Chemistry 212

DETERMINATION OF CALCIUM CARBONATE CONTENT IN TUMS

LEARNING OBJECTIVES

The learning objectives of this experiment are

- The goal of this lab is to determine the amount (mass) and the weight percent of calcium carbonate in a tums tablet.

BACKGROUND

Calcium carbonate, which is found in many antacids, calcium supplements, eggshells and seashells, reacts with hydrochloric acid in the following manner:

$CaCO_3(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

For this testing, you will be collecting the carbon dioxide released from a reaction of tums tablet with excess hydrochloric acid. During each reaction, you will measure the volume of CO_2 produced using a displacement technique (bubble gas into an inverted graduated cylinder filled with water). Using the ideal gas law and stoichiometry, you will determine the mass of $CaCO_3$ in the tums tablet. This information will be used for calculating the (wt/wt)% $CaCO_3$ in tums.

SAFETY AND WASTE

The 3M HCl should be handled with care because it is relatively caustic. You should also avoid direct contact with the vapors from the solution. If the acid containing solutions come in contact with your skin, immediately rinse your skin with excess water for at least 15 minutes. You should use baking soda (sodium bicarbonate) to neutralize acid spills prior to cleaning up with excess water.

EXPERIMENTAL PROCEDURE

You will need to perform a minimum of 3 good trials (free from obvious error) on tums tablets (keep in mind that it might take you and additional 1-2 trials before you develop a good technique for collecting and measuring the gas collected). A typical experiment involves reacting 1 tums tablet with 10 ml of 3M HCl. The specific set-up for the reaction and the calculations is described below.

1. Fill the large plastic tub about 2/3 full with tap water. Let it sit while you set up the rest of the experiment so that it reaches room temperature.

2. Record the atmospheric pressure in the room (use the barometer on the wall).

3. Gather the following materials:
    - Large graduated cylinder
    - Ring stand and clamp (clamp should be large enough to fit around the large graduated cylinder)
    - Thermometer
    - Erlenmeyer flask with tube and stopper

4. Place the large graduated cylinder sideways in the tub to fill it with the water from the tub. *Note:* do not completely fill the cylinder; you will need to allow a small amount of space to be able to take an initial volume reading as described in subsequent steps.

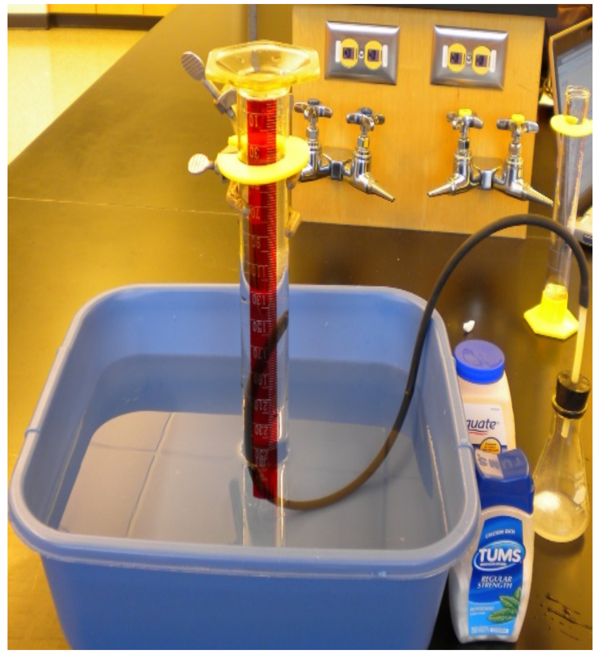

Figure 1. Experimental setup (photo by N. Whaley)

5. Invert the mostly-full cylinder: the water should remain in the cylinder as long as you keep the opening below the water level in the tub. Clamp the cylinder so that its opening is suspended between the bottom of the tub and the surface of the water in the tub.

6. Record the initial volume of water in the cylinder. Remember that the cylinder is inverted, so the volume values go up as you go down the tube, similar to a burette.

7. Weave the free end of the tube under the water and up into the graduated cylinder (see Figure 1).

8. Remove the stopper from the Erlenmeyer flask (if that hasn't already been done) and place 10 mL of 3 M HCl in the flask. (Wear gloves and goggles when dealing with the HCl!)

9. Find and record the mass of a Tums tablet (either regular or ultra-strength. Choose one type and use it consistently throughout all trials.)

10. Record the temperature of the water in the tub (hopefully by this time it will be quite close to room temperature).

11. Place the Tums tablet in the flask with the HCl, and as *quickly* (yet carefully) as possible, place the stopper on the flask. You should see the water level in the inverted cylinder drop as it fills with CO_2(*g*) produced by the reaction described in the introduction.

12. Gently swirl the flask until the Tums tablet is fully dissolved, the solution stops bubbling, and the water level in the cylinder no longer changes.

13. Record the final water level in the cylinder.

14. Clean out the Erlenmeyer flask and repeat the experiment for several more trials. You want a total of three *good* trials that produce consistent results. (This means that in reality you'll probably need to do this procedure at least five times.)

