Identification of a Metal Carbonate

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Abstract

In this experiment, a sample of unknown metal carbonate was reacted with hydrochloric acid to produce water and carbon dioxide gas. The mass of the escaping carbon dioxide gas was determined and used to calculate the molar mass of the unknown metal carbonate. This mass was then used to determine the identity of the unknown out of a selection of possibilities. The mean calculated molar mass from three trials was 119.6 M with a percent error of less than 5 %. The unknown metal carbonate was determined to be sodium carbonate hydrate.

Keywords

Acid Test, Carbonate, Carbon Dioxide, Hydrochloric Acid, Metal, Stoichiometry

1 Introduction

The purpose of this experiment was to identify an unknown metal carbonate based on the amount of carbon dioxide gas released during a reaction with hydrochloric acid. This technique is known as the "acid test," and is used by geologists to identify carbonate-containing rocks.[1]

The equation of the reaction follows the form:

$$M_2CO_3 + 2\,HCl \longrightarrow 2\,MCl + H_2O + CO_2 \tag{1}$$

Or, in the case of a bicarbonate (hydrogen carbonate):

$$MHCO_3 + HCl \longrightarrow MCl + H_2O + CO_2 \tag{2}$$

During this reaction, water and carbon dioxide are formed. Although carbon dioxide is soluble in water at high pressures, the standard atmospheric pressure of the lab environment allows it to escape as a gas.[2] Through repeated weighing, the mass of the escaped carbon dioxide gas can be determined. Stoichiometry then allows us to determine the moles of the carbon dioxide produced from the reaction.

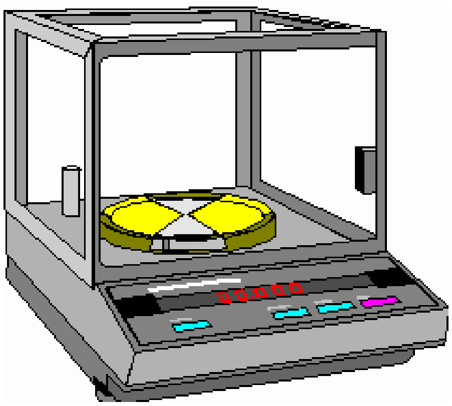
The balanced equation above shows us that the moles of unknown metal carbonate must equal the moles of released carbon dioxide gas. We use this information, along with the mass of the unknown sample, to determine the molar mass of the unknown. We can then choose from a given selection of 5 possible metal carbonates (Figure 1) the one our determined molar mass most closely matches.

Chemical Name	**Chemical Formula**	**Molar Mass (M)**
Sodium Carbonate	Na_2CO_3	105.99
Sodium Carbonate Hydrate	$Na_2CO_3 \cdot \frac{1}{2}\,H_2O$	114.99
Sodium Bicarbonate	$NaHCO_3$	84.008
Potassium Carbonate	K_2CO_3	138.21
Potassium Bicarbonate	$KHCO_3$	100.118

Figure 1: Possible metal carbonates and their molar masses

2 Experimental Details

2.1 Materials



- 4.0 MHydrochloric Acid
- Analytical Balance
- Erlenmeyer Flask
- Graduated Cylinder
- Lab Notebook
- Paper Towels
- Safety Goggles
- Styrofoam Cup
- Unknown Metal Carbonate Sample

2.2 Safety Considerations

Hydrochloric acid and some of the metal substances used in this experiment are dangerous and corrosive.[3] I avoided skin contact and was prepared rinse the affected area immediately if contact was made. I made efforts to not inhale corrosive mist from the reaction. I wore safety goggles for the duration of the experiment.[4]

2.3 Methods

I first measured 10.0 mL of 4.0 MHCl in a graduated cylinder and poured it into a styrofoam cup. I weighed a small erlenmeyer flask on an analytical balance, then added approximately 2 g of of my unknown metal carbonate to the the flask and reweighed it to the nearest 0.0001 g. I weighed the cup, flask, and sample together, then the cup and acid alone. Back in my work area, I poured the acid slowly into the flask. I waited 5 minutes for the reaction to finish, then blew into the flask to clear the remaining CO_2 gas. Again I weighed the cup, flask, and contents together.[5] After recording all my measurements, I disposed of the flasks contents in a lab sink and rinsed all my materials. I repeated this procedure 2 more times for a total of 3 trials.

3 Theoretical Basis

From any balanced chemical equation, we can determine the mole ratios between any reactants or products.[6] For example, from the balanced equation in equation 1 we know that, for a reaction of M_2CO_3 with HCl, there is 1 mol of CO_2 for every 1 mol of M_2CO_3, and 2 mol HCl for every 1 mol CO_2.

