2 The Law of Definite Proportions

Purpose

The objective of this experiment is to describe the law of definite proportions and to give students experience in gravimetric analysis and error calculations.

Theory

- The ***law of definite proportions*** states that the elemental composition of a pure compound is always the same. This law predicts that the composition and properties of a pure compound to be the same regardless of its source. For example, the chemical combination of pure water compound, H_20, always is in a ratio of 1:8 by mass for hydrogen and oxygen.

The other fundamental law is the ***law of conservation of mass***, which states that the total mass of materials present after a chemical reaction is the same as the total mass before the reaction.

- **Determination of % composition of elements using chemical formulas**

There are some compounds that contain the same elements but in different proportions. In order to verify which compound was made, we can compare our experimental percentages (calculated in the last example) with the percentages calculated from the chemical formula (this example).

$$\%\, element = \frac{(no.\ of\ atoms \times atomic\ weight)}{formula\ weight\ of\ compound} \times 100$$

Formula weight of a compound is the sum of the atomic weights of all the atoms in the compound. The atomic weights are found on the periodic table

- ***Error*** is the difference between the experimental and the theoretical values. The error and the percentage of error can be calculated respectively by

$$Error = experimental\,value - theoretical\,value$$

$$\%Error = \frac{|experimental\,value - theoretical\,value|}{theoretical\,value} \times 100$$

- **Types of Chemical Reactions**

Many chemical reactions fall intı the one of these following categories:

A. **Combination Reaction:** A + B → AB

An example: Ca + S → CaS

In the above example two elements combine to form a compound. The combination of two smaller compounds to form a larger one also meets this criterion.

B. **Decomposition Reaction:** AB → A + B

An example: 2 $KClO_3$ → 2 KCl + 3 O_2

The starting material, usually a single compound, is broken into its component elements or simpler compounds.

C. **Displacement Reaction:** AB + C → CB + A

An example: $CuCl_2$ + Zn → Cu + $ZnCl_2$

An element reacts with a compound in this type of reaction. The free element, which is chemically more active, forces an element to leave and takes its place.

Experimental Procedure

Chemicals List	***Equipments***
Manganese (IV) oxide, MnO_2 Potassium chlorate, $KClO_3$	Test tube Bunsen burner Balance

Decomposition of $KClO_3$ salt

In this experiment, potassium chlorate ($KClO_3$) salt will be decomposed thermally with a presence of catalyst (MnO_2). MnO_2 will be used as a catalyst to increase the rate of reaction without being consumed. The decomposition reaction will be as follow

$$2KClO_3(s) \xrightarrow{heat} 3O_2(g) + KCl(s)$$

Due to above equation, the oxygen will be produced and be expressed as a percentage of the original mass of $KClO_3$. The mass percent of oxygen will be calculated form the mass difference after and before heating the $KClO_3$ salt.

1. Take a clean and dry test tube.
2. Add approximately one teaspoonful of MnO_2 to the test tube.
3. Heat the test tube slowly to dry the catalyst until all the moisture is taken off.
4. <u>Cool the test tube to room temperature</u> before weighing (!). Weigh the test tube including the catalyst and write it on the report data sheet as W_0.
5. Add around 2 grams of $KClO_3$ to the test tube and mix the $KClO_3$ and MnO_2 thoroughly. Weigh the mixture and write it as W_1.
6. Calculate the weight of $KClO_3$ as W_2.
7. Heat the test tube slowly around 10 minutes. The mixture will first melt, then produce gas strongly and finally solidify in to a purify mass.
Be sure not to apply heat to one point of the test tube and not to melt it(!).
8. Cool the test tube slowly by closing the Bunsen burner. Allow the test tube to cool and then weigh it as W_3.
9. Heat the test tube again for another 5 min. Cool the test tube and weigh it as W_4.
10. Check the values of W_3 and W_4. The oxygen will be taken off completely if these values are in agreement. If they are not, heat the test tube and weigh it again until you get the same value for these two measurements. Show these measurements on the report data sheet as well. Write your last weighing, as W_f, which must be the same as W_4.
11. Calculate the mass of oxygen and write as W_{oxygen}.
12. Calculate the experimental percentage of oxygen by mass in $KClO_3$ and write it on the report data sheet.
13. Calculate the theoretical percentage of oxygen by mass in $KClO_3$ and write it on the report data sheet. (At. Wt. O=16.0 g/mol, Cl=35.5 g/mol, K=39.1 g/mol)
14. Calculate the percent error.
15. Clean your tube.

Experiment 2 – Report

Name of the student:	Student ID:
Name and signature of the assistant:	Section & Date:

Data and Calculations

(5 pts) Mass of the test tube including catalyst, MnO_2	$\mathbf{W_0}$	
(5 pts) Mass of the test tube including catalyst and $KClO_3$	$\mathbf{W_1}$	
(5 pts) Mass of $KClO_3$	$\mathbf{W_2}$	
(5 pts) Mass of the test tube and contents after first heating	$\mathbf{W_3}$	
(5 pts) Mass of the test tube and contents after second heating	$\mathbf{W_4}$	
(5 pts) Mass of the test tube and contents after last heating	$\mathbf{W_f}$	

a) (10 pts) Calculate the mass of oxygen that is reacted

b) (15 pts) Calculate the experimental % of oxygen by mass in $KClO_3$

c) (15 pts) Calculate the theoretical% of oxygen by mass in $KClO_3$

Experiment 2 – Report (Page 2)

Name of the student:	Student ID:

d) (10 pts) Calculate Percent error in experimental % of oxygen

QUESTIONS

1. (10 pts) What is the percentage composition of CaCO3?
2. (10 pts) What is the weight in grams of one copper atom?