EXPERIMENT #6

Calculation of the Atomic Mass of Magnesium

OBJECTIVES:
- Observe the reaction between oxygen and magnesium
- Accurately weigh reaction mixtures before and after reaction
- Calculate the atomic mass of magnesium

BACKGROUND:

Stoichiometry is the branch of chemistry dealing with mass relationships in chemical combinations; important principles include the law of constant composition, the law of multiple proportions, and the general statement that atoms combine in the ratios of small whole numbers to form chemical compounds. In this experiment we will see whether these principles can be demonstrated quantitatively in what seems to be a simple chemical change, the direct reaction of metallic magnesium with an excess of elemental oxygen.

Magnesium reacts with oxygen in the air according to equation (1).

\[ 2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO} \]  

(1)

Dry air contains only about 20% oxygen (\(\text{O}_2\)). Since the remaining 80% is almost all nitrogen (\(\text{N}_2\)), the desired reaction is complicated by a competing reaction of magnesium with nitrogen. The equation for the competing reaction is shown in equation (2).

\[ 3\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2 \]  

(2)

This competing reaction need not interfere with our study, because the magnesium nitride formed by equation (2) can be converted to magnesium hydroxide by adding water [equation (3)]. The \(\text{Mg(OH)}_2\), in turn, can be

\[ \text{Mg}_3\text{N}_2 + 6\text{H}_2\text{O} \rightarrow 3\text{Mg(OH)}_2 + 2\text{NH}_3 \]  

(3)

\[ \text{Mg(OH)}_2 \rightarrow \text{MgO} + \text{H}_2\text{O} \]  

(4)

converted to the oxide by heating, equation (4). The stoichiometric sum of equations (2), (3) and (4) is identical to equation (1).

The results from this experiment can be used to calculate the atomic mass of magnesium given the known atomic mass of oxygen, the mass of oxygen which reacts with a known mass of magnesium and assuming that the formula of the product magnesium oxide is \(\text{MgO}\).

From the mass of oxygen reacting, the number of moles of oxygen atoms can be calculated. Since the formula shows a one-to-one ratio of magnesium atoms to oxygen atoms, the number of moles of magnesium atoms in now known. From the number of moles of magnesium atoms and the mass of magnesium used, the atomic mass of magnesium can be calculated.
Example:

Magnesium, 0.271 g, reacts with oxygen to form 0.449 g of magnesium oxide. If the formula of the magnesium oxide is MgO, and the atomic mass of oxygen atoms is 16.0 g/mole, calculate the atomic mass of magnesium.

the mass of oxygen in the compound is: \[= 0.449 \text{ g} - 0.271 \text{ g} = 0.178 \text{ g}\]
the moles of oxygen atoms in the compound is: \[= \frac{0.178 \text{ g}}{16.0 \text{ g/mol}} = 0.0111 \text{ mol}\]
the moles of magnesium atoms in the compound is: \[= 0.0111 \text{ mol}\] [Since the subscript of each element is 1, for each mole of oxygen there is one mole of magnesium.]
the atomic mass of magnesium is: \[= \frac{0.271 \text{ g}}{0.0111 \text{ mol}} = 24.4 \text{ g/mol}\]

% error: \[= \frac{24.4 - 24.31}{24.31} \times 10^2 = 0.37\%\]
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ATOMIC MASS OF MAGNESIUM

EXPERIMENTAL PROCEDURE: (Work in the hood. Extinguish the Bunsen flame when not in use.)

1. Obtain two clean crucibles and covers. You must be able to distinguish between each pair of
   crucibles/ covers. Ask your instructor to demonstrate how to clean a crucible. (See step 9.)

2. If crucibles are clean and dry, determine the mass of the crucible and cover to the number of
   significant digits specified by you laboratory instructor. Then skip to step 4. To dry
   crucibles/ covers, perform the following. In the hood, heat each crucible and cover until the bottom
   of the crucible glows a dull red. The cover on the crucible should be slightly ajar (see FIGURE I).
   Using crucible tongs remove the cover from the crucible and place it on a piece of wire gauze (or a
   clean, dry watch glass) to cool. Then use the crucible tongs to remove the crucible from the
   triangle and place it on the wire gauze (or watch glass) to cool. For accurate results the crucible
   and cover must be at room temperature before weighing.

3. When no heat is felt when you hold your hand 1 to 2 cm from the crucible, use you crucible tongs
   to transfer the crucible and cover to the balance. Determine the mass of the crucible and cover to
   the number of significant digits specified by your laboratory instructor. Record this mass on your
   Data Sheet.

