONS

In a combustion reaction an organic compound reacts with oxygen to produce CO_2 and water. An organic compound will have carbon and hydrogen in its formula, and possibly oxygen or other nonmetals.

$$C_2H_6O(l) + 3\ O_2(g) \xrightarrow{\Delta} 2\ CO_2(g) + 3\ H_2O(g)$$

II. EXPERIMENT

CAUTION

- Silver nitrate solution will stain your hands, clothing, papers. Rinse your hands after handling.
- Solutions of sodium hydroxide, NaOH, and ammonia, NH_3, are can harm your skin and your eyes. Any base solution spilled on your skin or splashed into your eyes should be rinsed immediately with a large volume of water.
- Solutions of hydrochloric acid, HCl, and sulfuric acid, H_2SO_4, can harm your eyes, skin, and clothing. Handle with care. Any acid solution spilled on your skin or splashed into your eyes should be rinsed immediately with a large volume of water.

A. COMBINATION REACTIONS

1. Reaction of Magnesium and Oxygen

   In the HOOD, hold the end of a piece of magnesium ribbon in the hot spot of the Bunsen burner flame to ignite it. Avert your eyes.

   Observation: _____

   Reaction Equation: $2\ Mg(s) + O_2(g) \longrightarrow 2\ MgO(s)$

2. Reaction of Magnesium Oxide and Water

   Put the ash, MgO, from step 1 above onto your watch glass. Add a few drops of deionized water to it and mix well. Use litmus paper to determine whether the resulting mixture is acidic, basic, or neutral.

   Observation: _____

   Reaction Equation: $MgO(s) + H_2O(l) \longrightarrow Mg(OH)_2(aq)$

3. Reaction of a Phosphorus and Oxygen

Get a “gas collecting bottle” from the reagent bench and take it and your cover glass to the hood where the instructor will ignite a sample of phosphorus in a “def lagrating spoon” and lower it briefly into your gas bottle. As soon as the spoon is removed, rapidly place the cover glass over the mouth of the bottle so that the smoke does not escape.

Reaction Equation: $4\ P(s) + 5\ O_2(g) \longrightarrow 2\ P_2O_5(s)$

4. Reaction of Diphosphorus Pentoxide and Water

Lift the cover glass briefly to add about 1 mL of deionized water to the smoke in the bottle. Put the cover glass back on immediately and shake well. Test the solution with litmus paper to determine whether it is acidic, basic, or neutral.

Observation: _____

Reaction Equation: $P_2O_5(s) + 3\ H_2O(l) \longrightarrow 2\ H_3PO_4(aq)$

B. DECOMPOSITION REACTIONS

1. Decomposition of Hydrogen Peroxide

Put about 3 mL of hydrogen peroxide solution in a small test tube. Add a tiny amount of MnO_2 catalyst. (A catalyst makes a reaction occur faster.)

Observation: _____

Reaction Equation: $2\ H_2O_2(aq) \longrightarrow 2\ H_2O(l) + O_2(g)$

DISPOSAL:	Dispose of the hydrogen peroxide reaction mixture in the waste container labeled "Manganese dioxide/Hydrogen peroxide mixture".

2. Decomposition of Cupric Carbonate

Put a very small amount of solid copper (II) carbonate into your crucible and warm gently for one minute, then heat strongly for an additional 3 minutes.

Observation: _____

Reaction Equation: $CuCO_3(s) \longrightarrow CuO(s) + CO_2(g)$

DISPOSAL:	Dispose of the reaction mixture in the waste container for $CuCO_3$

C. SINGLE REPLACEMENT REACTIONS

1. Activities of Metals and Hydrogen

Use your spot plates for parts b-e below. (Part a will be demonstrated by your instructor.) Some of the reactions are slower than others. If a reaction does not appear to occur immediately, do not assume it is not reacting. Give it some more time —say 10-15 minutes.

a. Reaction of Sodium and Water (demonstration)

Observation: _____

Reaction Equation: $2\ Na(s) + 2\ H_2O(l) \longrightarrow 2\ NaOH(aq) + H_2(g)$

Is sodium more active than hydrogen? _____

b. Reaction of Cu and Silver Nitrate

Place one piece of Cu in a well of a spot plate by itself, then add about 5 -10 drops of aqueous silver nitrate, $AgNO_3$, solution. Do not put any other samples in the spot plate.

