Evaluating Antacids via a Titration

Objectives

The objectives of this laboratory are to evaluate and compare two commercially available antacids, specifically:

- To perform a titration in order to determine the number of moles H\(^+\) neutralized per gram of each antacid, and
- To calculate the cost-effectiveness of each antacid.

Background

Acid indigestion is a common ailment caused by the overproduction of stomach acid, HCl (aq). Over-the-counter antacids can provide relief from the symptoms of acid indigestion. These antacids generally contain some mixture of weak bases such as Mg(OH)\(_2\), Al(OH)\(_3\), and CaCO\(_3\). The weak bases will neutralize HCl (aq) as shown in following net ionic equations:

\[
\text{H}^+ (aq) + \text{OH}^- (aq) \rightarrow \text{H}_2\text{O} (l) \\
2 \text{H}^+ (aq) + \text{CO}_3^{2-} (aq) \rightarrow \text{H}_2\text{O} (l) + \text{CO}_2 (g)
\]

In this experiment, a titration will be used to determine the number of moles of HCl (H\(^+\)) neutralized per gram of antacid. First, a sample of the antacid will be mixed with an excess of HCl (aq). Then the remaining HCl that has not reacted with the antacid is then titrated with standardized NaOH (aq) to a blue end point, using the indicator bromophenol blue.

The end point is defined as the volume of NaOH needed to see a color change. Because only the tiniest excess of NaOH over HCl can cause the color change of an indicator, the end point is a close approximation of the equivalence point. At the equivalence point, the number of moles of NaOH added is equal to the number of moles of excess HCl that had not been neutralized by the antacid. Thus, by knowing the total moles of HCl used, the number of moles of HCl neutralized by the antacid can thus be calculated:

\[
\text{total moles of HCl used} = \text{moles of HCl neutralized by antacid} + \text{moles of HCl neutralized by NaOH}
\]

Because the antacid includes both OH\(^-\) and CO\(_3^{2-}\), it is not possible to calculate the number of moles of each of these ion species independently. Instead, the number of moles of HCl neutralized by the antacid is determined. An equivalent of antacid is defined as the amount of antacid required to neutralize one mole of H\(^+\) (HCl), that is:

\[
\text{total equivalents of antacid} = \text{total moles of HCl neutralized by antacid}
\]

Finally, given information about the cost of the antacid per package, the cost-effectiveness of each antacid can be determined. The more cost-effective antacid is the one that costs fewer dollars per equivalent.
Procedure

Chemicals

Antacid tablets (Rolaids® and Tums®), 0.1M standardized HCl (aq), 0.1M standardized NaOH (aq), Bromophenol blue indicator solution.

Equipment

Two 50-mL burets*, stand and ring clamp, wire gauze, two small funnels, buret stand and clamp, two 150-mL beakers, two 250-mL Erlenmeyer flasks, Bunsen burner, mortar and pestle

*Items with an asterisk may have to be checked out from the stockroom.

Safety

① Be careful when handling the HCl (aq) and NaOH (aq). Should either of these solutions come in contact with your skin or eyes, immediately rinse the affected area thoroughly with water.
② Be sure to let the boiled antacid solution (hot!) cool to room temperature before touching it.

Instructions

Preparation of Antacid Sample

1. Choose an antacid and record its name on your lab report. Using a mortar and pestle, crush one tablet of antacid to as fine a powder as possible. Note that your instructor may already have performed this step.

2. Add 0.3 – 0.4 g of the powdered antacid into a pre-weighed 250-mL Erlenmeyer flask. Record the mass of the antacid sample to 0.001 g.

Preparation of Burets

3. Obtain two burets from the stockroom. Rinse them with distilled water (a properly cleaned buret will have no water droplets clinging on the inside after rinsing). Label one buret “HCl” and the other buret “NaOH”. Secure them firmly in place with the buret clamp.

4. Add about 100 mL of the standardized HCl (aq) to a beaker (rinsed, dried and labeled) and about 100 mL of the standardized NaOH (aq) to another beaker (rinsed, dried and labeled). Record the concentrations of these solutions on your report form (check the labels on the reagent bottles).

5. Before filling the burets, rinse them with a 5-mL portion of either HCl (aq) or NaOH (aq) as appropriate. This ensures that the acid and base used are not diluted with any of the water left over from rinsing in Step 3. Use your small funnels when adding these solutions to their respective burets.

6. Fill the burets with HCl (aq) and NaOH (aq). Use your small funnels to do this as carefully as possible. Next, drain a small amount of each solution (1-2 mL) out of the burets in order to “charge” the buret tips. Then record the initial buret readings for both HCl and NaOH on your lab report (to 0.01 mL).
Addition of Excess HCl to the Antacid

7. Record the initial volume of HCl (aq) in the buret, then quickly add ~40 mL of the standardized HCl solution to the antacid sample. Record the final volume of HCl (aq) in the buret.

8. Obtain a stand with a ring clamp from the back of the lab. Place your wire screen on the ring, and the Erlenmeyer flask containing the mixture of antacid plus HCl (aq) on the wire screen. Gently boil the mixture for about two minutes using the Bunsen burner. This will drive off as much dissolved CO$_2$ as possible, which could otherwise make the solution even more acidic. Then let the mixture cool to room temperature. Note that a significant amount of solids may still appear to be present in your mixture. These solids are a mixture of inactive ingredients such as the coating and some binding compounds. However, because the active ingredients of the antacid (the weak bases) are quite water soluble, these solids will not affect your results.

9. Add 6 - 8 drops of bromophenol blue indicator to the boiled solution.
   - If the solution turns yellow, this indicates that there is an excess of H$^+$ present, thus no more HCl (aq) is needed.
   - If the solution turns green or blue, this indicates there is an excess of OH$^-$ present, thus more HCl (aq) is needed. Simply add ~10 mL of HCl (aq) from the buret, then assess the color of the solution. If it is not yellow, continue adding small portions of HCl (aq) until it is. Make sure there is enough HCl (aq) in the buret before you do this – it is not possible to measure the volume of HCl (aq) if the level drops below the 50.00-mL mark! Record exactly how much extra HCl (aq) you have added on your lab report.

Titration of excess HCl with NaOH

10. Record the initial volume of NaOH (aq) in the buret. Then begin the titration by slowly adding the standardized NaOH solution (in 1 mL increments) to the boiled solution containing excess H$^+$. Mix well between additions by swirling the flask.

11. As more and more NaOH (aq) is added, the solution will turn from yellow to green and then finally blue. The titration reaches the end point when the addition of one to three drops of NaOH (aq) turn the solution grey-blue and that color is stable even after swirling for 20 seconds. Record the final volume of NaOH (aq) in the buret on your lab report.

Back–Titration: This step is only necessary if too much NaOH has been added and the end point has been exceeded

12. If your solution is intensely blue you have added too much NaOH. Don’t panic, this error can be corrected. First add a small amount of HCl (aq) to the solution until the color reverts back to yellow (3 - 5 mL). Record exactly how much extra HCl (aq) you have used on your lab report. Then resume the titration with NaOH (aq), adding the base in tiny increments until the end point is reached and solution turns the correct shade of gray-blue. Record the final volume of NaOH (aq) in the buret on your lab report – this will replace the volume recorded in Step 11.

Repeat

13. Repeat this procedure with the second antacid provided. Make every effort to reach an endpoint that has equivalent in its “blueness”. Then clean-up as directed by your instructor.