Investigating an Acid Mixture

In this experiment you will determine the quantitative composition of a solution, which is a mixture of a strong acid, HCl, and a weak acid, H_3PO_4. After titrating the mixture with a standard NaOH solution, you will employ quantitative volumetric analysis to determine the molar concentrations of the acids in the mixture.

The strong acid in the mixture completely dissociates in water and the weak acid partially dissociates. The extent of the weak acid dissociation is represented by an equilibrium constant, K_a. The weak acid in your mixture is triprotic, thus its dissociation is described by three equilibrium constants. Understanding the behavior of the acids as they dissociate is a key component to evaluating the results of the titration.

OBJECTIVES

In this experiment, you will

- Titrate a mixture of hydrochloric and phosphoric acids with standard NaOH solution.
- Calculate the molar concentration of each acid in the mixture.
- Calculate the K_{a2} (or pK_{a2}) for the weak acid.

Figure 1

MATERIALS

Vernier LabPro
Computer
Vernier pH Sensor
0.100 M sodium hydroxide, NaOH solution
HCl/H_3PO_4 mixture, unknown molarity
Vernier Stir Station w/ stirring bar
Vernier Electrode Support
wash bottle
distilled water
buret
utility clamp
250 mL beaker
10 mL graduated cylinder
50 mL graduated cylinder

PROCEDURE

1. Obtain and wear goggles.

2. Obtain about 25 mL of the acid mixture. Add 50 mL of distilled water to a 250 mL beaker. Use a graduated cylinder to transfer 10.0 mL of the acid mixture into the beaker. **CAUTION:** *Handle the acid mixture with care. It can irritate the eyes and skin.*

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

4. Connect a pH Sensor to Channel 1 of your LabPro. Connect the LabPro to the computer with a USB cable.

5. Secure a buret to the Stir Station with a utility clamp to conduct the titration (see Figure 1). Rinse and fill the buret with 0.100 M NaOH solution. **CAUTION:** *Sodium hydroxide solution is caustic. Avoid spilling it on your skin or clothing.*

6. Use an Electrode Support to suspend the pH Sensor on the Stir Station, as shown in Figure 1. Position the pH Sensor so that its tip is immersed in the CH_3COOH solution but is not struck by the stirring bar. Gently stir the beaker of acid solution.

7. Start the Logger *Pro* 3 program on your computer. To open a titration experiment file, choose File _ Open _ Probes & Sensors _ pH Sensor _ pH titration.

8. To conduct the first titration, follow the steps below. In this first run, you are simply looking for the rough equivalence points.
   a. Click Collect. Once the displayed pH reading has stabilized, click Keep. In the edit box, type "0" (for 0 mL added), and then click OK.
   b. Add ~1 mL of NaOH. When the pH stabilizes, click Keep. In the edit box, type the current buret reading as precisely as possible. Click OK.
   c. Continue adding NaOH solution in ~1 mL increments until the pH readings have reached a plateau of about 11.

9. When you have finished collecting data, click Stop. Dispose of the reaction mixture. Rinse the pH Sensor and the beaker with distilled water in preparation for the second titration.

10. Examine the graph of your titration and note the two equivalence points. These are the regions you want to titrate carefully in your second trial. If you wish to save the results of your first trial, open the Experiment menu and choose Store Latest Run. To delete the first run of data, open the Experiment menu and choose Clear Latest Run.

11. Repeat the necessary steps to conduct a second titration with a fresh 10.0 mL sample of the acid mixture.

12. Arguably the best method of determining the equivalence point of a titration is to prepare and examine a plot of the second derivative of the pH *vs*. volume data. To prepare and analyze your second titration and determine the equivalence points, follow the steps below.

    a. Open the Data menu and select New Calculated Column.
    b. (Optional) Enter a name, a short name, and units for your new column.
    c. Place your cursor in the Equation box and left click to make it active.
    d. Click the Functions button and select Calculus _ secondDerivative.
    e. Click the Variables (Columns) button and select Choose Specific Column. Select the pH data labeled as Latest. Click Done.
    f. Double click on the graph to view the Graph Options dialog box. Click the Axes Options tab at the top of the dialog box. Check the box next to the second derivative column that you created. Click Done. Rescale the axes of the graph, if necessary.
    g. Click the Examine button, , and trace the second derivative graph to the spots where the plot crosses the X-axis. These are the equivalence points of your titration. In the data table below, write down the volume of NaOH delivered to reach each equivalence point.
    h. Save your data as a file by opening the File menu and choosing Save As…. Give your new file a name you'll always remember and save the file to your computer's desktop.

13. If time permits, conduct a third titration with a new sample of the acid mixture.

DATA TABLE

Trial	Volume acid mixture (mL)	[NaOH] (M)	1st Equivalence point (mL)	2nd Equivalence point (mL)
1				
2				
3				

DATA ANALYSIS

1. How much NaOH, in moles, was used to reach the first equivalence point?

2. How much NaOH, in moles, was used to reach the second equivalence point?

3. What is the molar concentration of the HCl and the H_3PO_4 in the acid mixture? Explain how you calculated these values.

4. Use your titration data and the Henderson-Hasselbalch equation to calculate the K_{a2} for H_3PO_4. The literature value is 6.2 _ 10^{-8}. How does your calculated K_{a2} compare with the literature value? For the generic dissociation: HX _ $H^+ + X^-$, a version of the Henderson-Hasselbalch equation is shown below.

$$pH = pK_a + \log\frac{[X^-]}{[HX]}$$