Observation: _____

Reaction Equation: $Cu(s) + 2\ AgNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2\ Ag(s)$

Is copper more active than silver? _____

DISPOSAL: Before using the spot plate for any other samples, dispose of reaction mixture in special waste container labeled WASTE SILVER NITRATE or SILVER WASTE.

c. Reaction of Copper and Sulfuric Acid

Place one piece of Cu in a well of a spot plate and add about 5 drops of 3 M sulfuric acid, H_2SO_4 solution.

Observation: _____

Reaction Equation: $Cu(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2(g)$

Is copper more active than hydrogen? _____

d. Reaction of Zinc and Sulfuric Acid

Place one piece of "mossy" Zn in a well of a spot plate and add about 5 drops of 3 M sulfuric acid, H_2SO_4 solution.

Observation: _____

Reaction Equation: $Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$

Is zinc more active than hydrogen? _____

e. Reaction of Zinc and Magnesium Sulfate

Place one piece "mossy" Zn in a well of a spot plate and add about 5 drops of a 0.1 M magnesium sulfate, $MgSO_4$, solution.

Observation: _____

Reaction Equation: $Zn(s) + MgSO_4(aq) \longrightarrow ZnSO_4(aq) + Mg(s)$

Is zinc more active than magnesium? _____

DISPOSAL: Dispose of the reaction mixtures in your spot plate by first separating solids from liquids by filtration, then throwing the filter paper into the trash can an d the liquid in the sink.

f. Reaction of Calcium and Water

Put 1 piece of Ca in a test tube and add about 3 mL of room temperature deionized water. Do not put any other samples in the spot plate.

Observation: _____

Reaction Equation: $Ca(s) + 2\ H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g)$

Is calcium more active than hydrogen? _____

Does calcium replace hydrogen from water at room temperature? _____

DISPOSAL: Dispose of the reaction mixture by first separating solid from liquid by filtration, then put the unreacted Ca into the waste container labeled: Waste Calcium Metal. Put the filter paper into the trash can and pour the liquid down the sink.

g. Reaction of Magnesium and Water

Put 1 piece of Mg in a test tube and add abo ut 3 mL of room temperature deionized water.

Observation: _____

Does magnesium replace hydrogen from water at room temperature? _____

Is Mg more active than Ca? _____

DISPOSAL: Dispose of the mixture by first separating solid from liquid by filtration, then throwing the filter paper into the trash can and the liquid into the sink.

2. Write an activity series for the metals (and hydrogen) you tested:

MOST ACTIVE

_____

_____

_____

_____

_____

_____

_____

LEAST ACTIVE

D. COMBUSTION REACTIONS

When you light a Bunsen burner, you are igniting methane, CH_4, the primary component of "natural gas". Methane reacts with oxygen to produce carbon dioxide and water. Write the equation for the combustion of methane:

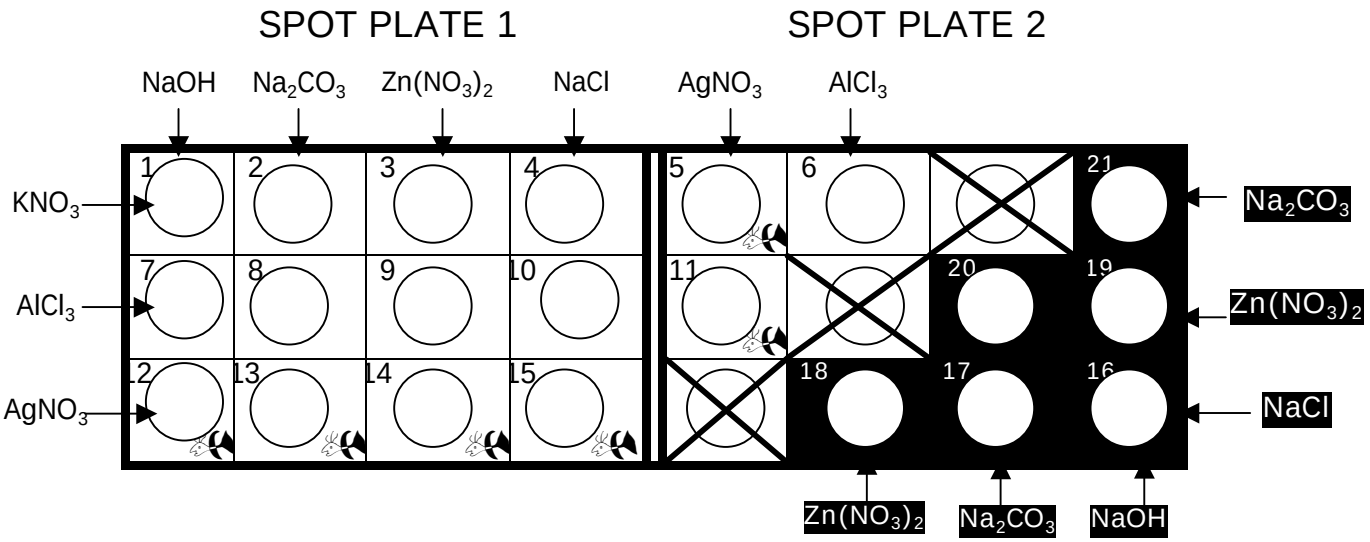
_____

STOP HERE

END OF DAY ONE

E. DOUBLE REPLACEMENT REACTIONS

1. Mix approximately equal volumes (4-5 drops each) of the solutions indicated below in the wells of your spot plates as indicated below and look for evidence of a chemical reaction. (If a precipitate is formed, be sure to write the color of the precipitate.) Record your observations in Table 11.1. (If no reaction occurs, write N.R. in the table.) Save the reaction mixtures until after you have identified your unknown solution.

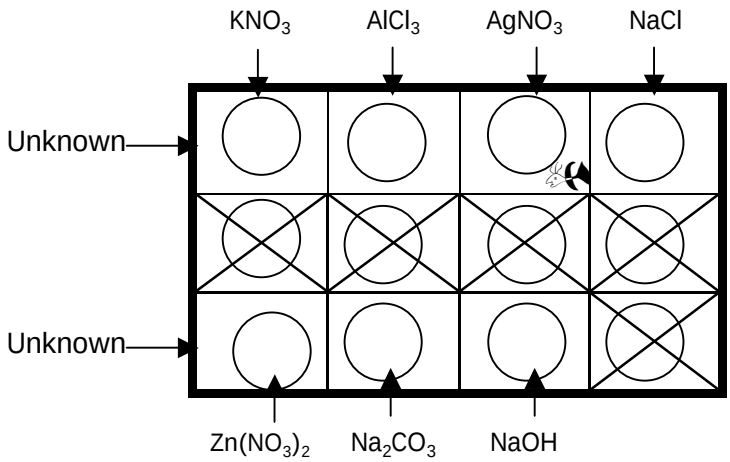


	NaOH	Na_2CO_3	$Zn(NO_3)_2$	NaCl	$AgNO_3$	$AlCl_3$
KNO_3	1	2	3	4	5	6
$AlCl_3$	7	8	9	10	11	
$AgNO_3$	12	13	14	15		
NaCl	16	17	18			
$Zn(NO_3)_2$	19	20				
Na_2CO_3	21					

Save the reaction mixtures until after you have identified your unknown solution.

2. Mix approximately equal volumes (4-5 drops each) of your unknown solution with each of the solutions indicated below. Record your observations in Table 11.2 below. Identify your unknown by comparison of the reaction mixtures in spot plate 3 with those in spot plates 1 & 2.

SPOT PLATE 3



Unknown _____

Table 11.2

	NaOH	Na_2CO_3	$Zn(NO_3)_2$	NaCl	$AgNO_3$	$AlCl_3$	KNO_3
Unknown							

Identity of unknown solution: _____

DISPOSAL: Reaction mixtures containing $AgNO_3$ and other silver compounds must be placed in a the special waste container labeled "SILVER WASTE". To dispose of these reaction mixtures, identified by the symbol, use your medicine dropper to transfer them from the spot plates to the special waste container.

To dispose of the remainder of the reaction mixtures, separate solids from liquids by filtration, and pour liquids into the sink and throw solids into the trash can.

3. On your report sheet, write balanced equations for all reactions that occur.

Report Experiment 11 CHEMICAL REACTIONS

Chem 110

Name _____ _____ Date _____
(last) (first)

Instructor's Initials_____

A. COMBINATION REACTIONS

1. Reaction of Magnesium and Oxygen

   Observation: _____

   Reaction Equation: _____

2. Reaction of Magnesium Oxide and Water

   Observation: _____

   Reaction Equation: _____

3. Reaction of a Phosphorus and Oxygen

   Observation: _____ _____

   Reaction Equation: _____

4. Reaction of Diphosphorus Pentoxide and Water

   Observation: _____

   Reaction Equation: _____

B. DECOMPOSITION REACTIONS

1. Decomposition of Hydrogen Peroxide

   Observation: _____

   Reaction Equation: _____ _____

2. Decomposition of Cupric Carbonate

   Observation: _____

   Reaction Equation: _____ _____

C. SINGLE REPLACEMENT REACTIONS

NOTE: Write equations only for those reactions that did occur.

