Experiment

TITRATION OF A COLA PRODUCT

The CCLI Initiative

Computers in Chemistry Laboratory Instruction

LEARNING OBJECTIVES

The objective of this laboratory experiment is to determine the molar concentration of phosphoric acid in a cola product.

BACKGROUND

Titration is an analytical technique used to find the concentration of a known volume of unknown substance by adding a known concentration of a known substance. As the unknown and known substance react, we look for a "telltale" indication that the reaction is complete, which allows us to determine the concentration of the unknown.

The most common type of titration is known as an **acid-base titration**. In an acid-base titration, we start with a known amount (usually a volume) of an unknown concentration of acid and add to it known amounts of a known concentration of base (or *vice versa*).

For our purposes, the **equivalence point** is the most crucial point in the titration. It is the point during the titration where the moles of base added will equal the moles of acid in the unknown solution (or *vice versa*). Since the volume of base added can be read from the buret at this point and the concentration of the base and the volume of the acid are also known, the concentration of the unknown acid solution can be determined.

There are a number of ways to determine the equivalence point, two of which can be used in this experiment. The first is by measuring the pH of the solution as you add base to the acid. There is a dramatic increase in the pH of the solution at the equivalence point(s) as shown in Figure 1 on the following page. A second way to detect the equivalence point is by using a thermometric method. Because acid-base reactions are exothermic, the solution being titrated warms as base is added. At the equivalence point, there is no further acid-base neutralization reaction and solution warming decreases or ceases abruptly. If you have a precise enough temperature measuring device, this abrupt change in the heating curve can be detected.

The acid content of many foods and beverages contribute significantly to the taste. Soft drinks often contain varying quantities of several acids. In cola products, these acids are predominantly carbonic acid (from the carbonated water) and phosphoric acid. By decarbonating the cola, you can determine the phosphoric acid concentration via titration. The phosphoric acid content is usually quite low, so good technique is critical.

Phosphoric acid is a weak acid. It is also a polyprotic acid, which means it will liberate more than one proton (H^+) in solution. Phosphoric acid reacts with NaOH in the following manner:

$$H_3PO_{4(aq)} + OH^-_{(aq)} \Longrightarrow H_2PO_4^-{}_{(aq)} + H_2O_{(l)} \quad (1)$$

$$H_2PO_4^-{}_{(aq)} + OH^-_{(aq)} \Longrightarrow HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \quad (2)$$

$$HPO_4^{2-}{}_{(aq)} + OH^-_{(aq)} \Longrightarrow PO_4^{3-}{}_{(aq)} + H_2O_{(l)} \quad (3)$$

Each of the above reactions will have its own equivalence point. However, because of the concentration of the base used for the titration, you can only see the equivalence points for reactions (1) and (2). The overall titration curve will look similar to Figure 1.

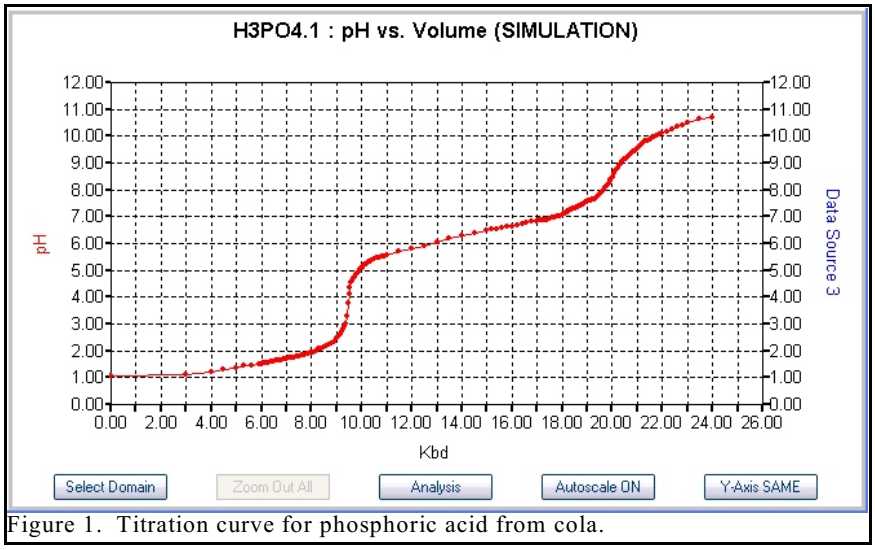

Figure 1. Titration curve for phosphoric acid from cola.

The only equivalence point of concern here is the first one, since it will give you the concentration of H_3PO_4.

