Experiment 4 - Determination of the Empirical Formula of Magnesium Oxide

Introduction

A **molecular formula** tells the number of atoms in the molecule (such as H_2O for water or H_2O_2 for hydrogen peroxide). The **empirical formula** of a compound merely gives the ratio of atoms in the compound based on experimental evidence (such as H_2O for water or HO for hydrogen peroxide).

When magnesium and oxygen are heated together, they react:

magnesium + oxygen $\rightarrow$ magnesium oxide Rxn 1

From the masses of magnesium and oxygen that combine, we can calculate the **empirical formula** of magnesium oxide. We will weigh the magnesium before it combines with the oxygen, and we will also weigh the product of the reaction, magnesium oxide. The final weighing is necessary because we need to subtract the original weight of magnesium from this weight of product. We "weigh" the oxygen in this indirect way because it is easier than weighing the oxygen gas before it combines with the magnesium.

If magnesium is heated in open air, its reaction with oxygen is rapid and spectacular. The metal catches fire, burning with an intense white flame and with production of white smoke. (The metal has been used in flares to provide light for night-time military operations.) We can slow down the reaction by limiting the supply of oxygen that reaches the magnesium; we do that by putting a cover on the crucible that contains the magnesium sample.

Our procedure in this experiment is complicated by another fact. Magnesium is such an active metal that it reacts with the relatively inactive element nitrogen:

magnesium + nitrogen $\rightarrow$ magnesium nitride Rxn 2

This occurs in competition with the reaction of magnesium with oxygen, so it is called a "side reaction." You should realize that this side reaction uses up some of the magnesium that is supposed to be combining with oxygen. Fortunately it is possible to "undo" the reaction in this way:

magnesium nitride + water $\rightarrow$ magnesium hydroxide + ammonia Rxn 3

and

magnesium hydroxide $\rightarrow$ magnesium oxide + water vapor Rxn 4

To get Rxn 3 and Rxn 4 to occur, we add water to the crucible contents at the end of the first heating period. We then heat again to speed up the reactions and to evaporate any excess water. Ammonia is a gas, so it will also diffuse out of the crucible.

Safety Precautions:

- Wear your safety goggles!
- When the magnesium is burning, do not look directly at the flame. It is bright enough to damage your eyes.
- The crucibles can shatter when heated. This is not a day to be careless about goggles!
- Be careful not to burn yourself on the hot crucible, ring, etc.

Waste Disposal:

- The solid product of this reaction can be discarded in the regular garbage can after the experiment. (Scrape it out with a spatula.)

Procedure

1. Choose a clean crucible with no cracks or flaws. Heat a clean, dry porcelain crucible with cover on a clay triangle (supported on a ring stand), using a direct flame, for about 5 minutes. This will dry the crucible.
2. Turn off the burner, and let the crucible and cover cool. Leave the crucible and cover resting on the clay triangle. (If you wish to remove the hot crucible from the clay triangle, set it on the base of the ring stand to cool.)
3. Weigh the empty, dry crucible and cover on the digital balance. Record this mass. Record the mass of the crucible and cover separately also, in case the cover breaks.
4. Obtain a strip of magnesium ribbon that is about 10 to 15 cm long. If it is not shiny, polish it briefly with steel wool to remove any oxide coating.
5. Wrap the ribbon around a pencil to make a loose, flat spiral. Set the spiral in the crucible; it should sit flat against the bottom of the crucible. (See diagram below.)
6. Carefully weigh the crucible, cover, and magnesium ribbon together. Record this total mass, from which the mass of the ribbon will be calculated.
7. Put the cover aside for a moment, and start heating the crucible with the magnesium in it. Have the cover close by, with some crucible tongs ready to handle it with.
8. The instant that the magnesium starts to burn, put the cover on the crucible (using the crucible tongs) to put out the fire.
9. Continue heating the covered crucible for a minute or so, then take off the cover again. Wait for the magnesium to catch fire again, then quickly re-cover the crucible. When handling the cover, notice that some material sticks to the inside of it. This is also your product. Hold the cover upside-down and try not to knock the product off it to get the best data.
10. Repeat steps 8 and 9 until the magnesium no longer catches fire when the cover is removed.
11. Heat the sample strongly for 5 minutes, with the cover on the crucible. Make sure the bottom of the crucible becomes red hot.
12. Turn the burner off and let the crucible cool until it is only barely warm to the touch. Record the mass of the crucible, cover and product.
13. To the cooled crucible, add about 10 drops of deionized water. Make sure to wet the entire surface of the sample, not just one spot.

Commented [JS1]: it burns the boards and soot deposits on the crucibles

14. Warm the crucible with the damp sample using a gentle flame for a minute or so, then heat it moderately strongly for about 10 minutes. (The crucible need not become red hot for this phase of the experiment, and the cover is not needed for this heating.)

15. Let the crucible and contents cool until the crucible is barely warm to the touch.

16. Weigh the cooled crucible, cover, and contents of the crucible, recording this total mass.

17. Perform the calculations, and write your mole ratio (from step 5) of Mg to O on the board along with your names. The instructor will distribute a photo of the board with all the data so you can use it for your post-lab analysis.

Calculations

1. From the total mass recorded in step 16 and the mass of the empty crucible and cover, you can calculate the mass of the crucible contents. These contents should be fairly pure magnesium oxide.

2. Calculate the mass of oxygen that combined with your mass of magnesium in this experiment using subtraction. Also calculate the mass of magnesium used if you did not measure it directly.

3. Calculate the number of moles of magnesium you started with.

4. Calculate the number of moles of oxygen that reacted with the magnesium.

5. Calculate the mole ratio of magnesium to oxygen. To do this, divide the moles of magnesium by the moles of oxygen. Express the result to the correct number of significant figures.

6. Using the above ratio, write the empirical formula of magnesium oxide by rounding off the ratio to the nearest whole number.

Name: Section:

Experiment 4 Pre-Lab Sheet

1. (1 pt) Why shouldn't you look straight at the burning magnesium?

2. (1 pts) Why do you add water?

3. (1 pt) Why do you heat the crucible again after adding water?

4. (6 pts) The following data were collected during a very similar experiment using tin. Perform the following sample calculations (show your work, with units canceling):
   mass of crucible and cover: 19.8413 g
   mass of crucible, cover and Sn: 21.2325 g
   mass of crucible, cover and product: 21.6006 g

   mass of Sn:

   mass of O reacted:

   moles of Sn:

   moles of O reacted:

   mole ratio (mol Sn/mol O):

   empirical formula:

5. (1 pt) Will your mole ratio increase or decrease if a lot of white powder falls off the lid of the crucible and onto the bench?