Figure 2 shows the balanced chemical equations for each possible reaction:

$$\begin{aligned}
&\mathrm{Na_2CO_3 + 2\,HCl \longrightarrow 2\,NaCl + H_2O + CO_2}\\
&\mathrm{Na_2CO_3 \cdot 10\,H_2O + 2\,HCl \longrightarrow 2\,NaCl + 11\,H_2O + CO_2}\\
&\mathrm{NaHCO_3 + HCl \longrightarrow NaCl + H_2O + CO_2}\\
&\mathrm{K_2CO_3 + 2\,HCl \longrightarrow 2\,KCl + H_2O + CO_2}\\
&\mathrm{KHCO_3 + HCl \longrightarrow KCl + H_2O + CO_2}
\end{aligned}$$

Figure 2: Balanced chemical equations

The "acid test" in this experiment works because of these mole ratios. We measure the mass of the metal carbonate, then we determine the mass of the CO_2.[7] Stoichiometry allows us to use these measurements, along with our mole ratios and the known molar mass of CO_2, to identify the unknown carbonate (represented here as M_2CO_3) by its own molar mass:[8]

$$gCO_2 \times \frac{1\,molCO_2}{44.01\,gCO_2} \times \frac{1\,molM_2CO_3}{1\,molCO_2} = molM_2CO_3 \tag{3}$$

$$\frac{molM_2CO_3}{gM_2CO_3} = \textsc{m}M_2CO_3 \tag{4}$$

In order to to determine the accuracy of our measurements we can calculate the percent error between our result and the known molar mass of whichever metal carbonate we believe our unknown to be:

$$\%\text{err.} = \frac{|\text{true value} - \text{experimental value}|}{\text{true value}} \times 100 \tag{5}$$

4 Results and discussion

Mass	**Trial 1**	**Trial 2**	**Trial 3**
Empty Flask	102.5692	102.5694	102.5685
Empty Cup	2.2105	2.4618	2.4683
Flask + Sample	104.5708	104.6971	104.7928
Cup + Acid	13.0347	13.3504	13.1154
Flask + Sample + Cup + Acid (before reaction)	117.6056	118.0472	117.9076
Flask + Contents + Cup (after reaction)	116.8486	117.2619	117.0819

Figure 3: Recorded masses (g)

Figure 3 shows all the recorded mass measurements I made for each of the three trials. The mass of the empty flask and cup did not fluctuate significantly, though a different cup (with a different mass) had to be used for the second and third trials. The other masses varied slightly, and the results of those variations are discussed below.[9]

Figure 4 shows the calculations I did based off of the data in figure 3. The path from grams, to moles, to molar mass can be seen here. It should be noted that the moles of CO_2 and the moles of sample are equal for each trial because the mole ratio of the reaction is 1 : 1.[10]

Value	Trial 1	Trial 2	Trial 3
Mass Sample (g)	102.5692	102.5694	102.5685
Mass CO_2 (g)	2.2105	2.4618	2.4683
Moles CO_2 (mol)	104.5708	104.6971	104.7928
Moles Sample (mol)	13.0347	13.3504	13.1154
Molar Mass Sample(M)	117.6056	118.0472	117.9076

Figure 4: Calculated values

The mean of the three final calculations of the unknown carbonate's molar mass is 119.6 M.[11] This was closest to sodium carbonate hydrate (figure 1), which had a given molar mass of 114.99 M. The percent error was 4.0 %; accurate enough for confidence in the result. The error likely came from measurement error when using the analytical balance, and from failure to completely remove the heavy CO_2 gas from the inside of the cup before reweighing.

4.1 Sample Calculations

Sample calculations for Trial 1 are included below:

$$m_{sample} = m_{flask+sample} - m_{flask} = 104.5708\,\mathrm{g} - 102.5692\,\mathrm{g} = 2.0016\,\mathrm{g} \tag{6}$$

$$m_{\mathrm{CO_2}} = m_{before} - m_{after} = 117.6056\,\mathrm{g} - 116.8486\,\mathrm{g} = 0.7570\,\mathrm{g} \tag{7}$$

$$mol_{\mathrm{CO_2}} = m_{\mathrm{CO_2}} \times \frac{1\,\mathrm{molCO_2}}{44.01\,\mathrm{gCO_2}} = 0.7570\,\mathrm{g} \times \frac{1\,\mathrm{molCO_2}}{44.01\,\mathrm{gCO_2}} = 1.720 \times 10^{-2}\,\mathrm{mol} = mol_{sample} \tag{8}$$

$$M_{sample} = \frac{m_{sample}}{mol_{sample}} = \frac{2.0016\,\mathrm{g}}{1.720 \times 10^{-2}\,\mathrm{mol}} = 116.4\,\mathrm{M} \tag{9}$$

$$\%\text{err.} = \frac{|\text{true value} - \text{experimental value}|}{\text{true value}} \times 100 = \frac{|114.99\,\text{M} - 116.4\,\text{M}|}{114.99\,\text{M}} \times 100 = 1.2\,\% \quad (10)$$

5 Conclusions

The "acid test" proved to be a viable method of identifying an unknown metal carbonate.[12] Careful measurement of mass before and after reaction, identification of molar ratios from a balanced equation, and calculation of the molar mass of carbon dioxide from the periodic table supplied sufficient information to determine the molar mass of the unknown sample.[13] Careful repetition of the procedure compensated adequately for the various sources of error.

Acknowledgement

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