Titration of a Weak Acid

Aim: To determine the molar mass, pk_a and the identity of an unknown weak acid by titration.

Introduction

A weak acid undergoes partial dissociation in an aqueous solution. There exists an equilibrium between the ions and the undissociated acid molecule. The equilibrium constant for this process is K_a is the acid dissociation constant. Consider a weak monoprotic acid HA:

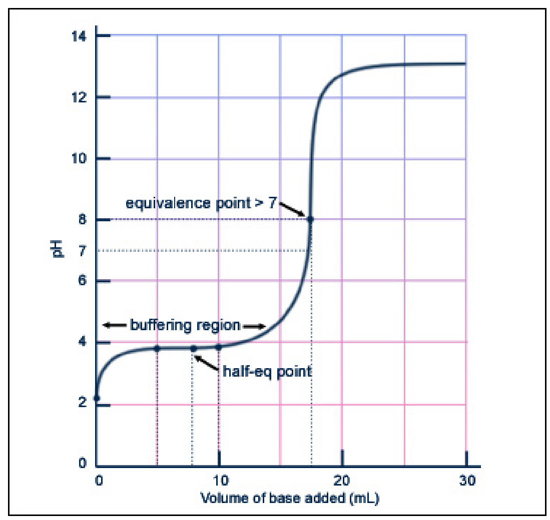
$$\mathbf{HA\,(aq) + H_2O\,(l) \rightleftarrows A^-(aq) + H_3O^+(aq)} \qquad K_a = \frac{[A^-][H_3O^+]}{[HA]}$$

In any acid–base titration, a solution of known concentration (the **titrant**) is slowly added from a **burette** to a solution of unknown concentration (the **analyte**) until the reaction is complete. The equivalence point occurs when stoichiometrically equal amounts of the acid and base are present. A plot of pH vs volume is known as a *titration curve.*

When the acid HA is titrated with NaOH, the reaction taking place is:

$$\mathbf{OH^-\,(aq) + HA(aq) \longrightarrow A^-(aq) + H_2O(\mathit{l})}$$

As the titration proceeds, the nature of the solution will change.



1. Initially when no NaOH had been added, the only species in solution are the weak acid and a small amount of H_3O^+ and A^- formed by the slight dissociation of the weak acid. The pH of the solution depends only on the molar concentration or the acid and the K_a of the acid.

2. After some NaOH(aq) has been added, but before the equivalence point, the acid and its conjugate base will both be present in amounts that are roughly comparable. In this region of the titration the solution is a buffer. At the point in the titration where [HA] = [A^-], the pH of the solution = pK_a. This will occur halfway to the equivalence point in terms of the amount of NaOH added. Thus, at the "half equivalence point" or "halfway point", pH = pK_a.

3. After the equivalence point, the pH of the solution depends on the NaOH in excess.

4. If the acid is polyprotic, then there will be more than one equivalence point which can be identified from the titration curve. We can thus calculate pK_a for each step for a polyprotic acid.

In today's lab, a weak acid will be titrated with a known concentration (standardized) solution of NaOH(aq) to determine the pKa, molar mass and the identity of the acid.

SUPPLIES:

Standardized NaOH(aq) (not the .1M from the hydrolysis and buffers lab.)

Buret	buret clamp
Ring stand	funnel
LabQuest	pH meter
Hot plate with stir option (heat off)	teflon coated stir bar

Possible Unknown acids: Potassium hydrogen phthalate, Tartaric acid, Ascorbic acid or Maleic acid

Spill/Disposal Reaction Mixture : A ***Spill/Disposal : B1***,

Procedure:

1. **Weigh out the quantity of the solid unknown as indicated on your unknown bottle**. Your instructor may assign you the unknown. Record the identity and the exact mass of your unknown acid in the data sheet.

