

Lab: Acid-Base Titration

Introduction

Titration is a method of volumetric analysis—the use of volume measurements to analyze an unknown. In acid-base chemistry, titration is most often used to analyze the amount of acid or base in a sample or solution. A substance in a solution of known concentration (the **titrant**, usually in a buret) is reacted with another substance in a solution of unknown concentration (the **analyte**). The goal of titration is to use the stoichiometric ratio between the titrant and analyte to determine the unknown concentration of the analyte.

Indicators are usually added to acid-base titrations to detect the equivalence point. The *endpoint* of the titration is the point at which the indicator changes color and signals that the equivalence point has indeed been reached. For the titration of a strong acid with a strong base (or vice versa), the pH of the solution would be acidic (< 7) before the equivalence point and basic (> 7) after the equivalence point. The pH at the equivalence point should be exactly 7, corresponding to the neutral products.

Experimental Method

We will use a strong base, NaOH, to determine the concentration of an unknown solution of HCl. During the first stages of the titration, the NaOH will be completely neutralized, and an excess of acid will remain. However, at the theoretical endpoint, the acid and the base will have neutralized one another exactly: the number of moles of NaOH used will be equal to the number of moles of HCl in the unknown solution.

The progress of an acid-base titration can also be followed by measuring the pH of the solution being analyzed as a function of the volume of titrant added. A plot of the resulting data is called a pH curve or titration curve. Titration curves can also be approximated as long as the equivalence point is known. In this experiment, the initial solution is entirely the unknown acid, which will have a pH well below 7. At the end of the titration, the base will be in excess, meaning the pH will be well above 7. This information, along with the equivalence point volume and pH can be used to determine the approximate shape of the titration curve.

The titration will be performed twice. The first trial will allow you to approximate the equivalence point to within 1 mL. The second trial will allow you to find the precise volume of titrant necessary to reach the equivalence point.

Materials:

Sodium hydroxide solution, NaOH, 0.0500 M

Hydrochloric acid solution, HCl, *unknown concentration*

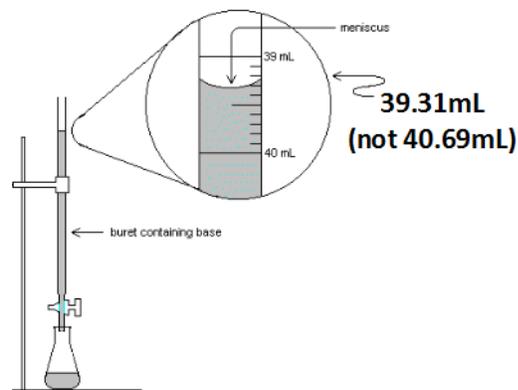
indicator solution, 1.0%, 1 mL

Flask (250 mL), Buret (50 mL)

Procedure:

Set Up:

1. Your buret has been pre-filled with 0.0500 M NaOH solution. If needed, open the buret stopcock to lower the volume of NaOH until it reaches exactly 0.00 mL.
2. Measure the precise volume in the buret and record this value in **Data Table 2** as the initial volume. Note: Volumes are read from the top down in a buret. Always read from the bottom of the meniscus remembering to include the appropriate number of significant figures.



- Carefully measure 30-50 mL of the unknown concentration HCl solution, using a graduated cylinder, and record the precise (with correct sig figs) amount of HCl used in **Data Table 1**.
- After recording the amount of HCl in your graduated cylinder, pour it into a 250 mL flask. **Add 8 drops of indicator to the solution in the flask.**
- Gently swirl your flask to thoroughly mix the indicator into the analyte.

Trial One (Approximate Equivalence Point):

- Begin the titration by adding 1 mL of the NaOH solution to the flask.
- Swirl the contents of the flask. Record the exact volume added and the corresponding color of the solution in **Data Table 2**.
- Continue adding NaOH in 1 mL increments. Be sure to swirl the solution thoroughly and record the color and the exact volume of NaOH added after EACH addition.

General Titration Procedure

- Add NaOH from buret.
- Swirl solution into flask so acid/base have completely reacted.
- Record new solution color **and** volume of NaOH (be precise!)
- Repeat!

- When the color of your solution is beyond the expected color at the equivalence point, you have completed your first trial. Stop adding titrant.
- Analyze your data. Find the last volume measurement before you reached your equivalence point. That is the volume you will need to pay special attention to in your second trial.

