



Determining K_a

Experiment
5

Introduction

In part 1, an unknown weak mono-protic acid will be partially neutralized so that three different ratios are obtained of the acid/ conjugate base pair. From the acid/conjugate base ratio and the pH of each solution, the values of pK_a and K_a can be calculated using the Henderson-Hasselback equation.

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

part 2, a strong acid will be titrated against a strong base and the pH vs volume of titrant will be plotted. In part, 3 and 4 a monoprotic weak acid and a triprotic acid will be titrated with a strong base and the pH vs volume will be plotted. From the plot, the pK_a will be determined and the K_a will be calculated.

Procedure

Part 1: Day 1

1. From the stock room, obtain a 50mL buret, 25mL pipet and bulb, 250 mL bottle and 4 vials. Fill the bottle with 0.1M NaOH, mix thoroughly and use this as your own supply for all work in this lab.
2. Fill the buret with 0.1M NaOH.
Use a small beaker and a funnel to transfer the solution and remember:
 - a. Rinse the buret with three portions of base, coating the barrel each time before emptying out the solution.
 - b. After filling, flush out the tip thoroughly, making sure no bubbles are caught in the tip.
 - c. Check the stopcock for leaks.
3. Bring a clean dry 250 mL beaker to the instructor for a sample of unknown weak acid.

Reserve a small sample of the acid for later measurement of pH along with the solutions you will prepare in step 6. Use vials for storage.

4. Pipet 25mL of acid into an Erlenmeyer flask, then titrate with the NaOH solution to the phenolphthalein endpoint. Remember:
 - a. Rinse the pipet with three portions of the acid, coating the walls each time

- b. Record all measurements including initial and final buret readings.
- c. Wash down the walls of the flask with distilled water as you near the endpoint. Record the volume of base titrated. Repeat the titration to get three values that agree within 1 %. Discard solutions from this titration.

5. Find the average volume of NaOH titrated, V_n . Calculate $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ of this volume.
6. Make up three solutions of partially neutralized acid by pipetting the acid into a flask and transferring the required amount of base into the flask from the buret.

Solution	Volume acid	Volume NaOH	
1	25.00mL	$\frac{1}{4} V_n$	
2	25.00mL	$\frac{1}{2} V_n$	
3	25.00mL	$\frac{3}{4} V_n$	

Each time rinse down the walls of the flask and mix thoroughly. Transfer a portion of each solution to a storage vial. The pH meter should be calibrated using a pH 4 buffer. Measure and record the pH. Each solution can be discarded after recording the pH.

Calculations

For each of the solutions prepared:

1. Calculate $[H^+]$ from the pH measurement. $[H^+] = \text{antilog}(-\text{pH})$.
2. The conjugate base/acid ratios, $[A^-] / [HA]$ are the following:

	Solution 1	Solution 2	Solution 3
$[A^-]$	$\frac{1}{4} V_n = 1$	$\frac{1}{2} V_n = 1$	$\frac{3}{4} V_n = 3$
$[HA]$	$(1 - \frac{1}{4}) V_n = 3$	$(1 - \frac{1}{2}) V_n = 1$	$(1 - \frac{3}{4}) V_n = 1$

3. Use the Henderson-Hasselback equation, the above ratios and the experimental values of $[H^+]$ to calculate the pK_a and K_a values for each solution. Compare them and report the average value of pK_a and K_a value for your acid.

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

Part 2:

pH curves for titrations of strong and weak acids

A 0.10 M NaOH will be titrated against 0.1 N solutions of HCl and $\text{HC}_2\text{H}_3\text{O}_2$ or H_3PO_4 , using a pH meter to monitor the change in pH by addition of increments of base. The pH of the indicator color change may be noted, and compared with the equivalence point pH as determined from the titration curve.

Procedure

(Only one trial for each day is needed because of the shortage of pH meters.)

Day 2 – Strong Acid(HCl) – Strong Base titration.

Set-up a buret with 0.1 M NaOH and place 25mL 0.10 M HCl and 25 mL distilled H_2O in a 150ml beaker with a magnetic stirrer. Set-up a pH meter alongside the buret assembly and calibrate the glass electrode with pH 4.0 buffer for the first part of the titration. Add 2-3 drops of phenolphthalein indicator to the acid solution. Titrate the NaOH in 1.0mL increments, recording the pH and volume after each addition, until about 20 mL have been added. Then proceed with 0.5 mL additions until 3mL after the equivalence point has been reached. Methyl red or methyl orange indicator may be used as well as phenolphthalein to observe the pH at which the color change occurs. For a strong acid-strong base titration, use phenolphthalein.

Day 3 – Weak acid (acetic acid) –Strong Base titration.

Repeat the procedure using 0.10 M acetic acid in place of the HCl. Again, record the pH after each addition of base in 1.0 mL increments until about 20 mL have been added, then proceed with 0.5 mL additions until 3 mL after the equivalent point. The smaller increments should be about twice the volume required to reach the pK_a for this acid. You may look up the pK_a of acetic acid to estimate the correct volumes. Again note the pH of the indicator color change. Would you expect the equivalence point to be acidic, neutral, or basic for a weak acid-strong base titration?

Day 4 – Weak acid (phosphoric acid) – Strong Base titration.

Repeat the procedure with 0.10 N (0.033M) H_3PO_4 for the acid. Add the base in 1.0 mL increments in the regions where pH changes slowly (pK_a ranges). Look up the pK_a values for phosphoric acid and add the 1.0 mL increments within the buffer zone (+ or – 1 pH unit from pK_a). Use smaller increments of base when the pH changes are larger. This should occur around the equivalence point (twice the volume to reach the pK_a).

Report

Graph on excel the results for each of the titrations. Plot pH on the vertical axis with the volume of NaOH added on the horizontal axis. Identify the equivalence point pH for each curve and the region of indicator color change for each. For your weak acids, estimate the pK_a from your plot and calculate the K_a for each acid. The pK_a is the pH at the half-equivalence point volume. Look up the literature values for the pK_a of each acid and calculate the % error in pK_a for each.

Add each plot into the report and tabulate the results into a table.