1. Activities of Metals and Hydrogen

a. Reaction of Sodium and Water

Observation: _____ _____

Reaction Equation: $2\ Na(s) + 2\ H_2O(l) \longrightarrow 2\ NaOH(aq) + H_2(g)$

Is sodium more active than hydrogen? _____

b. Reaction of Copper and Silver Nitrate

Observation: _____ ____

Reaction Equation: _____

Is copper more active than silver? _____

c. Reaction of Copper and Sulfuric Acid

Observation: _____ ____

Reaction Equation: _____

Is copper more active than hydrogen? _____

d. Reaction of Zinc and Sulfuric Acid

Observation: _____ ____

Reaction Equation: _____

Is zinc more active than hydrogen? _____

e. Reaction of Zinc and Magnesium Sulfate

Observation: _____ _____

Reaction Equation: _____

Is zinc more active than magnesium? _____

f. Reaction of Calcium and Water

Observation: _____ _____

Reaction Equation: _____

Is calcium more active than hydrogen? _____

Does calcium replace hydrogen from water at room temperature? _____

g. Reaction of Magnesium and Water

Magnesium and Room Temperature Water.

Observation: _____

Reaction Equation: _____

Does magnesium replace hydrogen from water at room temperature? _____

Is Mg more active than Ca? _____

2. Activity Series for Metals and Hydrogen

MOST ACTIVE

_____

_____

_____

_____

_____

_____

_____

LEAST ACTIVE

D. COMBUSTION REACTIONS

Equation for the combustion reaction of methane, CH_4.

_____

E. DOUBLE REPLACEMENT REACTIONS

Table 11.1

	$NaOH$	Na_2CO_3	$Zn(NO_3)_2$	$NaCl$	$AgNO_3$	$AlCl_3$
KNO_3	1	2	3	4	5	6
$AlCl_3$	7	8	9	10	11	
$AgNO_3$	12	13	14	15		
$NaCl$	16	17	18			
$Zn(NO_3)_2$	19	20				
Na_2CO_3	21					

Table 11.2

	$NaOH$	Na_2CO_3	$Zn(NO_3)_2$	$NaCl$	$AgNO_3$	$AlCl_3$	KNO_3

Unknown Solution Letter _____ Identity of Unknown Solution _____

DOUBLE REPLACEMENT REACTION EQUATIONS: Complete and balance the equation for each double replacement reaction that actually occurred. (Otherwise write N.R.) Include correct physical states for all products.

Reaction	EQUATION
1	$KNO_3(aq) + NaOH(aq) \rightarrow$
2	$KNO_3(aq) + Na_2CO_3(aq) \rightarrow$
3	$KNO_3(aq) + Zn(NO_3)_2(aq) \rightarrow$
4	$KNO_3(aq) + NaCl(aq) \rightarrow$
5	$KNO_3(aq) + AgNO_3(aq) \rightarrow$
6	$KNO_3(aq) + AlCl_3(aq) \rightarrow$
7	$AlCl_3(aq) + NaOH(aq) \rightarrow$
8	$AlCl_3(aq) + Na_2CO_3(aq) \rightarrow$
9	$AlCl_3(aq) + Zn(NO_3)_2(aq) \rightarrow$
10	$AlCl_3(aq) + NaCl(aq) \rightarrow$
11	$AlCl_3(aq) + AgNO_3(aq) \rightarrow$
12	$AgNO_3(aq) + NaOH(aq) \rightarrow$
13	$AgNO_3(aq) + Na_2CO_3(aq) \rightarrow$
14	$AgNO_3(aq) + Zn(NO_3)_2(aq) \rightarrow$
15	$AgNO_3(aq) + NaCl(aq) \rightarrow$
16	$NaCl(aq) + NaOH(aq) \rightarrow$
17	$NaCl(aq) + Na_2CO_3(aq) \rightarrow$
18	$NaCl(aq) + Zn(NO_3)_2(aq) \rightarrow$
19	$Zn(NO_3)_2(aq) + NaOH(aq) \rightarrow$
20	$Zn(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow$
21	$Na_2CO_3(aq) + NaOH(aq) \rightarrow$