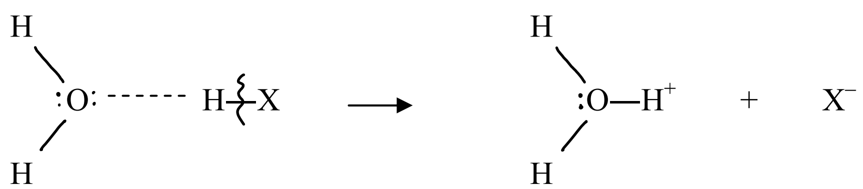
EXPERIMENT 5 ACID-BASE NEUTRALIZATION AND TITRATION

In class we are learning about how a molecule's structure affects its behavior. One special type of behavior is how the molecule responds to water.

Water is a bit of a bully to some of those things that dissolve in it. When something dissolves, there are attractions between the water and the dissolved molecule. The attraction coming off the oxygen can be so strong, that it can actually rip a hydrogen off the molecule it is attracted to. The result of this process is the creation of the hydronium ion, H_3O^+. The presence of a hydronium ion is the sign that an ***acid*** is present in the water.



water acid hydronium ion what's left of the acid

This doesn't happen to all HX's. Sometimes the X^- fights back and takes the H^+ back to remake the HX molecule. Sometimes the covalent bond between H–X is so strong, the bully water can't change it. These three cases are summarized below.

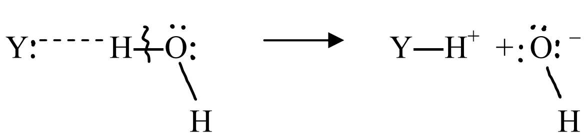
Behavior of HX in H_2O	HX is called ___.
H^+ is ripped away from X entirely	strong acid
Back and forth fight between X^- and H_2O	weak acid
No change in H_2O	not an acid (it may have some other behavior)

Some common examples of acids are given below. (All but the last two are weak acids. Last 2 are strong acids.)

Chemical Name	Formula	Use
citric acid	$H_3C_6H_5O_7$	found in citrus fruits
ascorbic acid	$H_2C_6H_6O_6$	vitamin C
acetylsalicylic acid	$HC_9H_7O_4$	aspirin
acetic acid	$HC_2H_3O_2$	vinegar
boric acid	H_3BO_3	used for eye infections
hydrochloric acid	HCl	stomach acid
sulfuric acid	H_2SO_4	used in car batteries

Acids are identified from their formula either by beginning with an H or by containing a special combination of atoms called a carboxylic acid, COOH or CO_2H, in their formula. Some acids are able to lose more than one H^+, such as boric acid and sulfuric acid.

There are some substances that are bigger bullies than water. Their attraction with the H in water can end up breaking the H–O bond in water. A structural feature that these bigger bullies all have is ***a lone pair of electrons***.



Like with the acid case, there may also be a struggle or total victory depending on the substance. The presence of the hydroxide ion, OH^-, always results when this type of compound (a ***base***) is added to water.

Behavior of Y: in H_2O	Y: is called a ___.
Y: rips H^+ off H_2O entirely	strong base
Y: battles with H_2O over the H^+	weak base
No change in H_2O	not a base (it may have some other behavior)

The base, Y:, can be a molecular compound containing a $\ddot{N}$ (such as NH_3) or it can be the anion part of an ionic compound (such as ClO^-).

Some common bases are below.

Chemical Name	Formula	Use
ammonia	NH_3	window cleaner
sodium hydroxide	$NaOH$	drain cleaner
calcium carbonate	$CaCO_3$	Tums, chalk
sodium bicarbonate	$NaHCO_3$	baking soda
magnesium hydroxide	$Mg(OH)_2$	milk of magnesia
sodium hypochlorite	$NaClO$	bleach
adenine	$NH_2C_5N_4H_3$	a purine, found in DNA
cytosine	$NH_2C_4N_2H_3O$	a pyrimidine, found in DNA

For the ionic compounds in the list, the cation does not interact with the water, just the anions.

