EXPERIMENT 0

Conversion Factors and Problem Solving

A. Goal

The goal of this laboratory experiment is to practice ballancing equations while observing chemical reactions happen. The goal is also to understand the existing different types of chemical reactions.

B. Materials

- ☐ Magnesium ribbon
- ☐ Bunsen burner
- ☐ metallic Zn and Cu
- ☐ a 1M $CuSO_{4(aq)}$ solution
- ☐ an 1M $HCl_{(aq)}$ solution
- ☐ a series of 0.1M $CaCl_{2(aq)}$,$Na_3PO_{4(aq)}$,$FeCl_{3(aq)}$, and $KSCN_{(aq)}$ solutions
- ☐ $Na_2CO_{3(s)}$
- ☐ a 3% $H_2O_{2(aq)}$ and 0.1M $KCl_{(aq)}$ solution

C. Background

Chemical reactions

When we eat we burn food with molecular oxygen (O_2) to produce carbon dioxide and water. Similarly, when we start the engine of the car to go to work, gasoline burns to produce the same chemicals: CO_2 and H_2O. These are two examples of chemical reactions, but there are many other examples. Nitrogen from the air reacts with hydrogen to produce ammonia, a common chemical used in the production of fertilizers. This section covers the basics of chemical reactions. You will learn how to balance reactions and how to classify reactions.

Simple chemical reactions

Magnesium is a metal that reacts with oxygen to produce magnesium oxide. Magnesium is solid $Mg_{(s)}$ whereas oxygen is gas and contains two oxygen atoms per molecule $O_{2(g)}$. Magnesium oxide, the result of the reaction, is solid $MgO_{(s)}$. The reaction between magnesium and oxygen to produce magnesium oxide

$$2\,Mg_{(s)} + 1\,O_{2(g)} \longrightarrow 2\,MgO_{(s)}$$

Mg and O_2 combine–that is why we use a plus sign– to produce MgO–we use an arrow to indicate that a chemical is being produced. Also, the symbols *(s)* or *(g)* indicates solid or gas state. The reactants are located before the arrow and the products are after the arrow. The numbers in front of the reactants and products (2,1 and 2) are called stoichiometric coefficients, and we will talk more about them in the following sections.

Reading a chemical reaction

Chemical reactions can be read in words. To read a chemical reaction you need to connect the reactants with the word “react” and then use the words “to produce” and after that, you need to read the products. The numbers in front of the reactants and products represent the number of moles, and you need to include those numbers in the reading. For example, the following reaction

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

should be read as: "two moles of Mg react with one mole of O_2 to produce two moles of MgO".

Balanced chemical reactions

Chemical reactions contain molecules, which are made of atoms. Some chemical reactions are balanced, and others need to be balanced. To identify a balanced reaction, you should use the stoichiometric coefficients and the indexes in the molecular formulas to break down the reactants and products into atoms. In a balanced chemical reaction, the atoms of reactants should be the same as the atoms of the products. Consider the following reaction,

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

The table below shows all reactants and products in the form of atoms.

$2\,Mg(s) + O_2(g) \longrightarrow 2\,MgO(s)$		
Reactants	Products	
2Mg	2Mg	✓
O_2=2O	2O	✓

The number of Mg atoms in the reactants and products is the same and equals two. On the other hand, the number of O atoms in the reactants and products is the same, equal to two. For this reason, we say this reaction is *balanced*.
Now consider the following reaction:

$$C(s) + O_2(g) \longrightarrow CO(g),$$

The number of C atoms in the reactants and products is the same and equals one. In contrast, the number of O atoms in the reactants and products is not the same, and for this reason, we say this reaction is *not balanced*.

$C(s) + O_2(g) \longrightarrow CO(g)$		
Reactants	Products	
1C	1C	✓
O_2=2O	O	✗

Balancing chemical reactions

To balance a reaction, we need to introduce the stoichiometric coefficients that make the number of atoms of reactants and products the same. To balance the number of oxygens, we will multiply CO by two, and that will give us two oxygens and two carbons as well. If we do this, now the carbon atoms of reactants and products will not be the same. We can solve this by multiplying C(s) by two. The following table summarizes the changes we made:

$2\,C(s) + O_2(g) \longrightarrow 2\,CO(g)$		
Reactants	Products	
2C	2C	✓
O_2=2O	2O	✓

The reaction is now balanced after introducing two stoichiometric coefficients and the number of C and O atoms in the reactant molecules and products is the same.

Sample Problem 1

Balance the following reaction:

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$$

SOLUTION

We will break down each molecule into atoms. In the case of O, both CO_2 and H_2O contain oxygen and hence you will have to combine both oxygen atoms:

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$$

Reactants	Products	
1C	1C	✓
4H	2H	✗
2O	3O	✗

The reaction is not balanced as the number of H and O atoms for the reactants and products is not the same. In order to balance the H, you can multiply by two H_2O, and that will balance H but also affect O.

