Confirmation of a Chemical Formula

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AP Chemistry S439-3
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1 Purpose

In this lab we will be converting $Mg_{(s)}$ to $MgO_{(s)}$ by means of

1. $2\ Mg_{(s)} + O_{2(g)} \longrightarrow 2\ MgO_{(s)}$
2. $3\ Mg_{(s)} + N_{2(g)} \longrightarrow Mg_3N_{2(s)}$
3. $Mg_3N_{2(s)} + 6\ H_2O_{(\ell)} \longrightarrow 3\ Mg(OH)_{2(aq)} + 2\ NH_{3(g)}$
4. $Mg(OH)_{2(aq)} \longrightarrow MgO_{(s)} + H_2O_{(\ell)}$

We intend to confirm the formula of our product by comparing the experimental and theoretical percent Mg along with the experimental and theoretical mass produced of MgO.

2 Pre-Laboratory Questions

1. Calculate the percentage by mass of magnesium and oxygen in magnesium oxide, MgO.

$24.305\frac{g}{mol}\text{Mg}+16.0\frac{g}{mol}\text{O} = 40.305https://88df6ea0630aed8027ff-0caf779119a6537399728d4d80$

$\frac{24.305\frac{g}{mol}\text{Mg}}{40.305\frac{g}{mol}\text{MgO}} = 60.303\%\ \text{Mg}$

$\frac{16.0\frac{g}{mol}\text{O}}{40.305\frac{g}{mol}\text{MgO}} = 39.697\%\ \text{O}$

2. Suppose 2.033 g of magnesium is heated in air. What is the theoretical amount of magnesium oxide that should be produced?

$\frac{|2.033\cancel{g\text{Mg}}}{1}|\frac{1\cancel{mol\text{Mg}}}{24.305\cancel{g\text{Mg}}}|\frac{\cancel{2}\cancel{mol\text{MgO}}}{\cancel{2}\cancel{mol\text{Mg}}}|\frac{40.305g\text{MgO}}{1\cancel{mol\text{MgO}}}| = 3.371g\,\text{MgO}$

3 Procedure

Materials: Porcelain crucible and cover, crucible tongs, clay triangle, magnesium ribbon, pH paper

3.1

Clean out the crucible with a scapula and paper towels. If necessary, wash crucible and watch glass with distilled water and evaporate with bunsen burner. After cooling, record mass of crucible/lid and watch glass.

3.2

Spiral $10 - 12cm$ Mg ribbon and place in crucible. Record mass.

3.3

Heat crucible with cover ajar in clay triangle above small bunsen burner flame for 5-10 minutes. If smoke is observed, immediately remove from heat for 2-3 minutes and decrease flame. After time is finished, remove from heat for 1-2 minutes.

3.4

Remove cover and check for remaining Mg (metallic silver). Continue heating in five minute intervals until no Mg is remaining. Then, heat at full flame for 5 minutes and heat another 5 minutes with cover half off.

3.5

Record mass. Break apart any chunks with stirring rod. Add 10 drops DI water throughout material and heat on very small flame with cover ajar. Test steam with pH paper to determine if any $NH_{3(}g)$ is escaping. See Figure 1.

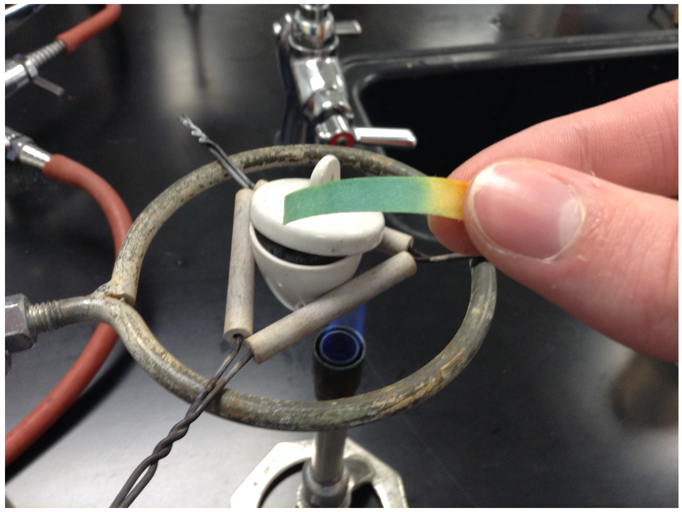

Figure 1: Basic gas.

3.6

When water is eradicated, position cover so it is half open and heat for five minutes full flame. Record Mass. Heat another five minutes. Record mass.

