LAD A.2 Magnesium Oxide

Name________________________Per___

Law of Constant Composition and Empirical Formula

Introduction

Magnesium will react with oxygen in the air by heating the two together. In order to determine if the ratio between Mg and O is constant, the mass of Mg and the mass of oxygen must be measured or otherwise experimentally determined.

Recall from the Introduction in LAD A1, John Dalton was an Englishman, a teacher, and an exceptional theoretical chemist. He developed and wrote the modern atomic theory at the turn of the 19^{th} century (documents point to 1803). He was influenced by the experiments of two Frenchmen, Antoine Lavoisier and Joseph Louis Proust. In the late 1700's Proust studied chemical compounds and noticed that the elements always combined in constant mass ratio. In this lab the mass ratio that forms when magnesium and oxygen are combined, will be analyzed. A fundamental component of the modern atomic theory is that the mass ratios of elements in a compound will be constant and that the mole ratios of elements in a compound will be *small whole* numbers (*Law of Definite Composition sometimes called the Law of Definite Proportions*). By comparing the class data, the law of constant composition should be verified. The whole number mole ratio is commonly referred to as the empirical formula of a compound.

One of the challenges in finding the proper chemical formula for a compound is that there may be more than one plausible mole ratio for the elements in that compound. This occurs because of the ability of elements to exist in more than one oxidation state. Dalton called this the L*aw of Multiple Proportions*. For example, if you were testing a compound that contained copper and sulfur, the plausible chemical formula could be CuS or Cu_2S. If you experimentally determine the mass of copper and the mass of sulfur present in a given mass of the compound, you will be able to establish the empirical chemical formula of that particular compound. Magnesium is not an element that can be used to verify the law of multiple proportions because it only exists in one oxidation state.

PreLAD ***This must be done before class.***

1. Read the Procedure Overview, the Procedure, and Processing the Data and then make a Data/Results Table − please do it in a NEW TAB of your same Google Spreadsheet from the last lab. You should embed formulas for calculations before lab.

2. Write a balanced equation for the reaction occurs between magnesium and oxygen. Is this a redox reaction? What other *two* categories does this reaction fall into? (Note that we do not worry about net ionic in this case, because net ionic is only relevant for reactions that take place in solution.) (5)

3. What we did not discuss in first year chemistry, is that if conditions are right, a side reaction between the magnesium and nitrogen in the air may occur. Write a balanced equation for this synthesis reaction. (3)

4. We will use another reaction to remove any magnesium nitride that may have formed. By adding water to the crucible after heating, magnesium nitride will be converted to ammonia (NH_3) and magnesium hydroxide. Write a balanced equation for this reaction. (3)

5. You should be thinking about the magnesium oxide that is also in the crucible − what happens to it when water is added? It is well worth memorizing that metal oxides react with water to form metal hydroxides. Write a balanced equation for the reaction of magnesium oxide with water. (3)

6. Lastly, after you have added water and converted all the chemicals in the crucible to a *slurry* of magnesium hydroxide in water, heating strongly will convert that mixture back into magnesium oxide, with the water leaving the dish as vapor. Write a balanced equation to represent this reaction. It is standard practice to put a delta symbol (Δ) over the arrow when heat is used to induce the reaction. (3)

Materials ***on each tray, shared by two lab groups***

At the Lab bench shared by 2 groups

- crucible and cover ×2
- tongs, stirring rod ×2
- ring, burner, & clay triangle ×2
- small beaker ×2
- magnesium strip ×4 (~ 12 cm each)
- small dropping pipet (for water)

At center Lab bench

- balances

Procedure ***Goggles are NOT optional. They are a MUST.***

A. Determine the mass of the clean, dry, empty crucible and cover. The Mg must be completely free of any "rust" – so clean and shine the metal strip using sand paper. After cleaning the magnesium, brush off any dust and determine the mass of the magnesium strip. Then crumple it and place it in the crucible as shown in class, maximizing the amount of Mg that makes contact with the bottom of the crucible. The Mg must be touching the bottom of the crucible in order for it to ignite, yet you should not coil it in a tight ball or it is difficult for the air to get at all of the magnesium.

BE SURE AND READ THIS ENTIRE SECTION BEFORE BEGINNING.

B. Put the crucible without the cover on the clay triangle. Light the burner off to the side and adjust the flame so that you have a hot inner blue cone. Having a hot flame and adjusting the height of your ring so the inner cone just strike the bottom of the crucible will be critical to getting the Mg to ignite. When all is adjusted, place the flame under the crucible and heat until Mg ignites. To reduce the loss of any product (magnesium oxide powder) as smoke, quickly cover the crucible (but continue to hold the cover with your tongs) to catch the smoke, and REMOVE the burner IMMEDIATELY after it ignites. Lift the cover carefully to take a quick peek and see if the reaction has subsided, and is smoking less. If it has, replace the burner (remain ready to remove as necessary) and watch carefully as the coil may ignite again causing more smoke, which you again should try to catch with the cover. When the combustion inside the crucible has subsided completely and the magnesium does not light up again, continue to heat with the cover off for about 5 minutes.