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(g)$$

Reactants	Products	
1C	1C	✓
4H	4H	✓
2O	4O	✗

You can balance O by multiplying O_2 by two. That will give you the final balanced reaction in which all atoms (O, H and C) are the same in the product and reactant molecules.

$$CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(g)$$

Reactants	Products	
1C	1C	✓
4H	4H	✓
4O	4O	✓

STUDY CHECK

Balance the following reaction: $Fe_2O_3(s) + C(s) \longrightarrow Fe(s) + CO(g)$

Five types of reactions

Most chemical reactions can be classified according to five types: combination, decomposition, single replacement, double replacement, and combustion.

In a *combinations reaction* two reactants combine to generate a product. An example of a combination is the reaction between Mg and oxygen to produce MgO:

$$2\,Mg(s) + O_2(g) \longrightarrow 2\,MgO(s) \text{ (combination)}$$

In a *decomposition reaction* a single reactant breaks down into several products. An example of a decomposition reaction is the thermal reaction of $CaCO_3$ to produce calcium oxide (CaO) and carbon dioxide

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \text{ (decomposition)}$$

In a single replacement reaction, an element replaces another element in a chemical. An example would be the reaction of Zn with HCl, in which Zn replaces hydrogen:

$$Zn(s) + 2\,HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g) \text{ (Single replacement)}$$

In a double replacement reaction, the first element in the reacting compounds switches places. An example is the reaction between $AgNO_3$ and NaCl, in which Ag from $AgNO_3$ replaces Na in NaCl:

$$AgNO_3(aq) + NaCl(aq) \longrightarrow NaNO_3(aq) + AgCl(s) \text{ (Double replacement)}$$

Finally, in a combustion reaction, a carbon-based chemical reacts with oxygen to produce carbon dioxide and water. An example would be the combustion of methane (CH_4):

$$CH_4(g) + 2\,O_2(g) \longrightarrow 2\,H_2O(g) + CO_2(g) \text{ (Combustion)}$$

D. Procedure

Magnesium and oxygen

Step 1: – Obtain a 1-in strip of magnesium.

Step 2: – Start the Bunsen burner and place the strip in the blue cone of the flame using crucible tongs to hold the strip.

Step 3: – As soon as the metal starts to burn, remove it from the flame without direcly looking into the buring flame of magnesium which can damage your sight.

Step 4: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 5: – In the Experiment section, balance the reaction involved.

Step 6: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 7: – Use the disposals to get rid of any reactant or product.

Zinc and copper(II) sulfate

Step 1: – Pour 3mL (aproximately 60 drops) of a 1M $CuSO_4$ solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 2: – Obtain a small piece of zinc and place it into the test tube containing $CuSO_4$.

Step 3: – Wait 30 min for the reaction to complete. In the meantime you can proceed with the rest of the experiment.

Step 4: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 5: – In the Experiment section, balance the reaction involved.

Step 6: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 7: – Use the disposals to get rid of any reactant or product.

Metals and hydrochloric acid

Step 1: – Pour 3mL (aproximately 60 drops) of a 1M HCl solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 2: – Obtain small pieces of Zn, and place it into the test tube containing the acid.

Step 3: – Observe the reaction and record any evidence of reaction (heat exchange, bubbles, color change, solid appearing).

Step 4: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 5: – In the Experiment section, balance the reaction involved.

Step 6: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 7: – Now, repeate the procedure with Cu.

Step 8: – Now, repeate the procedure with Mg.

Step 9: – Use the disposals to get rid of any reactant or product.

$CaCl_2$ and Na_3PO_4

Step 1: – Pour 3mL (aproximately 60 drops) of a 0.1M $CaCl_2$ solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 2: – Pour 3mL (aproximately 60 drops) of a 0.1M Na_3PO_4 solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 3: – Pour the content of one test tube into the other.

Step 4: – Observe the reaction and record any evidence of reaction (heat exchange, bubbles, color change, solid appearing).

Step 5: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 6: – In the Experiment section, balance the reaction involved.

Step 7: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 8: – Use the disposals to get rid of any reactant or product.

$FeCl_3$ and KSCN

Step 1: – Pour 3mL (aproximately 60 drops) of a 0.1M $FeCl_3$ solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 2: – Pour 3mL (aproximately 60 drops) of a 0.1M KSCN (names potassium thiocyanide) solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 3: – Pour the content of one test tube into the other.

Step 4: – Observe the reaction and record any evidence of reaction (heat exchange, bubbles, color change, solid appearing).

Step 5: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 6: – In the Experiment section, balance the reaction involved.

Step 7: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 8: – Use the disposals to get rid of any reactant or product.

HCl and Na_2CO_3

Step 1: – Pour 3mL (aproximately 60 drops) of a 1M HCl solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 2: – Pour a peasize of Na_2CO_3, a solid reagent, into the test tube containing the acid.

Step 3: – Observe the reaction and record any evidence of reaction (heat exchange, bubbles, color change, solid appearing). For this experiment, place a lighted match insude the neck of the test tube and record what you see.

Step 4: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 5: – In the Experiment section, balance the reaction involved.

Step 6: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 7: – Use the disposals to get rid of any reactant or product.

