

Experiment 17A

FV 7/15/06

THE NEUTRALIZING ABILITY OF ANTACIDS

MATERIALS: Four 125 mL Erlenmeyer flasks, two 50 mL burets, two 100 mL beakers, 250 mL beaker, two 25.00 mL pipets, phenolphthalein, standardized 0.1 M NaOH, standardized 0.5 M HCl, Bunsen burner, two ring stands, iron rings, wire gauze, buret clamps, buret funnel, grease pencil, hot hand holders, antacid tablets, stir motor, stir bar.

PURPOSE: The purpose of this experiment is to perform a back titration to determine the neutralizing ability of an antacid, and to evaluate the relative effectiveness of different antacids based on class data.

LEARNING OBJECTIVES: By the end of this experiment, the student should be able to demonstrate the following proficiencies:

1. Use pipets and burets correctly.
2. Perform a titration accurately and precisely.
3. Calculate the molarity and the mass of components in a solution from stoichiometry information.
4. Understand the concept of a back titration.

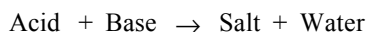
PRE-LAB: Read this experiment and complete the pre-lab questions on page E17-6 **before lab**. Your instructor will check your work before allowing you to start the experiment.

DISCUSSION:

In order to aid in the digestion of food and to protect your stomach against bacterial growth, your stomach secretes gastric acid consisting mainly of hydrochloric acid (HCl) at a pH of about 2. Your stomach is protected by a mucous lining which can be damaged if the acidity becomes too high, possibly causing a peptic ulcer over time or leading to gastroesophageal reflux disease (GERD). Heartburn, indigestion, or upset stomach is also a result of too much acid in your stomach. For many people, acid indigestion can originate from eating too much, eating too quickly, eating high-fat foods, or stressful situations.

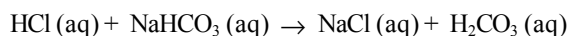
Treatment of indigestion involves lowering the production of stomach acid or neutralizing the acid. Histamine-2 receptor antagonists, or H₂ blockers (such as Tagamet, Pepcid, Zantac), are drugs that prevent or block the production of stomach acid. Antacids, such as Tums and Rolaids, neutralize acid in the stomach raising the pH level to between 3 and 4. This can significantly relieve symptoms for most people. Antacids provide relief more quickly and are less expensive than H₂ blockers, but H₂ blockers provide longer-lasting relief.

Most antacid products contain one or more of four active ingredients: Al(OH)₃, Mg(OH)₂, NaHCO₃, or CaCO₃. These active ingredients are alkaline (or basic) species which react with acid in a *neutralization reaction*¹:



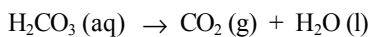
For example, for Al(OH)₃, $3 \text{HCl} (\text{aq}) + \text{Al}(\text{OH})_3 (\text{s}) \rightarrow \text{AlCl}_3 (\text{aq}) + 3 \text{H}_2\text{O} (\text{l})$

three moles of hydrochloric acid are neutralized by every one mole of aluminum hydroxide. For sodium bicarbonate, the neutralization reaction is:



where the H₂CO₃ (carbonic acid) further dissociates into carbon dioxide gas and water,

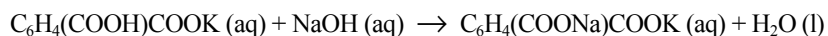
¹See "Chemistry, the Molecular Science", Moore, Stanitski, and Jurs, pages 176-180.



giving an overall reaction of: $\text{HCl}(\text{aq}) + \text{NaHCO}_3(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$