Trial Two (Exact Equivalence Point):

- Empty your flask into the waste container and rinse at the sink.
- Repeat the setup procedures performed before Trial One. Be sure to use the same volume of analyte that you used in your first trial. Record this volume in **Data Table 1**.
- If more than half the volume of your buret has been emptied, ask your teacher to refill it.
- Begin adding NaOH 1 mL at a time, as before. Be sure to record the volume of NaOH and the color of solution after each addition in **Data Table 3**.
- When you have added the last volume that can safely be added before reaching the equivalence point, **STOP**.
- At this volume, begin adding NaOH **drop by drop**. (For reals. One drop at a time!) **Record the exact volume of NaOH added and the indicator color at equivalence point in Data Table 4.**
- Stop titrating when the color of your solution is definitively beyond the equivalence point.

Clean Up:

- Empty flask into the waste container and rinse at the sink.
- Wipe up any mess at your lab area.

Data:

Data Table 1: Volume of Analyte

Analyte Name	Trial One: Volume of Analyte (mL)	Trial Two: Volume of Analyte (mL)

Data Table 2: Determination of the Approximate Equivalence Point

Volume NaOH Added (mL)	Solution Color	Volume NaOH Added Continued (mL)	Solution Color	Volume NaOH Added Continued (mL)	Solution Color

Data Table 3: Determination of the Exact Equivalence Point

Volume NaOH Added (mL)	Solution Color	Volume NaOH Added Continued (mL)	Solution Color	Volume NaOH Added Continued (mL)	Solution Color

Data Table 4: Volume of Titrant Added at Equivalence Point

Volume NaOH Added at Equivalence Point (mL)	Indicator Color

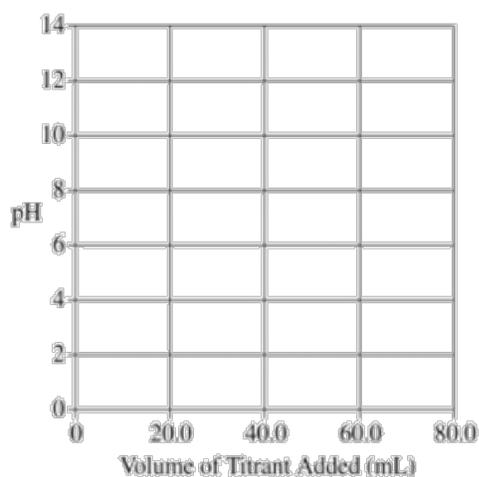
Calculations: For the titration of unknown HCl, determine:

1. The moles of NaOH used to reach equivalence point.
2. The moles of HCl present in your initial solution.
3. The concentration of HCl, [HCl], in your initial solution.
4. The pH of your initial HCl solution. (This will be the initial pH of your titration curve)
5. The pH of your initial 0.0500 M NaOH solution. (This will be the final pH of your titration curve)
6. What is the accepted (true) value of [HCl]? _____ Calculate your percent error!

$$\left[\frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}} \right] \times 100 = \text{Percent Error}$$

Analysis:

1. Use the graph below to sketch your titration curve. A picture of this graph should be included in your final lab report.



Hints:

- 1) Use the info from Data Table 4 to graph your equivalence point.
- 2) Use Calculations 4 and 5 to mark your initial and final pH values.
- 3) Approximate the middle sections using what you know about titration curves.

2. Write the balanced reaction for the neutralization reaction performed in this lab (including states of matter).
3. Write the **net ionic** reaction for the neutralization reaction performed in this lab (including states of matter).

4. Would the addition of several milliliters of distilled water to the **flask** during the titration affect the results of the titration? Explain your answer.

5. Suppose you instead titrated an **unknown** concentration of NaOH in your flask with a **known** concentration of HCl in your buret.
 - a. Identify at least **two** things about your data that would be different from the data you collected in lab, and explain why they would be different.

 - b. Identify at least **one** thing about your data that would be the same as the data you collected in lab, and explain why it would be the same.

Error Analysis: Describe the errors that may have occurred during your titrations. Identify **at least 2** specific and **likely** sources of error, and explain the probable effect of these errors on your data and final results.

***Note about over- and under-titrating:** if you believe that your group over-titrated (added too much from the buret) or under-titrated (added too little much from the buret), **GIVE EVIDENCE** to support your conclusion. Hint: what happened to the color of your indicator?

