Experiment 26: Titration of a Commercial Antacid

(This experiment was adapted from CUNY.)

Purpose

To determine the amount of $CaCO_3$ present in a commercial antacid tablet.

Background

The parietal cells in the stomach secrete hydrochloric acid (HCl) at a concentration of roughly 0.16 M. The flow of HCl increases when food enters the stomach. If you eat or drink too much, you may develop heartburn or indigestion. Antacids are used to neutralize this excess acid.

The active ingredient in antacids is calcium carbonate, $CaCO_3$, a base. There are also other ingredients, such as binders and flavors present in each tablet.

HCl is neutralized by calcium carbonate as illustrated below:

$$CaCO_{3\,(aq)} + H^{+}_{(aq)} \rightleftharpoons Ca^{2+}(aq) + HCO_3^{1-}{}_{(aq)}$$

$$HCO_3^{1-}{}_{(aq)} + H^{+}_{(aq)} \rightleftharpoons H_2CO_{3(aq)} \rightleftharpoons CO_2\,(g) + H_2O\,(l)$$

To determine the quantity of $CaCO_3$ in the antacid tablet, we are first going to dissolve the tablet in an excess amount of acid, HCl, of known concentration. Some of the HCl will be neutralized by the carbonate, but there will be some remaining. We will then perform a titration with NaOH to figure out the amount of excess HCl. Then, from this, we can calculate how much acid reacted with the antacid, followed by the amount of antacid present in the mass of tablet used. This method of analysis is called a back-titration.

The reactions above are reversible, which means that the CO_2 dissolved in water would produce some carbonic acid. This acid would react with the NaOH we are titrating and give us inaccurate results. Therefore, it is important to boil the solution when the calcium carbonate reacts with acid, to remove CO_2 as a gas. The net result is below:

$$CaCO_{3(aq)} + 2\,HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)}(\uparrow) + H_2O_{(l)}$$

Chemicals

0.10 M hydrochloric acid, HCl
0.10 M sodium hydroxide, NaOH
Antacid tablets, 500 mg $CaCO_3$
Phenolphthalein, 1%
Deionized water

Equipment

Buret, buret stand and clamp
Erlenmeyer flask, 125 mL
Pipet, 20 mL, and pipettor (red)
Beakers, as needed
Hot plate (use the one in the hood)

Procedure

1. Obtain a 400 mL beaker and fill it half-way with tap water. Put this beaker with water on a hotplate set at medium heat, in the fume hood. Let this water get hot enough to boil. You will be using this to heat your acid and antacid mixture.

2. In a 125 mL Erlenmeyer flask, pipet in exactly 40.00 mL of 0.10 M HCl. You will be using a 20.00 mL pipet.

3. Obtain two antacid tablets. Find their exact, combined mass with the lab balance.

4. Crush both tablets with a mortar and pestle, until they are a course powder.

5. Determine the exact mass of approximately 0.500 g of this powder. Your sample mass can be slightly less than 0.500 g, but do not use more than 0.500 g. Transfer this sample into the Erlenmeyer flask.

6. Dissolve the antacid power in the acid in the Erlenmeyer flask and place this flask in the hot-water bath for 5 minutes. After the two minutes, remove the Erlenmeyer flask from the hotplate and allow it to cool on your lab bench. Placing the Erlenmeyer in a cool-water bath will help cool it faster.

7. Rinse your buret with DI H_2O, and then rinse it three times with 2 mL-portions of the NaOH solution. Fill the buret with the 0.10 M NaOH solution. Allow enough of the NaOH solution to drain from the buret to remove the air bubble in the tip of the buret.

8. Add three drops of phenolphthalein indicator to the Erlenmeyer flask. Mix well.

9. Record you initial buret volume. Titrate the solution in the flask until the endpoint is reached. The endpoint will be visible when the indicator turns very faint pink.

10. Repeat steps 5 – 9 for two more trials. You should have a total of 3 useable trials. Do one trial at a time, from start to finish.

Data Needed

For each trial, make sure you record the following information:

a) Exact mass of two antacid tablets

b) Volume of HCl pipetted into the Erlenmeyer flask

c) Exact mass of antacid powder added to the Erlenmeyer flask

d) The initial volume of NaOH (before the titration is started)

e) The final volume of NaOH (after the titration is stopped)

Calculations

For each trial, calculate the following: (remember, M=moles/L)

a) Calculate the number of moles of HCl pipetted into the Erlenmeyer flask
b) Calculate the number of moles of NaOH delivered from the buret
c) Subtract the moles NaOH from the moles HCl; this difference is the twice the moles of $CaCO_3$ in the flask that was neutralized by the HCl ($2\ H^+ : 1\ CO_3^{2-}$)
d) Convert the moles of $CaCO_3$ in the flask to grams of $CaCO_3$
e) Divide the grams of $CaCO_3$ by the mass of the antacid power put into the flask; (g $CaCO_3$ / g antacid)
f) Divide the mass of the two antacid tablets by two; this gives the average mass of one tablet
g) Calculate the g $CaCO_3$ / tablet with the following calculation:

$$\frac{\text{g } CaCO_3}{\text{g antacid}} \times \frac{\text{g antacid}}{\text{one tablet}} = \frac{\text{g } CaCO_3}{\text{tablet}}$$

h) Average the three values of the g $CaCO_3$ / tablet
i) How does this average g/tablet compare to the manufacture's claim? Calculate the percent difference between your experimental average result and the value on the bottle of antacid.

$$\%\ \text{difference} = \frac{/\ \text{exp. g/tablet} - \text{true g/tablet}\ /}{\text{true g/tablet}} \times 100$$

*the true g/tablet is the value from the bottle