CALCULATIONS

The goal of the data analysis is to use the volume of $CO_2(g)$ produced to determine the amount of $CaCO_3(s)$ present in a Tums tablet. You will be able to use the ideal gas law ($PV = nRT$) to find the moles of $CO_2(g)$ produced. Then you can use the balanced equation to figure out how many moles and ultimately grams of $CaCO_3(s)$ were reacted.

1. Find the volume (V) of gas produced during the reaction by taking the difference between the final and initial water volumes in the cylinder.

2. The gas in the cylinder is mostly $CO_2(g)$ and some water vapor [$H_2O(g)$]. To find the pressure (P) of the $CO_2(g)$ alone, you will need to subtract the pressure exerted by the water vapor from the total air pressure in the cylinder (which is assumed to be equal to the barometric pressure in the room):
   i) You can find the pressure exerted by the water vapor molecules (P_{H2O}) at different temperatures in the "Vapor Pressure of Water" table in a chemistry textbook appendix, or at the following website: http://www.wiredchemist.com/chemistry/data/vapor-pressure.
   ii) Then find the pressure exerted by the $CO_2(g)$ according to this equation:

$$P_{CO} = P_{TOTAL} - P_{H2O}$$

(where P_{TOTAL} = the total atmospheric pressure from the barometer in the room)

3. Rearrange the ideal gas law ($PV = nRT$) to solve for the number of moles of $CO_2(g)$ produced (n).
   i) $P = P_{CO2}$ = pressure of $CO_2(g)$ produced (in atm)
   ii) V = volume gas produced during reaction (in L)
   iii) T = temperature of gas produced during reaction (in K; assume this is equal to the temperature of the water in the tub)
   iv) R = universal gas constant = 0.0821 $atm \cdot L \cdot mol^{-1} \cdot K^{-1}$

4. Use the balanced equation shown in the introduction to convert the moles of $CO_2(g)$ produced into a number of moles of $CaCO_3$ reacted.

5. Convert the moles of $CaCO_3$ produced into a mass in grams and also into milligrams (mg).

6. Calculate the percent (by mass) of $CaCO_3$ in the Tums tablet:

$$\%\text{ by mass} = \frac{\text{mass } CaCO_3 \text{ reacted}}{\text{total mass Tums tablet}} \cdot 100\%$$

7. Calculate the average mass of $CaCO_3$ in a Tums tablet over all good trials (you should have at least three good trials).

8. Calculate the average percent by mass of $CaCO_3$ in a Tums tablet over all good trials (you should have at least three good trials).
9. Calculate the percent error between the average mass of $CaCO_3$ per Tums tablet relative to the mass stated on the Tums bottle label:

$$\%\text{ Error} = \frac{|\text{Experimental} - \text{True}|}{\text{True}} \cdot 100\%$$

LAB REPORT

The lab report must be computer generated (see additional information on webpage). It must include the following sections:

A. Title Page
- a single page (separate from the other pages of the report) containing the following information: Experiment Title, Student Name(s), Lab Day and Time, and Lab Instructor's Name

B. Purpose Statement
- A brief description of the purpose of the experiment. What is the specific desired outcome of the experiment? Most often this will be a specific quantity that is determined through data collection and calculation. If an experiment has more than one part, it will have more than one purpose. This section is usually only one or two sentences.

C. Graphs, Data, and Calculations

Use brief sentences and/or labels to clearly introduce each of the following:
- Mass of $CaCO_3$ content per Tums tablet from bottle label.
- Atmospheric pressure (from barometer in classroom).
- Provide a table that shows the following for each trial:
  - Mass of Tums tablet
  - If using only half-tablets in this experiment, include the mass of the half-tablet
  - Initial and final volume of gas in the cylinder for each trial

- Temperature of the gas in the cylinder (which is assumed to be the same as the temperature of the water in the tub)
- Water vapor pressure (P_{H2O}) at the temperature of the gas (look this up)

- For one of the trials, clearly show (including units with all numbers in your work):
  - how P_{CO2} was calculated.
  - every step of how the mass of $CaCO_3$ in a Tums tablet was calculated.
  - how the percent (by mass) of $CaCO_3$ in the Tums tablet was calculated.
  - how the percent error in the mass of $CaCO_3$ in the Tums tablet was calculated.

D. Results

- State clearly and/or provide a table that shows the following:
  - Average experimental mass of $CaCO_3$ in a Tums tablet.
  - "True" mass of $CaCO_3$ in a Tums tablet from bottle label.
  - Average experimental percent by mass of $CaCO_3$ in a Tums tablet.
  - Percent error between experimental and "true" mass $CaCO_3$ in Tums tablet.
  - A measure of the precision of your results, such as the standard deviation or range of the experimental $CaCO_3$ masses over all three good trials.

E. Conclusions

Address the following questions using complete sentences:

- Restate the original purpose of the experiment and the key result(s) that fulfill that purpose.
- Do your results make sense? Why or why not?
- How do your results compare to the statement on the bottle label? That is, discuss the accuracy of your results and how you determined the accuracy level of your results.
- Discuss the precision of your results and how you determined the level of precision in your results.
- If you felt that your results were highly precise, state specific actions that did during the experiment to ensure high precision. If you felt that the precision of your results could be improved, state specific ways that you might improve precision if you repeat this experiment.