- a. Lab Error #1
 - i. What was the lab error? Describe its effect on your **data**.

 - ii. What affect did the lab error have on your calculations and final results? **Be specific**.

- b. Lab Error #2
 - i. What was the lab error? Describe its effect on your **data**.

 - ii. What affect did the lab error have on your calculations and final results? **Be specific**.

Pre-AP Formal Lab Report Requirements

Title of Lab

Date (lab was performed)

Your name, Lab partner(s) name(s)

Objectives (5 pts): *In your own words*, describe the purpose of the lab. Use complete sentences. You should answer two questions here:

- What was the goal of the lab?
- What experimental method did you use to accomplish this goal? (i.e. what was the lab set-up?)

Data /Graph (10 pts): Only Data Tables 1 and 4 need to be included, but you **must** include your titration curve.

Calculations (10 pts): Results of calculations should be in a typed table. You do NOT need to show the math, just your answers!

Analysis (20 pts): Answer the analysis questions in complete sentences; **number each question** so they are easy to locate and **DO NOT copy the question** into your lab report before answering it! (The system will flag you for “copying” someone else’s work.) The graph of your titration curve should be inserted as an image into your report.

Error Analysis (5 pts):

Answer all analysis and error analysis questions from the lab procedure: **these should be two separate sections**. **Number each question** so they are easy to locate and **DO NOT copy the question** into your lab report before answering it! (The system will flag you for “copying” someone else’s work.)

Conclusion (30 pts): This section is the most important part of your lab report, and should include ALL of the following:

- Thesis statement: intro to your paragraph that reminds the reader about the goal of the lab. (Hint: if you’re stuck, you can choose to summarize your objectives here.) [3 pts]
- Brief recap of lab procedure and data collection method. (DO NOT explain how to math. Just explain lab procedures.) NOT step-by-step: summarize in 2-4 sentences. [6 pts]
- Explanation of your results. (Be specific: include data! But not all data. Summarize the highlights.) **Be sure to identify if you achieved the objectives you outlined in section 1.** [5 pts]
- When applicable, identify how your results compare to the accepted value (**cite your calculated percent error**) and, if error existed, briefly discuss why you think that error occurred. [5 pts]
- Reflection: identify what you learned from this lab, and how it connects to current Pre-AP chemistry content. How was the content you learned **in this unit** essential for understanding the lab? [8 pts]
- Concluding statement: wrap up your conclusion! This is **different** from your reflection. Tie it back to your introductory sentence or thesis statement. [2 pts]

References: If you’ve used any outside sources, create a reference list here. Follow formatting from your English class.

Grading Hints (20 pts):

- Include the full heading (as shown at the top). [4 pts]
- Label all sections (objectives, analysis, etc). [4 pts]
- Write the **objectives** and **conclusions** sections in **complete sentences**. [4 pts]
- Use **paragraphs** (aka more than one) for the **conclusion** section. [3 pts]
- Do not capitalize chemicals names – they are NOT proper nouns (i.e. write “copper” not “Copper”). [2 pts]
- Use subscripts and superscripts when needed (i.e. write “Cr₂O₇²⁻” not “Cr2O7 2-”) [1 pt]
- Do not double-space: 1.5 or 1.15 spacing! [1 pt]

Helpful Sentence Starters (use if desired!)

Objective:

- *The purpose of this lab was to...*
- *We accomplished the goal of this lab by...*

Procedure:

- *We accomplished this goal by ...*

Results:

- *We found that ...*
- *Our value was ... than the accepted value.*

Error Analysis:

- *This lab error possibly occurred because ...*
- *As a result of this lab error, my final results would be different because...*

Reflection:

- *In order to complete this lab, it was necessary to understand that ...*
- *This information was essential for understanding the lab because ...*

Concluding Thoughts:

- *In conclusion, in this lab we ...*

Warning about Plagiarizing

Just because you worked in the same lab group as someone else DOES NOT mean you are allowed to have identical (or similarly-worded) sections of your lab report. The ONLY sections that can be the same across a lab group are data/calculations tables. **YOU WILL RECEIVE A ZERO FOR YOUR LAB REPORT IF YOUR REPORT COMES UP AS A SUSPICIOUSLY HIGH MATCH WITH ANOTHER STUDENT (even if you completed the lab first).** Any work that is truly your own will show up as statistically different from all other students!