C. The completed reaction will result in a light gray residue. If it appears that all of the Mg has not reacted then heat again strongly. Turn off the burner, use the tongs to set the crucible on the wire square to cool. Mass the crucible and cover with the magnesium oxide product in it.

D. When the crucible is *completely cooled*, add a few milliliters of water using the pipet. Gently use the stirring rod to break up the solid and mix with the water. Watch closely for bubbles and waft gently to try to detect any ammonia smell. Observe if the aqueous mixture in the crucible is cloudy or clear. (You will need to have made these observations to answer Post LAD Questions.)

E. Place the crucible back on the clay triangle and heat with a hot flame, but prepared to remove the burner from time to time to avoid any spattering. When the excess water has been heated off, continue to heat strongly for about 5 minutes to be sure that the chemical in the dish is completely dry. Turn off the burner, use the tongs to set the crucible on the wire square to cool. Mass the crucible and cover with the magnesium oxide product in it

PROCESSING THE DATA – ***Remember, these items should be line items in your data/results table.***

1. Calculate the mass of the magnesium oxide product – for first heating and for second heating after adding water.
2. Calculate the mass of oxygen that combined with the starting mass of magnesium (for both heatings).
3. Calculate moles of both oxygen and magnesium (for both heatings)
4. Calculate the mole ratio in order to determine the empirical formula (for both heatings).
5. Calculate the experimental mass ratio of mass of magnesium to mass of oxygen: Mg/O (for both heatings).
6. Use the masses of Mg and O in the periodic table to calculate the theoretical mass ratio for magnesium oxide.

POST LAD QUESTIONS

1. The word “slurry” was used in the PreLAD. Look this word up in a dictionary and write a concise definition as the term “slurry” applies to this lab. What compound in the mixture is causing this mixture to be a slurry, and not a solution? (2)

2. What caused the initial reaction to stop, and if the product compound had been heated longer would the mass ratio have changed. (2)

3. If magnesium nitride had formed during the combustion of your magnesium, describe two pieces of *qualitative* evidence would result when you added water to eliminate this magnesium nitride? (2)

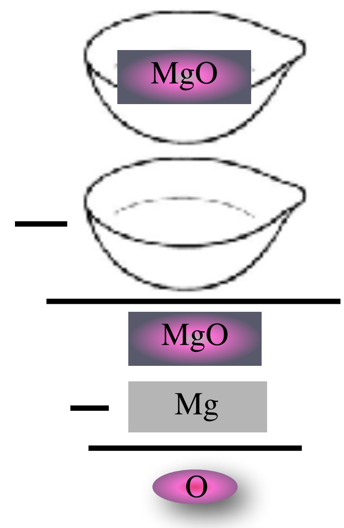
4. Consider the quantitative implications of the formation of magnesium nitride during the combustion of the magnesium. *Show your work.*
   a. Calculate the mass of magnesium oxide that you would expect to form from 1 g of magnesium. (2)

   b. Calculate the mass of magnesium nitride that you would expect to form from 1 g of magnesium. (2)

   c. When you added water to eliminate any magnesium nitride, and then dried it out again, would you expect the mass of the final product should increase or decrease? Justify your answer by commenting on the calculations above. (2)

5. Considering that this was only the first or second time you performed this experiment, although the data is not completely precise, the class data does a decent job of verifying the Law of Constant Composition. What does the term precision mean? Of course we have the luxury of knowing the theoretical mass ratio, which allowed us decide that the class average as a whole, was fairly accurate, but most early chemists did not have that information. What does it mean to be accurate, in contrast to the term precision? Why is it important to analyze data of more than one trial in order to verify the Law of Constant Composition? (3)

6. You used the cover to contain the "smoke" during the reaction. Just what was this "smoke?" If the smoke had been lost while heating the magnesium, would you expect the mass ratio of Mg/O to be larger or smaller than the theoretical ratio? Justify your response. (4)



7. If soot (What is soot?) had collected on the bottom of the dish during the heating, would you expect the mass ratio of Mg/O to be larger or smaller than the theoretical ratio? Justify your response. (4)

8. If the magnesium had been covered with a thick coating of "rust" (What compound is the rust made of?) before burning, would you expect the mass ratio of Mg/O to be larger or smaller than the theoretical ratio? Justify your response. (4)

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Scoring Rubric (out of 100 pts)

5 PreLab Data Table done BEFORE Lab day

5 PreLab Questions done BEFORE Lab day

17 PreLab Questions

27 PostLab Questions

40 Data Table (What makes a good data table? Be sure and read the info document to find out) Stapled to the END of this lab sheet.

6 All the rest…