When an acid and base come together, the acid easily loses its H^+ to the base (since the base is a bigger bully than water). This type of interaction is called a **neutralization reaction**.

$$H{-}X \ + \ Y: \longrightarrow X^- + HY^+$$

or

$$H{-}X \ + \ Y:^- \longrightarrow X^- + HY$$

For example, if an aqueous solution of nitric acid (a very common acid used in chemistry) is mixed with an aqueous solution of sodium hydroxide, a hydrogen ion is transferred from the nitric acid to the hydroxide ion of the sodium hydroxide, making water and leaving the nitrate ion (NO_3^-) and the sodium ion (Na^+) floating in water. The reaction can be represented as

$$HNO_3 + NaOH \longrightarrow NaNO_3 + H_2O$$

When a hydroxide compound is the base, the products of the reaction are water and an ionic compound (often called a salt). The cation (positive ion) of that salt comes from the hydroxide compound and the anion (negative ion) comes from the acid as in the example given above.

Hydrochloric acid is present in the human stomach to aid in digestion. Sometimes the concentration of HCl in the stomach is too high resulting in conditions known as hyperacidity and acid indigestion. One way to treat these conditions is to neutralize the excess acid with antacid tablets such as "Tums", "Rolaids" or "Phillips Milk of Magnesia Tablets". These tablets contain bases to neutralize the excess HCl.

In today's experiment you will test the neutralizing power of one of these antacid tablets, TUMS. The technique you will use is a quantitative analytical technique known as **titration.** Let us see how the technique works. You will be given a solution of hydrochloric acid (HCl) of unknown concentration and a solution of sodium hydroxide (NaOH) of known concentration. You will slowly add the sodium hydroxide solution to a certain volume of the hydrochloric acid solution until the acid is just neutralized. From knowledge of the volume of HCl solution, the volume of NaOH solution necessary to neutralize the HCl, and the concentration of NaOH solution, the concentration of the HCl solution can be calculated.

This is the way we do the calculation. The concentration unit we use is molarity, M, which is the ratio of the amount of solute (in a unit called a mole which we introduced in the last lab) to the volume of the solution in liters.

$$\text{molarity} = \frac{\text{moles solute}}{\text{volume solution (in L)}} \qquad (1)$$

Therefore, if we wish to determine the number of moles of solute in a certain volume of solution we simply multiply the molarity by the volume of solution:

$$\text{moles solute} = (\text{molarity}) \times (\text{volume in } \textbf{liters}) \qquad (2)$$

The acid-base neutralization reaction being used in today's titration is given below.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

This equation tells that one mole of NaOH will just neutralize one mole of HCl; or in the general case, if we had a certain number of moles of HCl then in order to just neutralize the HCl we would need exactly the same number of moles of NaOH or

$$\text{Number of moles of HCl} = \text{Number of moles of NaOH} \qquad (3)$$

From this equation and (2) above we get

$$\underbrace{(\text{molarity HCl})}_{\text{quantity unknown}} \times \underbrace{(\text{vol. HCl})}_{\text{quantity known}} = \underbrace{(\text{molarity NaOH})}_{\text{quantity known}} \times \underbrace{(\text{vol. NaOH})}_{\text{quantity known}} \qquad (4)$$

Rearranging equation (4) using simple algebra, we get the equation we will use.

$$\text{molarity HCl} = \frac{(\text{molarity NaOH}) \times (\text{vol. NaOH, L})}{\text{vol. HCl, L}} \qquad (5)$$

To convert to milliliters, a more convenient volume unit, we multiply both the top and bottom of the fraction on the right by 1000 since there are 1000 mL in one liter; the top and bottom 1000's cancel and we get

$$\text{molarity HCl} = \frac{(\text{molarity NaOH}) \times (\text{vol. NaOH, mL})}{\text{vol. HCl, mL}} \qquad (6)$$

Therefore, in order to determine the molarity of HCl we multiply the molarity of the NaOH solution by the volume of NaOH solution necessary to neutralize the HCl and divide the product by the volume of HCl solution used.

In this experiment you will first determine the molarity of HCl solution. Then you will neutralize a portion of the HCl with an antacid tablet and you will determine the molarity of HCl after the partial neutralization. This will allow you to measure how much HCl was neutralized by the tablet.

Procedure

Part A. Determination of the Molarity of the Hydrochloric Acid Solution.

