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I’m Drinking Acid?!: Explorations in Food Chemistry

Experiment

I’m Drinking Acid?!

- Go Direct® pH Sensor

Workshop Presenter

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I'm Drinking Acid?!

Unless you are drinking just water, many of the beverages you commonly consume contain acids.

In this activity you will measure the pH of some common beverages. Then you will determine the concentration of the acid in the drink using a common laboratory technique called titration.

A simple acid, one that only contains one reacting hydrogen ion per molecule, is called *monoprotic*. When an acid reacts with a base, the hydrogen ion from the acid reacts with the hydroxide ion from the base according to the following chemical equation:

$$HA + NaOH \rightarrow NaA + H_2O$$

In this chemical equation representing an acid reacting with a base, the acid (HA) reacts with the base, sodium hydroxide (NaOH), to produce a salt (NaA) and water. The products of acid/base reactions are very commonly a salt and water. The exact point in a titration where all the acid is completely neutralized by the base is called the equivalence point.

pH is a measure of the concentration of hydrogen ion in an acid or base. The pH scale ranges from 0 to 14. Acids have pH values below 7, while bases have pH values over 7. Neutral substances have pH values close to 7.

A common misconception is to try to relate the concentration of an acid to the strength of an acid. Concentration is a measure of how much of the substance is dissolved per unit of volume. Common units of concentration can be the percentage of substance dissolved, or moles of dissolved substance per liter of solution, commonly called molarity.

The strength of an acid is related to how well the substance dissolves in water and reacts with other chemicals. Strong acids react much more vigorously than weak acids for example.

It is possible for a strong acid and a weak acid to have the same concentration and yet have completely different reactions with other materials.

Surprisingly, your stomach contains a strong acid called hydrochloric acid. Normally this would not be a safe substance to get on your tissues, but your stomach is lined with material to prevent the acid from reacting with the tissue in your stomach.

OBJECTIVES

- Measure the pH of common beverages.
- Learn the technique of titration.
- Determine the concentration of acid in a common beverage.

MATERIALS

Chromebook, computer, or mobile device
Graphical Analysis app
Go Direct pH
goggles
Stir Station
magnetic stirring bar
Electrode Support
50 mL buret
10 mL pipet
buret clamp or utility clamp
three 250 mL beakers
sensor soaking solution
various beverage samples
0.05 M NaOH solution
pipet bulb or pump
wash bottle
distilled water

PRE-LAB ACTIVITY

Do some research to determine the primary acid in the following beverages. Find and record the chemical formula for each. Make a prediction of the pH of the beverage.

	Name of primary acid or base in beverage	Chemical formula of acid or base in beverage	Predicted pH
Carbonated soda			
Orange juice			
Apple juice			
Sports drink			
Grape juice			

PROCEDURE

Part I How acidic is this drink?

1. Obtain and wear goggles.
2. Prepare the pH sensor for data collection.
   a. Launch Graphical Analysis.
   b. Connect the Go Direct pH Sensor to your Chromebook, computer, or mobile device.
   c. Remove the pH sensor from the sensor storage solution bottle by loosening the cap first.

d. Rinse the tip of the sensor with distilled water and place the sensor tip into a 250 mL beaker containing sensor soaking solution. Use an Electrode Support to fasten the pH sensor to a Stir Station, as shown in Figure 1.

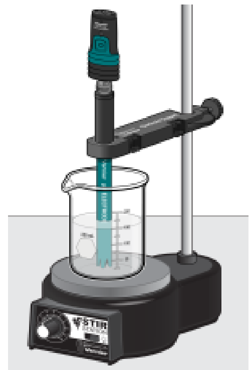

Figure 1

3. Raise the pH sensor from the sensor soaking solution and set the solution aside. Use a wash bottle filled with distilled water to thoroughly rinse the pH sensor. Catch the rinse water in another 250 mL beaker.

4. Obtain a sample of one of the five beverages supplied by your teacher. Raise the solution to the pH sensor and swirl the solution about the sensor. When the pH reading stabilizes, record the name of the beverage and the pH value.

5. Prepare the pH sensor for reuse.

   a. Rinse it with distilled water from a wash bottle.
   b. Place the sensor into the sensor soaking solution and swirl the solution about the sensor briefly.
   c. Rinse with distilled water again.

6. Determine the pH of the other solutions using the Step 4 procedure. You must clean the pH sensor between tests using the Step 5 procedure.

7. When you are finished, rinse the sensor with distilled water and return it to the sensor soaking solution.

Part II Determining the concentration of the acid by titration

8. Add 50 mL of distilled water to a third 250 mL beaker, and then add 10 mL of the beverage assigned to you to the beaker.

9. Place the beaker on a Stir Station and add a magnetic stirring bar.

10. Set up the data-collection mode.

    a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
    b. Enter **Volume** as the Event Name and **mL** as the Units. Click or tap Done.

Figure 2

11. Use an Electrode Support to suspend the pH sensor on the Stir Station (see Figure 2). Position the pH sensor so that its tip is immersed in the beverage solution but is not struck by the stirring bar. Gently stir the beaker of solution.

12. Rinse and fill a 50.0 mL buret with 0.05 M NaOH solution Attach the buret to the Stir Station using a clamp (see Figure 2). **DANGER**: *Sodium hydroxide solution*, NaOH: *Causes severe skin burns and eye damage. Do not breathe mist, vapors, or spray*.

