6—Acid Neutralizing Power of Commercial Antacids

Name: _____

Date: _____

Section: _____

Objectives
- Reinforce the procedure of acid/base titration (using phenolphthalein)
- Introduce the concept of buffers
- Introduce the concept of back-titration
- Determine the acid neutralizing power of two commercial antacids and how the two compare

Pre-Laboratory Requirements
- Read Chapter 19.2 in Silberberg
- Watch the instructional videos titled "Mass Balance/Analytical Balance" and "Pipetting"
- Pre-Lab Questions (if required by your instructor)
- Laboratory Notebook—prepared before lab (if required by your instructor)
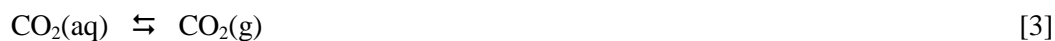
Safety Notes
- Eye protection must be worn at all times.
- Hydrochloric acid and sodium are caustic and should not come in contact with your skin or clothing. Wear gloves when handling these chemicals. A lab coat or lab apron is recommended.
- Hot glass looks the same as cold glass. Handle potentially hot glassware appropriately.
- NEVER combine acids and bases while they are hot; the solutions could spatter and result in serious injury.
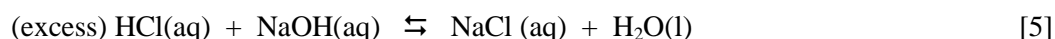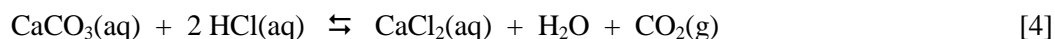
Discussion

In this experiment, a real-world example will be used in order to gain a unique experience in practical chemistry. Many products are available to relieve acid indigestion and upset stomach caused by excess stomach acid, and all of them claim to be effective. However, clearly some must be more effective than others. One product may claim to absorb some number times its weight in acid, and another may claim to have some percentage more neutralizing power than others. But what does this "acid neutralizing power" really mean?

Antacids typically contain multiple ingredients, including flavors, substances that soothe the stomach, and binders that hold the tablet together). However, only the <u>active</u> ingredient works to neutralize or buffer the excess H^+ (acid) in the stomach. Some of the most common active ingredients in antacids are $Mg(OH)_2$, $NaHCO_3$, $CaCO_3$, $MgCO_3$, $Al(OH)_3$, and $NaAl(OH)_2CO_3$.

This experiment focuses on $CaCO_3$ as an active ingredient. $CaCO_3$ works as antacid by the HCO_3^-/CO_3^{2-} buffer system. The system uses the following equilibria:

$$CO_3^{2-}(aq) \ + \ H^+(aq) \ \leftrightarrows \ HCO_3^-(aq) \tag{1}$$

$$HCO_3^-(aq) \ + \ H^+(aq) \ \leftrightarrows \ H_2CO_3(aq) \ \leftrightarrows \ H_2O \ + \ CO_2(aq) \tag{2}$$

$$CO_2(aq) \ \leftrightarrows \ CO_2(g) \tag{3}$$

In this experiment, the acid-neutralizing power of the antacids will be determined by adding a known excess of hydrochloric acid (stomach acid) and back-titrating the excess acid with standardized sodium hydroxide. The overall reactions are:

$$CaCO_3(aq) \ + \ 2\,HCl(aq) \ \leftrightarrows \ CaCl_2(aq) \ + \ H_2O \ + \ CO_2(g) \tag{4}$$

$$(excess)\ HCl(aq) \ + \ NaOH(aq) \ \leftrightarrows \ NaCl\,(aq) \ + \ H_2O(l) \tag{5}$$

Since a buffer (CO_3^{2-}/HCO_3^-) is formed as the antacid is reacted with acid (equation [1]), the pH change per mL of NaOH titrant will be very small, and the endpoint will be very difficult to detect. This difficulty can be overcome by boiling the acidified antacid mixture to remove the CO_2 gas. This will shift the equilibrium position of equation [3] (and therefore equation [2]) to the right, eventually breaking the buffer. Subsequently, adding NaOH to the boiled solution (containing only excess HCl, not H_2CO_3 or HCO_3^-) will result in a more dramatic pH change near the equivalence point and, consequently, a sharper color change at the endpoint. By measuring **(1)** the exact volume of HCl solution (of known molarity), **(2)** the volume of standardized NaOH solution required to neutralize the excess HCl, and **(3)** the mass of the antacid, you can calculate the neutralizing power of the antacid in terms of millimoles of HCl reacted with per gram of antacid present.