H_2O_2 and KI

Step 1: – Pour 3mL (aproximately 60 drops) of a 3% H_2O_2 (names hydrogen peroxide) solution into a test tube. You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 2: – Pour 3mL (aproximately 60 drops) of a 0.1M KI solution into a test tube (this chemical acts as a catalyst). You can use a measuring cylinder to measure volume. Place the test tube into a test tube rack.

Step 3: – Pour the content of one test tube into the other.

Step 4: – Observe the reaction and record any evidence of reaction (heat exchange, bubbles, color change, solid appearing).

Step 5: – In the Experiment section, describe the appearance of the reactants and products of this reaction.

Step 6: – In the Experiment section, balance the reaction involved.

Step 7: – In the Experiment section, identify the type of reaction (combination, decomposition, single replacement, double replacement, combustion).

Step 8: – Use the disposals to get rid of any reactant or product.

STUDENT INFO

Name: ______________________ Date: ______

Pre-lab Questions

Conversion Factors and Problem Solving

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1. Balance the following reaction:

$$P_4(s) + O_2(g) \longrightarrow P_4O_{10}(s)$$

2. Balance the following reaction:

$$Al(s) + O_2(g) \longrightarrow Al_2O_3(s)$$

3. Balance the following reaction:

$$FeS(s) + O_2(g) \longrightarrow Fe_2O_3(s) + SO_2(g)$$

4. Classify next reaction as combination, decomposition, single replacement, double replacement, or combustion:

$$2\,RbNO_{3(aq)} + BeF_{2(aq)} \longrightarrow Be(NO_3)_{2(aq)} + 2\,RbF_{(aq)}$$

STUDENT INFO	
Name: ____________________	Date: ______

Results
EXPERIMENT

Conversion Factors and Problem Solving

Magnesium and oxygen

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	
$\_\_\_Mg(s) + \_\_\_O_2(g) \longrightarrow \_\_\_MgO(s)$	

Zinc and copper(II) sulfate

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	

$$\_\_\_Zn(s) + \_\_\_CuSO_4(aq) \longrightarrow \_\_\_Cu(s) + \_\_\_ZnSO_4(aq)$$

Metals and hydrochloric acid

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	

$$\_\_\_Zn(s) + \_\_\_HCl(aq) \longrightarrow \_\_\_ZnCl_2(aq) + \_\_\_H_2(g)$$

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	
$\_\_Cu(s) + \_\_HCl(aq) \longrightarrow \_\_CuCl_2(aq) + \_\_H_2(g)$	

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	
$\_\_Mg(s) + \_\_HCl(aq) \longrightarrow \_\_MgCl_2(aq) + \_\_H_2(g)$	

$CaCl_2$ and Na_3PO_4

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	

$$\_\_\_CaCl_2(aq) + \_\_\_Na_3PO_4(aq) \longrightarrow \_\_\_Ca_3(PO_4)_2(aq) + \_\_\_NaCl(aq)$$

$FeCl_3$ and KSCN

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	

$$\_\_\_FeCl_3(aq) + \_\_\_KSCN(aq) \longrightarrow \_\_\_Fe(SCN)_3(aq) + \_\_\_KCl(aq)$$

HCl and Na_2CO_3

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	

$$\_\_\_ Na_2CO_3(s) + \_\_\_ HCl(aq) \longrightarrow \_\_\_ CO_2(g) + \_\_\_ H_2O(l) + \_\_\_ NaCl(aq)$$

H_2O_2 and KI

Reactants appareance	
Products appareance	
Sign of reaction (heat exchange, bubbles, color change, solid appearing)	
Type of reaction (combination, decomposition, single replacement, double replacement, combustion)	

$$\_\_\_ H_2O_2(aq) \xrightarrow{KI} \_\_\_ H_2O(l) + \_\_\_ O_2(g)$$

STUDENT INFO

Name: ______________________ Date: ______

Post-lab Questions

Conversion Factors and Problem Solving

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1. Balance the following reaction:

$$NH_3(g) + O_2(g) \longrightarrow NO(g) + H_2O(g)$$

2. Classify next reaction as combination, decomposition, single replacement, double replacement, or combustion:

$$Pb_{(s)} + FeSO_{4(s)} \longrightarrow PbSO_{4(s)} + Fe_{(s)}$$

3. Classify next reaction as combination, decomposition, single replacement, double replacement, or combustion:

$$C_6H_{12(g)} + 9\,O_{2(g)} \longrightarrow 6\,CO_{2(g)} + 6\,H_2O_{(g)}$$

4. Why the reaction between sodium carbonate and hydrochloric acid can suffocate a lighted match?

5. Balance the following reactions:

   A Liquid hexane C_6H_{14} reacts with molecular oxygen O_2 to form carbon dioxide and water.

B Solid potassium reacts with molecular oxygen O_2 to form potassium oxyde.

6. Complete and balance the following equations:

A $CaCO_3(s) \longrightarrow$ (Decomposition)

B $H_2(g) + F_2(g) \longrightarrow$ (Combination)

C $NaCl(aq) + AgNO_3(aq) \longrightarrow$ (Double displacement)

D $Zn(s) + CuF_2(aq) \longrightarrow$ (Single displacement)