4 Data

Item	Mass(g)
Watch Glass	53.913
Crucible and Cover	20.774
With Magnesium	20.958
After First Heating	21.097
After Second Heating	21.087
After Third Heating	21.083

5 Calculations

1. Mass of Mg that was taken.
(Mass of crucible + mass of magnesium) − mass of crucible = mass of magnesium

$20.958g - 20.774g = 0.184g$ Mg

2. Mass of MgO present at end of reaction.
(Mass of crucible + mass of MgO) − mass of crucible = mass of MgO
$21.083g - 20.774g = 0.309g$ MgO

3. Percentage of Mg in MgO from experimental data.
$\frac{0.184g\,\text{Mg}}{0.309g\,\text{MgO}} = 59.5\%$ Mg

4. Percent error based off percent Mg.
$|\frac{\text{Theoretical}-\text{Experimental}}{\text{Theoretical}}| * 100\% = \text{Percent Error}$
$|\frac{60.3\%\text{Mg}-59.5\%\text{Mg}}{60.3\%\text{Mg}}| * 100\% = 1.25\%$ error

5. Theoretical mass of MgO produced given starting Mg.
$\frac{0.184g\text{Mg}}{1}|\frac{1mol\text{Mg}}{24.305g\text{Mg}}|\frac{2mol\text{MgO}}{2mol\text{Mg}}|\frac{40.305g\text{MgO}}{1mol\text{MgO}}| = 0.305g\,\text{MgO}$

6. Percent error based off mass of MgO.
$|\frac{\text{Theoretical}-\text{Experimental}}{\text{Theoretical}}| * 100\% = \text{Percent Error}$
$|\frac{0.305g\text{MgO}-0.309g\text{MgO}}{0.305g\text{MgO}}| * 100\% = 1.31\%$ error

6 Post Laboratory Questions

1. If water had not been added, what error in percent Mg determined would have resulted?
We would have recorded a lighter mass for our magnesium oxide because the synthesis of magnesium and nitrogen yields a lighter product for the same about of mass as the synthesis of magnesium and nitrogen. Let's assume 78% of the time, synthesis with nitrogen occured.
$|\frac{0.144g\text{Mg}}{1}|\frac{1mol\text{Mg}}{24.305g\text{Mg}}|\frac{1mol\text{Mg}_3\text{N}_2}{3mol\text{Mg}}|\frac{100.935g\text{Mg}_3\text{N}_2}{1mol\text{Mg}_3\text{N}_2}| = 0.199g\text{Mg}_3\text{N}_2$
$\frac{0.040g\text{Mg}}{1}|\frac{1mol\text{Mg}}{24.305g\text{Mg}}|\frac{2mol\text{MgO}}{2mol\text{Mg}}|\frac{40.305g\text{MgO}}{1mol\text{MgO}}| = 0.0663g\,\text{MgO}$
$0.199g\text{Mg}_3\text{N}_2 + 0.0663gMgO = 0.265g$
$\frac{0.184g\,\text{Mg}}{0.265g\,\text{MgO}} = 69.4\%$ Mg
$|\frac{\text{Theoretical}-\text{Experimental}}{\text{Theoretical}}| * 100\% = \text{Percent Error}$
$|\frac{60.3\%\text{Mg}-69.4\%\text{Mg}}{60.3\%\text{Mg}}| * 100\% = 15.1\%$ error

2. If MgO smoke had been lost in a great amount, would this have made the percent Mg too high or low?
Percent Mg is found be the equation $\frac{g\text{Mg}}{g\text{MgO}}$. As MgO decreases, the percent Mg increases. Therefore, the percent Mg would be too high.

7 Discussion

This experiment revolved around the fundamental law of Conservation of Mass. We made use of this law by verifying the formula MgO. This formula suggests that magnesium can maintain stability while being oxidized to molar equivalence. Over the course of the experiment, we verified that this is true. Accuracy in our mass measurements was essential. After rinsing our crucible and heating until all water was evaporated, we let our crucible sit until it became room temperature. This was done so no pocket of warm air would be created in the lip between the crucible and the digital scale and bear some of the weight that the crucible exerts on the scale. By doing so, along with using a very precise, tared digital scale with a covering, we were able to take extremely accurate measurements of the mass of both the crucible and the magnesium. While heating the magnesium, we left the crucible lid slightly ajar so the oxygen the metal received was minimal. This reduced the chance of ignition, but increased the amount of nitrogen that combusted with the magnesium which is why we had to add water.