13. Read this step completely before doing a titration. Instructions for doing a titration are in Step 14.

    a. It can be helpful to conduct a first titration run in a so-called "quick and dirty" manner, where you add the NaOH solution 0.5 mL at a time to get a rough idea of how the titration curve will develop. This will give you good information from which to plan a second, more accurate titration.

    b. As you perform a titration keep these tips in mind:

        i. Determine an initial pH reading, before adding any NaOH solution.

        ii. For a more accurate titration, add NaOH solution in small increments, raising the pH of the mixture by about 0.15–0.25 units at a time, until you are near an equivalence point.

        iii. Near an equivalence point, it is good to add NaOH solution drop by drop.

14. You are now ready to perform the titration. This process is faster if one person manipulates and reads the buret while another person enters volumes.

    a. Click or tap Collect to start data collection.

    b. Before you have added any drops of NaOH solution, click or tap Keep and enter **0** as the buret volume in mL. Click or tap Keep Point to store the first data pair.

    c. Add the next increment (0.5 mL) of NaOH titrant. When the pH stabilizes, click or tap Keep, enter the current buret reading (to the nearest 0.1 mL), and then click or tap Keep Point.

    d. Continue adding NaOH solution until the pH value remains constant.

15. Click or tap Stop to stop data collection.

16. Dispose of the reaction mixture as directed. Rinse the pH sensor with distilled water.

17. Take note of the volume during the titration where the pH changed the greatest when 0.5 mL of NaOH was added. The equivalence point is near this volume.

18. Repeat the necessary steps to titrate a second 10 mL sample of your beverage. In the second data-collection run, add the NaOH solution carefully near the equivalence point. Add increments of NaOH titrant (enough to raise the pH about 0.15 units). At some point, this may require only one drop of NaOH be added at a time. When the pH stabilizes, click or tap Keep, enter the current buret reading (to the nearest 0.01 mL), and then click or tap Keep Point.

19. Continue adding NaOH in this manner until the pH stabilizes then click or tap Stop to stop data collection.

20. Dispose of the reaction mixture as directed. Rinse the pH sensor with distilled water and return the electrode to the storage solution.

21. Click or tap on the graph of pH *vs*. volume to examine the data and find the equivalence point—that is the largest increase in pH upon the addition of 1 drop of NaOH solution. Move to the region of the graph with the largest increase in pH (you can adjust the Examine line by dragging the flag). Find the NaOH volume just before this jump. Record this value in the data table. Then record the NaOH volume after the drop producing the largest pH increase was added. **Note**: Another method for determining the equivalence-point volume is described in the Alternate Equivalence Point Method of this experiment.

ALTERNATE EQUIVALENCE POINT METHOD

An alternate way of determining the precise equivalence point of the titration is to take the first and second derivatives of the pH-volume data.

22. Determine the peak value on the first derivative *vs*. volume plot.

    a. Click or tap View, ⊞, and turn on Data Table. Dismiss the View menu.
    b. Click or tap More Options, ⋯, in the pH column header in the table. Then, choose Add Calculated Column.
    c. Enter **d1** as the Name and leave the Units field blank.
    d. Click or tap Insert Expression and choose 1st Derivative(Y,X) as the expression.
    e. Select pH as Column Y and Volume as Column X. Click or tap Apply.
    f. To display a graph of d1 *vs*. volume, click or tap the y-axis label, select only d1, and dismiss the box.
    g. On the graph of d1 *vs*. volume, examine the data to determine the volume at the peak value of the first derivative. This is the volume of NaOH added at the equivalence point. Record the value in the data table.

23. Determine the zero value on the second derivative *vs*. volume plot.

    a. Click or tap More Options, ⋯, in the Volume column header in the table. Then, choose Add Calculated Column.
    b. Enter **d2** as the Name and leave the Units field blank.

c. Click or tap Insert Expression and choose 2nd Derivative(Y,X) as the expression.

d. Select pH as Column Y and Volume as Column X. Click or tap Apply.

e. Click or tap the y-axis label, select only d2 to display a graph of d1 *vs*. volume, and dismiss the box.

f. Click or tap the y-axis label, select only the d2 column, and dismiss the box. On the displayed graph of d2 *vs*. volume, examine the data to determine the volume when the 2nd derivative equals approximately zero. This is the volume of NaOH added at the equivalence point. Record the value in your data table.

DATA TABLE

Part I

Beverage	pH

Part II

Beverage tested	
Concentration of NaOH used	M
NaOH volume added before largest pH increase	mL
NaOH volume added after largest pH increase	mL

Volume of NaOH added at equivalence point	mL
Moles NaOH	mol
Moles acid in beverage	mol
Concentration of acid in beverage	mol/L

DATA ANALYSIS

1. From your data, determine the number of moles of sodium hydroxide added to reach the equivalence point during the titration of each sample of beverage.

2. Remember the chemical equation for this reaction. Assuming that the acid molecules in the beverage only provided one hydrogen ion during the reaction with the sodium hydroxide, how many moles of acid were consumed in the reaction with the sodium hydroxide? How did you determine this value?

3. The formula to find the concentration of acid in the beverage in moles per liter is

$$\text{concentration} = \frac{\text{moles acid}}{\text{volume beverage}}$$

   Calculate the concentration of acid in each beverage you tested. If you diluted any beverages before titrating the sample, make sure to account for this in your calculations.

4. Most beverages are acidic but a few are basic. How would you modify this experiment to measure the concentration of base in a drink?