4. While the crucibles/ covers are cooling, obtain an untarnished piece of magnesium ribbon weighing
   0.3 - 0.5 g. The magnesium should be shiny and bright. If it appears to have a white coating on it,
   use a piece of sandpaper (or steel wool) to remove the tarnish. Loosely roll the magnesium ribbon
   into a ball. Place it in the crucible.

5. Weigh the crucible, magnesium, and cover on the balance previously used. Determine this mass to
   the number of significant digits specified by your laboratory instructor. Record this mass on your
   data sheet.

6. In the hood place each crucible, its cover, and the magnesium on the triangle as shown in the
   FIGURE I (cover ajar), and heat it gently. As soon as any white smoke appears from the crucible,
   remove the flame and cover the crucible completely using the crucible tongs. After 15 seconds lift
   the cover slightly. If the white smoke still appears, cover the crucible again. When the white
   smoke subsides, place the cover ajar and continue heating gently. Repeat this process until smoke
   (MgO) is no longer observed. Be careful not to lose any oxide, since some may adhere to the
   cover.

7. When smoke is no longer observed, place the cover slightly ajar and heat the crucible strongly
   until the bottom of the crucible glows a dull red. Continue heating this manner for 10 min. Let the
   crucible cool thoroughly before weighing.

8. Let each crucible cool as before, and carefully add 8 - 10 drops of deionized water using a
   medicine dropper or Beral pipet. Try to spread the water over the ash during the addition. Replace
   the cover (slightly ajar) and reheat gently (avoid spattering) for approximately 3 minutes, then
   strongly to dryness, approximately 9 minutes. Allow the crucibles and contents to cool before
   weighing.
9. Dispose of the magnesium oxide as directed by your lab instructor. Clean your crucible and covers by placing them in an empty beaker and adding 6 M hydrochloric acid to the crucible. The crucible covers should be inverted to insure that the inside (bottom) is cleaned. The acid will dissolve most of the oxide, but some dark material will remain in the crucibles. After about 10 minutes, rinse the crucibles and covers with water, brush them out with your test tube brush, and rub them with a paper towel. You will probably be unable to completely remove the dark stains from the crucibles. The hydrochloric acid washing may be safely poured down the sink, and then flushed with copious amounts of water.

10. Calculate the mass of oxygen reacting (by difference) and then calculate the number of moles of oxygen atoms.

11. Assuming that the empirical formula of magnesium oxide is MgO, calculate the number of moles of magnesium reacting in each trial.

12. Using the experimentally determined mass of magnesium in each trial and the number of moles of magnesium reacted (calculated above) calculate a value for the atomic mass of magnesium. Remember the unit of atomic mass is grams per mole. Report the average of your two trials. Also calculate the percent error of your value from the accepted value found on the periodic table.

FIGURE I: Apparatus for Heating Magnesium
DATA AND CALCULATIONS: Calculation of the Atomic Mass of Magnesium

Mass of crucible, cover, and Mg, g

Mass of crucible and cover, g

Mass of Mg, g

Mass of crucible, cover, and magnesium oxide, g (after step 7)

Mass of magnesium oxide, g

Mass of O combining with Mg, g

Number of moles of O

Number of moles of Mg

atomic mass Mg = \frac{\text{g of Mg}}{\text{moles of Mg}}

Average atomic mass

percent error

CLEARLY SHOW CALCULATIONS BELOW:
ADDITIONAL ASSIGNMENT I: Atomic Mass of Magnesium

A student performed an experiment similar to this one to determine the atomic mass of chromium. After heating 0.4550 g of pure Cr wire in an excess of air, the sample was cooled and weighed. The mass of the compound formed was 0.8749 g. The atomic mass of O is 16.00 g/mole. Assuming a formula of CrO$_3$ for the compound formed, calculate the atomic mass of Cr.

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<thead>
<tr>
<th>mass of oxygen in compound</th>
<th>moles of oxygen in compound</th>
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<table>
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<tr>
<th>moles of chromium in compound</th>
<th>atomic mass of chromium</th>
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ADDITIONAL ASSIGNMENT II: Atomic Mass of Magnesium

In his determination of the atomic mass of the element zinc, Zn, Berzelius determined that reaction of 4.032 g of Zn with oxygen formed 5.032 g of zinc oxide. He also assumed that the formula for the oxide was ZnO₂. Assuming that the atomic mass of oxygen is 16.00 g/mol, what value did Berzelius calculate for the atomic mass of zinc. **SHOW CALCULATIONS CLEARLY.**