Upon adding H_2O to the MgO/Mg_3N_2 mix, NH_3 was released. We confirmed this with pH paper as seen in Figure 1. Our calculations showed that we reacted 0.184g Mg to produce 0.309g MgO. This gives an experimental 59.5% magnesium mass content in MgO. This is 1.25% off of our theoretical calculation for the mass content of magnesium in magnesium oxide. We also calculated that 0.305g of MgO should have been produced. Our actual value was 0.309g which is 1.31% off of our theoretical value. Our data would have been better if we had more accurate mass taking equipment, a pure oxygen chamber, better attention paid to procedure, and better care in handling the supplies. Although there was error, we did accomplish our purpose of confirming the formula MgO and we believe our experiment was a success.

8 Experimental Sources of Error

Every time we measured our crucible, error was added to the experiment. The digital scales are very accurate, but are still subject to their own error in addition to human error of judging when the thousandths decimal has reached the proper number. This could make obtained values smaller or larger than they should be.

However, we believe our largest source of error was the eradication of Mg_3N_2. There is a low chance that all Mg_3N_2 was eradicated by the 10 drops of H_2O. We had no means of determining if all Mg_3N_2 had been eradicated, if there was not enough H_2O, or even when the reaction had stopped. This error could have been eliminated entirely by performing the experiment using an convection heater in an oxygen chamber. This would have given a smaller result for the final mass of MgO as demonstrated in Part 6 Question 1.

9 Questions

1. Calculate the percent composition of the elements in NaCl to three significant figures.

$22.99\frac{g}{\text{mol Na}} + 35.45\frac{g}{\text{mol Cl}} = 58.44\frac{g}{\text{mol NaCl}}$

$\frac{22.99\frac{g}{\text{mol Na}}}{58.44\frac{g}{\text{mol NaCl}}} = 39.3\%\ \text{Na}$

$\frac{35.45\frac{g}{\text{mol Cl}}}{58.44\frac{g}{\text{mol NaCl}}} = 60.7\%\ \text{Cl}$

2. Ethyl chloride is 37.2% carbon, 7.8% hydrogen, and 55.0% chlorine. What is the simplest formula?

$37.2\text{g C} \times \frac{1\text{mol C}}{12.01\text{g}} = \frac{3.10\text{mol C}}{1.55} \longrightarrow 2$

$7.8\text{g H} \times \frac{1\text{mol H}}{1.01\text{g}} = \frac{7.72\text{mol H}}{1.55} \longrightarrow 5$

$55.0\text{g Cl} \times \frac{1\text{mol Cl}}{35.45\text{g}} = \frac{1.55\text{mol C}}{1.55} \longrightarrow 1$

C_2H_5Cl

3. A sample of a lead oxide weighs 2.50 g. When reduced in a stream of hydrogen gas, it forms 2.27 g lead. What is the formula of the oxide?

$2.27\text{g Pb} \times \frac{1\text{mol C}}{207.2\text{g}} = \frac{0.0109\text{mol Pb}}{0.0109} \rightarrow 1 * 3 \longrightarrow 3$

$0.23\text{g O} \times \frac{1\text{mol H}}{16.0\text{g}} = \frac{0.0144\text{mol O}}{0.0109} \rightarrow 1.31 * 3 \longrightarrow 4$

Pb_3O_4

4. Hemoglobin contains 0.335% iron. There must be at least one atom of iron per molecule of hemoglobin. What is the minimum weight of a mole of hemoglobin?

$\frac{\text{Fe}}{\text{Hemoglobin}} \times 100 = .335\%$ Hemoglobin

$\frac{\text{55.846g Fe}}{\text{1mol Hemoglobin}} \times \frac{\text{1g Hemoglobin}}{\text{.00335g Hemoglobin}} = \frac{\text{\#g Hemoglobin}}{\text{1mol Hemoglobin}}$

$\frac{\text{55.846g Fe}}{\text{1mol Hemoglobin}} \times \frac{\text{1g Hemoglobin}}{\text{.00335g Hemoglobin}} = \frac{\text{16670.4g Hemoglobin}}{\text{1mol Hemoglobin}}$

10 Conclusion

We verify the formula for magnesium oxide MgO. This conclusion was based both on our experimentally calculated mass percentage of magnesium of 59.5% versus our theoretically calculated mass percentage of magnesium of 60.3% and our experimentally calculated resultant mass of magnesium oxide of 0.309g versus our theoretically calculated resultant mass of magnesium oxide of 0.305g. This gave us an error of 1.25% and 1.31%, respectively. Even with some error, our purpose of verifying the formula MgO was fulfilled. This experiment is repeatable and the procedure has been summarized in part 3.