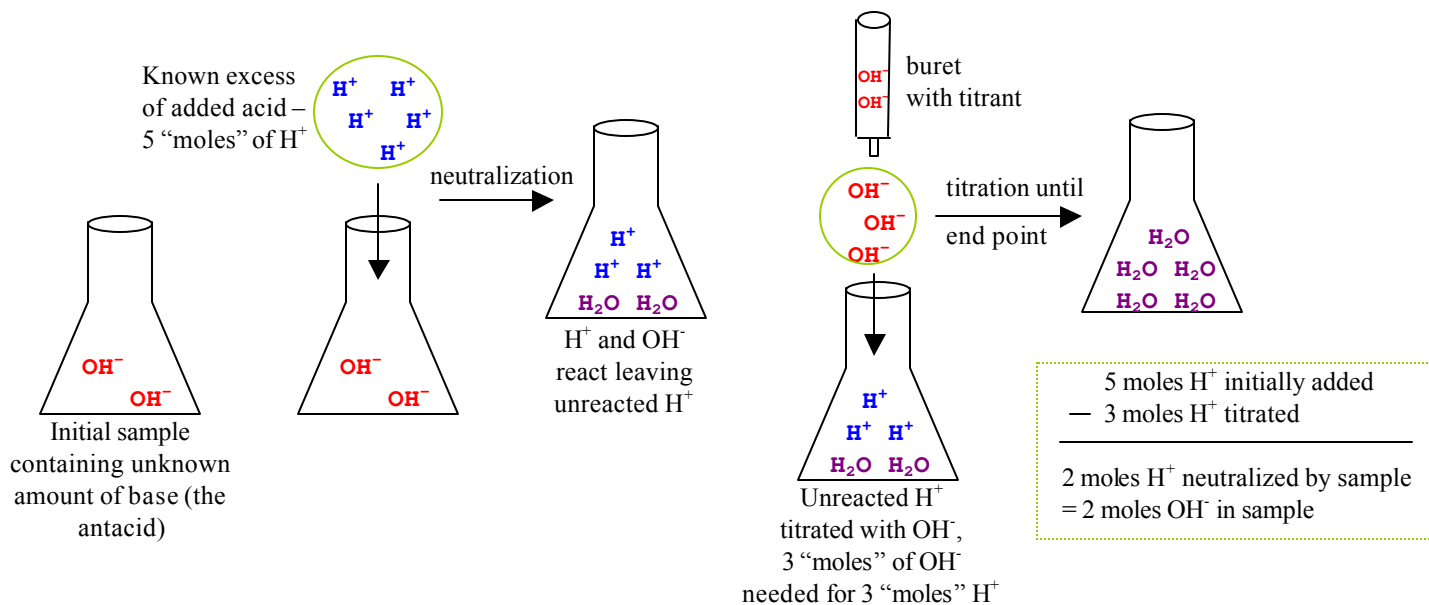
Not all antacids are alike. Some may neutralize more acid than others depending on their active ingredients and amounts. One goal of this experiment is to compare various antacids by their neutralizing abilities.

Sodium hydroxide (NaOH) is a *hygroscopic* solid which means it absorbs water from the air. A weighed quantity of NaOH therefore contains an unknown mass of water. Because of this, a solution of known molarity cannot be prepared by merely dissolving a known mass of solid NaOH in water. The concentration of an unknown NaOH solution must be determined experimentally using a method called a *standardization*. This is done by titrating the NaOH solution against a *primary standard*. A primary standard is a substance from which a solution of known concentration can be prepared. The primary standard usually used is potassium hydrogen phthalate, $\text{C}_6\text{H}_4(\text{COOH})\text{COOK}$, which is referred to by the shorthand notation of "KHP". KHP has several advantages: it does not absorb moisture readily (i.e., is *nonhygroscopic*); it is easily dried; it can be accurately weighed; it can be obtained in very pure form; it has a high molar mass (making it easy to weigh small amounts); and it is very soluble in water. KHP is an acid, which reacts in aqueous solution to neutralize the base, sodium hydroxide, as shown below:



Once the NaOH solution has been standardized (i.e., its concentration determined), it can be used to determine concentrations of unknown acid solutions. Due to time constraints here, the NaOH solution provided to you will already be standardized.

In this experiment, you will perform titrations to determine the neutralizing ability of your assigned antacid. To analyze your antacid, a *back titration* will be used because direct titration of the antacid requires an acidic titrant and there are other experimental complications due to insolubility, buffering, and CO_2 issues. With the back titration method, a known excess amount of HCl will be added to your antacid tablet. After the antacid has neutralized all the acid it can, the remaining HCl will be determined by titration with your standardized NaOH solution. The difference (in moles of H^+) between the amount of acid titrated and the amount of acid initially added will give the amount of acid that reacted with the antacid. Imagine that the HCl represents stomach acid (a known amount). You add the antacid and it neutralizes some of the acid. The amount of acid left over (not neutralized) is determined by the titration. By difference, you can determine how much acid the antacid neutralized.