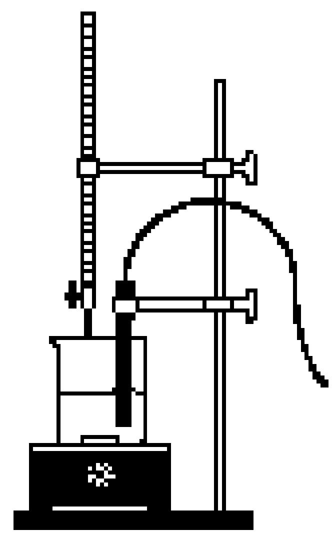
2. Place your unknown in a **250mL beaker** and add 100.0 mL of deionized water. Use a graduated cylinder to measure the water. Carefully place a teflon coated stir bar in the acid solution.

3. Clean your buret (including the tip) by rinsing it with deionized water. Now rinse the buret twice with small portions (no more than 2 ml) of the NaOH solution (including the tip)

4. Fill the buret with the standardized NaOH solution. Make sure that there are no air bubbles in the tip.

5. Note the exact concentration of NaOH(aq) on your data sheet.

6. Clamp a buret onto a ring stand and set a hot plate on the ring stand. Set the beaker on the hot plate. **Make sure that the heat is turned off.**



7. Put the electrode from the pH meter into your beaker. Make sure that the bulb of the pH electrode is completely immersed in the solution. Turn the stir option on to a gentle stir. Record the pH. This is your initial pH before any NaOH has been added.

8. Record the pH as you add 0.5 mL portions of the NaOH. Do not wait until the pH stabilizes as it won't. Add the 0.5 mL portion of NaOH, wait a set amount of time (5 – 10 seconds) and record the pH. Titrate until you have at least 3 measurements at pH 11.5 or above.

9. Repeat the titration if your instructor requires.

10. The waste may be disposed of down the drain.

11. Empty the remaining NaOH into the NaOH waste bottle and wash buret thoroughly (including the tip) with water three times before returning it to its storage place.

Notebook Work
• You may write your work on loose paper, in a notebook, or in a file • All work should be *in your own words*. Plagiarized notebooks will earn a zero. • Bring your notebook work with you to lab.
Submit before lab though Canvas: • Title of the lab • Write the procedure in your own words with enough detail that you could perform the lab without the manual. • Summarize safety hazards for NaOH(aq) and all four possible unknowns (potassium hydrogen phthalate, tartaric acid, ascorbic acid, maleic acid). (Hazards are in section 2 of SDS)
During the lab • Write the unknown letter or number. Write the mass (record all digits on scale!) of your unknown samples. • Record the standardized concentration of NaOH (0.1M is only approximate – there should be a molarity with 3-4 significant figures on the bottle) • Make a table with columns for volume of NaOH added (0.00 mL is the first entry) and pH. Record data for the titration. • If your procedure differed in any way from what was written before class, write it down. • Show your notebook to your professor before you leave.
For your report you will have to look up: • the molar mass of each unknown • the pKa(s) or K_a(s) of each unknown. Ignore any pK_as greater the 11 as they can't be seen with the base strength we are using.

Lab Report
• The report should be in your own words. Plagiarized reports will earn a zero. Review what constitutes plagiarism here if needed. Use of AI and paraphrase programs is plagiarism. • Follow the guidelines carefully. Your report should have the sections below, in the same order. • Lab reports **must be typed**, except for the calculation section.
Title Lab title, name, course section and semester/year included at top of report
Objective In one sentence, state the scientific goal of the experiment. This is an experimental goal, not a learning goal.
Procedure • Briefly summarize procedure and type in paragraph form. • Write what you did, not what was supposed to happen if it differs. • Write in past tense. You do not have to use passive voice and use of "I" is fine. • Include details of your experiment - include unknown number, measured mass and molarity from your notebook.

Data

Include a table of all data. Columns should have proper titles and units. Record data with correct significant figures.

Graph

- Make and embed in your report a **full page graph** of the titration data, labeled according to the instructions below. The data table used to make the graph should be copied into the data section of the report.