SAFETY PRECAUTIONS

You must wear lab goggles at all times. If the acid or base solutions get on your skin, rinse with plenty of water.

All solutions resulting from the titrations may be discarded in the sinks. Any unused base solution should *not* be returned to the storage containers; therefore, take only the quantities of solution that you will need.

BEFORE PERFORMING THIS EXPERIMENT . . .

... you will need a ***MicroLAB*** program capable of measuring pH and/or temperature with respect to the volume of titrant. This volume may be a time, a drop count, or a manually-input volume reading from the buret. Your instructor will indicate which of the ***pH-temperature*** programs you are to use.

EXPERIMENTAL PROCEDURES

Your titration set-up will look similar to that shown in Figure 2. Before using the pH electrode and/or temperature probe, they must be calibrated. Consult your instructor regarding the procedure to follow.

You should obtain temperature and/or pH, and volume data for at least 10 ml beyond the equivalence point. You should stir the solution with a stirring rod or magnetic stirrer at all times, leaving the thermistor and/or pH electrode stationary in the Styrofoam cup. You will observe the titration curve forming on the graph as you carry out the titration. If you use a drop counter, you will need to **Calibrate** the drops per ml, using the ***Drop Counter Calibration*** provided by your instructor to convert drops into volume. Your instructor will indicate which one you are to use.

1. Pour about 75 ml of cola into a clean, dry 250 ml beaker. To prepare the cola for titration, it must first be decarbonated. Cover the beaker containing the cola with a watch glass and gently boil for about 20 minutes using a Bunsen burner or a hot plate. This will remove the carbon dioxide from the cola, which would interfere with the phosphoric acid titration. Let the cola cool to room temperature before titrating.

2. Using a pipet, add 5.00 ml of room temperature, decarbonated cola into a clean, double-nested Styrofoam cup.

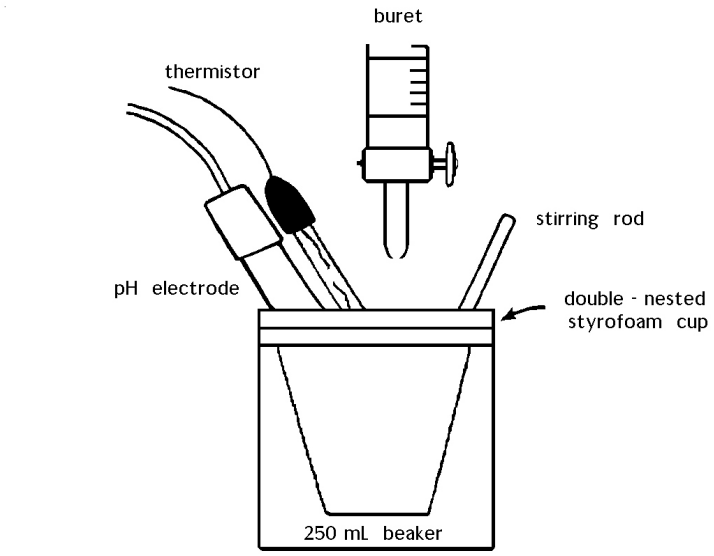

Figure 2. Set-up for the ***MicroLAB*** interface titration.

3. Using a 250 ml beaker, obtain about 55 ml of 0.01 *M* NaOH. Note the exact concentration of the NaOH from the container.

4. To prepare the buret for the titration, it should first be rinsed with deionized water and then rinsed with several small portions of the NaOH solution. To begin the titration, the buret should contain between 40 and 50 ml of NaOH.

5. Your instructor will inform you concerning which procedure you will use to carry out your titration.

6. You should conduct at least three titrations of the cola in order to determine your reproducibility.

DATA ANALYSIS

1. From the graphically-obtained pH and/or thermometric first equivalence points:

   a. Using the ***MicroLAB*** **Hand Enter** mode enter the equivalence point volumes for the three best titrations, and using the **Add Formula** function, set up a formula to calculate the moles of H_3PO_4 in each of the 5.00 ml samples of cola. Your instructor may want you to use the first derivative to obtain the equivalence point volume, then "click-drag" the formula to Column C.

   b. Again using the **Add Formula** function, set up a formula to calculate the molarity of H_3PO_4 in the cola for each sample, then "click-drag" the formula to Column D.

   c. Obtain the **Statistics** window by "right-clicking" on Column D, and determine the average and standard deviation for your molarity results.

2. For your report, print out the graphs for the three best titrations, the spreadsheet for the **Hand Entered** data, and the **Statistics** window.