An example of these observations and calculations can be followed here:

[HCl] = 0.100 M   volume of HCl added = 50.00 mL

[NaOH] = 0.100 M   volume of NaOH required = 5.00 mL

                                     mass of antacid = 0.600 g

$$\frac{mmol\ H^+\ reacted}{g\ antacid} = \frac{total\ mmol\ HCl\ added - excess\ mmol\ HCl}{mass\ of\ antacid\ (g)}$$

$$\frac{mmol\ H^+\ reacted}{g\ antacid} = \frac{(mL\ HCl)(M\ HCl) - (mL\ NaOH)(M\ NaOH)}{mass\ of\ antacid\ (g)}$$

$$\frac{mmol\ H^+\ reacted}{g\ antacid} = \frac{(50.00\ mL)(0.100\ M\ HCl) - (5.00\ mL)(0.100\ M\ NaOH)}{0.600\ g\ antacid}$$

$$\frac{mmol\ H^+\ reacted}{g\ antacid} = 7.50\ mmol\ H^+/g\ antacid$$

Procedure

1. Obtain an antacid tablet and grind it into a fine powder. Weigh out **two** samples of 0.35-0.4 grams of antacid powder in plastic weigh boats, recording the exact masses used in each trial.
2. Place <u>one</u> sample of the antacid tablet into a clean 250 mL Erlenmeyer flask and rinse the weigh boat using distilled water.
3. Add approximately 50 mL of distilled water, and stir the solution to dissolve the antacid sample. *(Note: the antacid will likely <u>not</u> completely dissolve.)*
4. Add 2 or 3 drops of phenolphthalein indicator to the solution. *(Note: the solution should become light red in color.)*
5. Clean a buret, and fill it with 0.1 M HCl solution. Add 49-50 mL HCl solution to the antacid solution, recording the exact volume used. At this point the indicator should turn colorless, and the rest of the sample should be dissolved.
6. Mix the solution thoroughly, and carefully warm the mixture on a hot/stir plate. Allow the solution to gently boil for about 2 minutes. (*Note: considerable bubbling will occur because of the liberation of CO_2 gas from the carbonic acid-bicarbonate system as mentioned in the discussion. See equations [2] and [3].*)

   **If the pink/red color returns during/after boiling, cool the flask and add acid ~1 mL of acid at a time until the color disappears. Boil again for two minutes. If the solution remains colorless, proceed as follows.
7. Cool the flask under cold tap water, and rinse down the inside walls of the flask with distilled water.
8. Clean a second buret, and fill it with standardized 0.1 M NaOH. Back-titrate the boiled antacid/HCl solution with NaOH solution. Titrate the solution to the first permanent (~10 seconds) pink color, and record the exact volume used.
9. Repeat steps 2-8 with the second antacid sample.
10. Repeat steps 1-9 with a second brand of antacid.

Data:

Molarity of HCl used: _____   Molarity of NaOH used: _____

	Trial 1	Trial 2	Trial 1	Trial 2
Commercial antacid (name)				
Mass of antacid (g)				
Initial volume of HCl (mL)				
Final volume of HCl (mL)				
Volume of HCl added (mL)				

	Trial 1	Trial 2	Trial 1	Trial 2
mmol of HCl added				
Initial volume of NaOH (mL)				
Final volume of NaOH (mL)				
Volume of NaOH added (mL)				
mmol of NaOH added				
mmol of H^+ reacted				
mmol of H^+ reacted/g of antacid				
Average mmol of H^+ reacted/g of antacid				
Average deviation				
Relative average deviation (%)				

Calculations:

Final Report

Your final report should include the average acid neutralizing power for both of the antacids you tested. Report the values to the correct number of significant figures with an estimate of the uncertainty of your values. You should discuss which antacid is more effective, how much more effective it is (slightly, significantly, dramatically, etc.), and how you know this information. Include a sample calculation of how you calculated the acid neutralizing power. The calculation may be handwritten if it is legible.