PROCEDURE:

Work with a partner. EACH member of the group should work with TWO samples of the SAME unknown, assigned by your instructor.

Part A. Preparation of the Antacid Tablets

1. Obtain your assigned antacid from your instructor. Record any pertinent information (identity, active ingredients and amounts, cost) from the bottle label.
2. Label 4 clean, 125 mL Erlenmeyer flasks. The flasks do not need to be completely dry; small droplets of distilled water are acceptable in this case.
3. With a weighing boat, obtain the mass of an antacid tablet on an analytical balance and add it to one of the labeled Erlenmeyer flasks. Repeat this for the other 3 flasks. Make sure to note which mass corresponds to which flask.
4. Draw some standardized HCl solution in a 100 mL beaker, and pre-rinse your 25 mL pipet with the solution. Carefully pipet 25.00 mL of the standardized HCl into each of the flasks. Record the concentration of the HCl solution you used. Remember that volumetric pipets are calibrated to deliver the specified amount without blowing out the remaining liquid in the tip; just touch the tip of the pipet to the flask and let it drain freely until it stops.



Answer In-Lab Question #1 on page E17-5.

5. Swirl the solutions gently recording any observations. Compare this behavior to reactions from other antacids that your classmates used.



Answer In-Lab Question #2 on page E17-5.

6. Set up two stations, each with a Bunsen burner and a ring stand with wire gauze.
7. To each flask, add a quick squirt of distilled water from a wash bottle to rinse down the sides of the flask.
8. One at a time, gently heat each solution until the tablet breaks up, then boil it gently for about 2 minutes to dissolve the active ingredients and expel CO₂. Make sure that you don't heat the solution so strongly that bubbles overflow the flask or splattering occurs. Do not boil to dryness. Gently moving the flame will help to control the heating. Some inactive ingredients in the antacids (starch, binders) will not dissolve and the solution will appear cloudy with small white particles.
9. Carefully remove the heated solution using Hot Hands, and allow it to cool on the lab bench. Repeat the heating procedure with the other 3 samples.

Part B. Analysis of Antacids

For consistent results, always obtain your NaOH solution from the same source, and record the exact concentration labeled on the carboy. Different bottles or carboys may have slightly different concentrations.

1. Once your antacid solutions from Part A are cool, rinse down the sides of the flask with a quick squirt of distilled water from a wash bottle. Swirl the solutions gently to mix.



Answer In-Lab Question #3 on page E17-5.

2. Add 2 drops of phenolphthalein indicator to each flask. Set up two titration stations, with ring stands and buret clamps.
3. With a clean DRY 250 mL beaker, draw ~150 mL of standardized NaOH solution from a carboy. Record the exact concentration listed on the container. Use this solution to pre-rinse and then fill two burets, one for each partner. Make sure there are no air bubbles in the buret tips. Record the initial buret readings.



Answer In-Lab Question #4 on page E17-5.

4. Titrate the acidified antacid tablet solution with your standardized NaOH to the phenolphthalein endpoint, which is when the final *drop* of base added brings about a color change from colorless to a *faint* pink color that persists for 30 seconds. A piece of white paper placed beneath the Erlenmeyer flask will make it easier to detect the color change. Make sure to continually swirl the titration mixture (or use a stir motor if available) for consistent results. Record the final buret reading. Since antacids are real samples and complex mixtures, results from your titration may be less than ideal. You may have cloudy or less distinct end points, so use your best judgment and careful technique to obtain consistent results.
5. Analyze your data (see Data Analysis section) and report your results (average mole H⁺/g antacid) to your instructor.

Clean Up:

1. Rinse all waste solutions down the drain.
2. Wash your glassware. Use a brush to remove any residue from the flasks.
3. Invert the burets and mount them in the buret clamp on the ring stand, with the stopcock open allowing them to drain.
4. Before leaving, return equipment to the drawers or bins from which they were originally obtained.