1. Using two of the beakers in your desk drawer, obtain approximately 100 mL of the HCl solution of unknown concentration and the NaOH solution of known concentration from the side shelf.
2. Rinse a 125 mL Erlenmeyer flask with a little distilled water. Rinse the 25 mL graduated cylinder twice with a few mL of HCl solution. Following the rinsing, carefully measure out 20 mL of hydrochloric acid and transfer it to the flask. Add two drops of phenolphthalein solution to the flask. Since phenolphthalein is colorless in acidic solution and red in basic solution, the presence of phenolphthalein will allow you to tell when you have added enough NaOH solution to just neutralize the hydrochloric acid solution.
3. Now rinse the 100 mL graduated cylinder twice with a few mL of NaOH solution. Following the rinsing carefully measure out 50 mL of NaOH solution and transfer it to a clean dry 100 mL beaker.
4. Using a dry clean dropping pipette, slowly add the NaOH solution from the 100 mL beaker to the flask containing the acid while swirling the flask. Add the NaOH solution until a faint pink color persists. This is the end point of the titration. You have added the amount of NaOH solution to just neutralize the acid.
5. Transfer the remaining NaOH solution in the 100 mL beaker back to the 100 mL graduated cylinder, and record the volume of NaOH solution remaining. The difference between the original volume of NaOH (50 mL) and the volume remaining is the volume of NaOH solution required to neutralize the acid. You are now ready to calculate the molarity of the hydrochloric acid solution. Perform the calculations on the data sheet.

Part B. Neutralization of Hydrochloric Acid with TUMS Antacid Tablets.

Obtain one Tums tablet and weigh it. Record its mass on the data sheet. Rinse a 125 mL Erlenmeyer flask with tap water followed by a little distilled water. Place 20 mL of hydrochloric acid in the flask as above in step 2. Place the Tums in the flask. Note the results.

This tablet will only partially neutralize the hydrochloric acid. After the Tums tablet has finished reacting, add two drops of phenolphthalein and titrate the remaining hydrochloric acid with the NaOH solution as you did in steps 3–5 (no rinsing of the 100 mL graduated cylinder is needed this time). Record the volume measurements on the data sheet.

Calculate the molarity of hydrochloric acid after the partial neutralization by the tablet. Determine the number of moles of HCl neutralized by the tablet and the number of grams of HCl neutralized by the tablet. Perform the calculations and record the results on the data sheet.

DATA SHEET

Determination of the Molarity of Hydrochloric Acid Solution.

Volume measurements and Calculated Data

(1) Initial volume of NaOH solution	____________________	mL
(2) Volume of NaOH remaining in beaker	____________________	mL
(3) Volume of NaOH added	____________________	mL

(4) Molarity of NaOH (from bottle label) ____________________ M

(5) Volume of HCl used ____________________ mL

(6) Molarity of HCl (use equation 6) ____________________ M

Calculations (Show calculations here.)

Neutralization of Hydrochloric Acid with Antacid Tablet
Masses of tablet, volume measurements and calculated data

(7) Mass of tablet ____________________ g

(8) Volume of NaOH solution ____________________ mL

(9) Volume of NaOH remaining ____________________ mL

(10) Vol. of NaOH added ____________________ mL

(11) Molarity of NaOH (from bottle label) ____________________ M

(12) Vol. of HCl added ____________________ mL

(13) Molarity of HCl after action of tablet (use equation 6) ____________________ M

Show calculation here.

(14) Molarity of HCl before action of tablet (line 6 above) ____________________ M

(15) No. of moles of HCl in 20 mL before action of tablet ____________________ moles

No. of mole of HCl = (molarity. of HCl before action of tablet) x (vol. of HCl in liters)

Show calculation here.

(16) no. of moles of HCl in 20 mL after action of tablet _________________ moles

No. of moles of HCl = (molarity of HCl after action of tablet) x (vol. of HCl in liters)

Show calculation here.

(17) no. of moles of HCl neutralized by tablet _________________ moles

(18) mass of HCl neutralized by tablet _____________________ g

mass = (no. of moles of HCl) x (36.461 g/mol)

Show calculation here.

Post lab questions.

1. Suppose you spill some drain cleaner on the floor. What could you do to the spill before cleaning it up?

2. Identify each of the following as being an acid or a base from looking at their chemical formulas.

HF NH_2CH_3 KOH CH_3COOH H_2CO_3