Guidelines for graphing:

1. Plot the titration curve as pH vs. mL of NaOH added using a computer graphing program. Make sure you plot mL of NaOH on the x axis, and pH on the y axis.
2. On your graph:
   - Plot as scatter plot with line format. Do not use a best fit curve.
   - Include gridlines at least every 0.5 mL and 0.5 pH units
   - Locate and label the equivalence point(s) on the titration curve. It is very unlikely that the equivalence point(s) will be actual data points. Find the steepest point(s) on the curve. This is/these are the equivalence point(s) – label as the equivalence point and write the volume of NaOH and pH for that point.
   - Label the areas of the curve where a buffer is present.
   - Identify the points where pH equals pK_a on the graph. Write the volume of NaOH added and the pH at this point. If the acid is polyprotic, label both.
   - Label where the strong base is in excess.

Calculations

As part of your lab report, you will need to show work for the following calculations

- molar mass of the compound
  - o Recall that at the first equivalence point, **moles of acid in the solution = moles of base added.**
  - o Determine the volume of NaOH needed to reach the first equivalence point from your graph. Note it is rarely a data point – estimate the volume at the steepest point.
  - o Using the mass of the acid and the moles of the acid, calculate the molar mass of the acid
- percent error for molar mass based on compound chosen:

$$Percent\ Error = \frac{|actual\ value - your\ experimental\ value|}{actual\ value}\ x\ 100\%$$

- K_a from pK_a (calculate both if polyprotic)
- initial pH of the weak acid based on experimental K_a
  - o First calculate the initial molarity of your unknown acid. Recall that the original volume of the solution was 0.100 L
  - o Using your calculated value of K_a and the initial concentration of the acid, calculate the initial pH of your acid. Set up an ICE table. You may need to use the quadratic formula.

Discussion

In paragraph form, discuss/include

-Whether your acid is mono or diprotic. Explain how you know.

-Include molar masses and K_as of all possible unknowns as well as your unknown acid.

-Explain how you determined identity based on the above.

-Compare experimental and calculated initial pH. Cite both values and discus.

-Cite your percent error value and discuss.

Conclusion

In one sentence, summarize your results. This should answer your objective section.

pKa of a Weak Acid Formal Lab Report

Write in paragraph form as a paper. Embed the graph and any calculations. Submit through the assignments tab in CANVAS, not by email or on paper.

Rubric

Notebook		
Before lab	/4	Submitted through Canvas before lab: procedure written in your own words with enough detail that you could perform lab without the manual. Summary of safety hazards for all naphthalene and all four possible unknowns.
During lab	/3	Written down during the lab: unknown letter, all masses, table of time and temperatures for all runs, changes to procedure, if any. All measurements have units and correct sig figs.
Lab Performance		
Performance	/3	Lab work performed correctly. Proper safety procedures followed and waste disposed of correctly. Work space and glassware cleaned up. Participated actively in the experiment.
Lab Notebook and Performance	/10	
Lab Report		
Title	/2	Lab title, name, course section and semester & year included at top of report
Purpose	/2	Goal of the lab is clearly stated in 1 sentence. (Scientific goals only, not learning goals.)
Procedure	/4	Procedure summarized in paragraph form. Includes actual mass and molarity. Write in past tense what you did, not what was supposed to happen. Put in your own words, do not copy paste from manual or lab partners.
Data	/2	Include a table of all data. Columns should have proper titles and units. Data is recorded with correct sig figs.
Graph	/4	One graph included of pH vs mL NaOH which *takes up an entire page of the report *has a descriptive title *has properly label axes with units *has gridlines every 0.5 mL and 0.5 pH units (see guidelines in instructions)
Interpretation of graphs	/6	*pK_a(s) and *equivalence point(s) correctly identified, pH and volume indicated for each point *Buffer and *strong base areas correctly identified. (see guidelines in instructions)
Calculations	/8	Calculations shown clearly and completely with units and proper sig figs for *molar mass of the compound *percent error for molar mass based on compound chosen *pK_a (include both if polyprotic) *initial pH of the weak acid based on experimental K_a
Discussion	/10	In paragraph form, discuss/include -Whether your acid is mono or diprotic. Explain how you know. -Include molar masses and K_as of <u>all possible unknowns</u> as well as your unknown acid. -Explain how you determined identity based on the above. -Compare experimental and calculated initial pH. -Discuss the percent error.
Conclusion	/2	In 1-2 sentences, summarize your conclusion and the main evidence supporting it.
Total	40	