Data Analysis (include your work):

1. Determine the neutralizing ability of your antacid tablet in units of moles of H⁺ neutralized by the antacid per gram of antacid used. Report your average value to your instructor. (Remember that you are performing a back titration in the analysis of the antacid so your calculations should reflect this.)
2. Collect the class results on the various antacids tested.
3. Using the pooled class data, construct a table which contains the following information:
 - a. Brand of antacid tested
 - b. Antacid active ingredients and their amounts
 - c. Cost per tablet
 - d. Average neutralizing ability of the tablet (in moles H⁺/gram antacid)

Questions for Consideration:

1. Based on the class results, which antacid was most effective in neutralizing acid?
2. Based on cost and effectiveness, which antacid would you buy and why?
3. Based on your results, calculate the average amount of active ingredient found in your antacid (in units of mg). Compare this to the value from the bottle label. Determine the % difference.
4. One of the least expensive and most readily available antacids can be found in the kitchen. Sodium bicarbonate, or baking soda, neutralizes acid quickly. Although sodium bicarbonate may provide a short-term solution to indigestion, too much bicarbonate can wreak havoc with the body's acid-base balance and lead to metabolic alkalosis. Sodium bicarbonate is also high in sodium. These issues aside, which is most effective in terms of neutralizing acid, 1 g of NaHCO₃ or 1 g of CaCO₃? Support your answer.
5. Look on the Internet and find out how acid inhibitors (such as Tagamet, Pepcid, Zantac) work. Are they better or worse than the antacids you tested? Include references for your information.
6. When using phenolphthalein as an indicator, why is it important to stop the titration at the faint pink end point? If a student over-titrates to a very dark pink end point and uses this volume of titrant in the calculations, how will this affect his or her results? Will the value for neutralizing ability be larger or smaller than the expected result?
7. Over time, as your completed titration solutions sit open to the air, you may notice that the end point color fades from faint pink to clear. Explain what is happening.
8. A 0.200 g sample of Roloids is added to 100 mL of water, heated to dissolve the solid, and then cooled. 50.00 mL of 0.100 M HCl is added to the antacid solution and the excess H⁺ titrated with base. If it requires 35.55 mL of 0.0950 M NaOH to reach the endpoint of this titration, what is the neutralizing ability of the antacid (in moles H⁺/g antacid)?

Name _____

Section _____

 **IN-LAB QUESTIONS** 
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(Turn in this page before you leave lab or as directed by your instructor.)

1. Calculate how many moles of H^+ you added to each flask (25.00 mL of the HCl solution). Make sure to use the actual concentration of the HCl you used in lab.
2. How did the antacids react with HCl during the neutralization? Did they all behave the same? Explain any differences in behavior based on the ingredients of the antacid.
3. You added an unknown amount of water to the sample each time that you used the squirt bottle. Why does it NOT matter what the added volume was?
4. Why is it necessary to pre-rinse volumetric glassware with the solutions to be measured? Would it matter if droplets of distilled water were left in the buret when it was filled with sodium hydroxide? Explain.

Name _____

Section _____

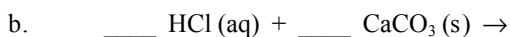
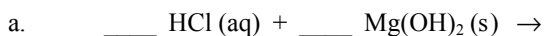
PRE-LAB QUESTIONS
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Complete these questions before lab.

1. If you used NO antacid tablet in your titration, you would be titrating 25 mL of 0.5 M HCl with 0.1 M NaOH. What volume of NaOH solution would be required to reach neutralization in this case?

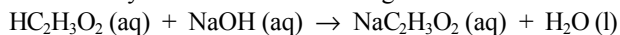
Since you ARE using an antacid tablet (after all, that's the point!), will the titration require more NaOH solution than the amount calculated above, or less? Explain your answer. (Remember, you are doing a *back-titration*.)

2. Different brands of antacids contain different alkaline species to neutralize stomach acid (HCl). Write the balanced, neutralization reactions for the following:



Note that species containing carbonate (CO₃²⁻) form carbonic acid in acidic solutions. Carbonic acid then dissociates into carbon dioxide gas and water.

3. Acetic acid reacts with sodium hydroxide in the following neutralization reaction:



A 25.00 mL sample of an unknown acetic acid solution is titrated. It requires 35.50 mL of 0.1022 M NaOH to reach the equivalence point. What is the concentration (in M) of the unknown acetic acid solution?

Concentration of
acetic acid solution =

4. Read the following picture of a buret to the correct number of significant figures.

Buret Reading = _____

See Appendix E for the proper procedure for reading graduated glassware.

