Ascorbic Acid Titration of Vitamin C Tablets

Introduction
This experiment illustrates how titration, the process of slowly adding one solution to another until the reaction between the two is complete, can be used to determine the ascorbic acid content of a Vitamin C tablet containing approximately 500 mg of Vitamin C. A Vitamin C tablet contains ascorbic acid, \( \text{HC}_6\text{H}_7\text{O}_6 \text{(aq)} \), as well as binder material that holds the tablet together. The balanced equation for the reaction between ascorbic acid and sodium hydroxide is shown below:

\[
\text{HC}_6\text{H}_7\text{O}_6 \text{(aq)} + \text{NaOH} \text{(aq)} \rightarrow \text{H}_2\text{O} \text{(l)} + \text{NaC}_6\text{H}_7\text{O}_6 \text{(aq)}
\]

You will titrate each Vitamin C sample with a standardized NaOH solution to determine the mg of ascorbic acid present in each sample.

First, you will perform an acid-base neutralization reaction to standardize the sodium hydroxide solution. Sodium hydroxide tablets are very hygroscopic and absorb water molecules quickly as they are weighed out. It is difficult to obtain an accurate mass of sodium hydroxide to calculate molarity so titration with a known molar concentration of an acid is used to determine the true molarity of a NaOH solution. In this experiment, the molarity of the sodium hydroxide solution will be determined first using a standardized stock solution of sulfuric acid.

To monitor the progress of a neutralization reaction, you will use an acid-base indicator, a solution that changes color depending on the pH (or acid-content) of the solution. One commonly used indicator is phenolphthalein, which is colorless in acidic and neutral solutions and pink in basic (or alkaline) solution. During a titration, the indicator is added to the sample being analyzed. The titrant is slowly added to the sample until the endpoint (when the indicator changes color) is reached, signaling that the reaction between the two is complete. Note that phenolphthalein turns pink only when excess sodium hydroxide has been added.

For more information: Chemistry: Atom’s First by OpenStax section 7.5 – “Quantitative Chemical Analysis”

Equations to use for the calculations:

\[
V_{\text{Total}} = V_{\text{Final}} - V_{\text{Initial}}
\]

Molarity = \( \frac{\text{moles solute}}{\text{L solution}} \)

Percent Vitamin C = \( \frac{\text{mass ascorbic acid} \times 100}{\text{mass original tablet}} \)

Percent Error = \( \left| \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \right| \times 100 \)

Materials:

- 400 mL beaker
- 250 mL beaker
- 150 mL beaker
- 25 mL buret
- 10 mL volumetric pipet
- pipet pump
- Teflon magnetic stir bar
- forceps
- 3 weigh boats
- phenolphthalein
- NaOH
- \( \text{H}_2\text{SO}_4 \)
- 3 500 mg Vitamin C tablets
- 6 250 mL Erlenmeyer flasks
- hot plate
- DI water bottle
- calculator
Procedure

- This lab will be completed individually over a two week period! Make sure you come prepared each week! This lab report is worth 100 points.
- This laboratory experiment has a formal report. Consult the guidelines for writing a formal laboratory report prior to doing this laboratory experiment so that you know what will be expected of you after the experiment is completed. The formal laboratory reports generally take much longer to type than regular laboratory reports take to write.

A rubric/report outline and order is available on page 7.

Week One:

1. Record the molarity of the standardized stock H₂SO₄ solution on your report sheet.
   CAUTION: Sulfuric acid, H₂SO₄(aq), is corrosive and can cause chemical burns and damage clothing. Any H₂SO₄(aq) spilled on skin must be rinsed immediately with water for 15 minutes. Any acid spilled on your work area must be neutralized, the area rinsed with water and wiped clean.

2. Use the NaOH pump dispenser to deliver 60 mL of NaOH into a clean, labeled 250 mL beaker. Condition a 25.00 mL buret with a few mL of the NaOH solution, then fill the buret with the NaOH solution. See technique “Using a buret to deliver a solution”. Drain a small amount of the NaOH solution into your waste beaker so it fills the buret tip (with no air bubbles present).
   CAUTION: Sodium hydroxide, NaOH, can cause chemical burns and damage eyes very quickly. Any NaOH spilled on your skin must be rinsed immediately with water for 15 minutes. Any NaOH spilled on the lab benches should be neutralized, and the area rinsed with water and wiped clean. Inform your instructor of any NaOH spills.

3. Record the exact initial buret reading. (Save the rest of the NaOH solution in the beaker to refill the buret later.)

4. Use the H₂SO₄ pump dispenser to dispense 40 mL of H₂SO₄ into a clean labeled 150 mL beaker.

5. Using the 10.00 mL pipet and a pipet pump, pipet 10.00 mL of the standard H₂SO₄ solution into a clean 250 mL Erlenmeyer flask. See technique “Pipetting a solution”.

6. Add about 10 mL of deionized water and 2 drops of phenolphthalein indicator to the acid. Repeat for the other two flasks. The 10 mL of water that you add does not need to be exact. Do not use the pipet to measure the 10mL.

7. Place a teflon magnetic stir bar in the Erlenmeyer flask. Place the flask on a cool stir plate. Adjust the stir setting so that your solution is continuously being mixed without splashing the solution on the insides of the flask.

8. Slowly add the NaOH from the buret to the acid solution in the flask, while swirling the flask to get homogeneous solutions. See technique “Performing a titration”. When you begin seeing flashes of pink, add the base dropwise, occasionally rinsing the sides of the flask with deionized water from a wash bottle. See note next page!
   Note: The slower the NaOH is added near the end of the titration, the more accurately you can catch the endpoint. The closer you stop the titration at the endpoint, the less likely you will have to redo a trial. Stop adding base when one drop causes a permanent (>1 minute) faint pink coloration of the solution in the flask. Record the reading on the buret at this endpoint to the nearest 0.01 mL.

9. Refill your buret with the NaOH solution. Titrate the other two H₂SO₄ samples with the NaOH solution. Record the exact initial and final buret readings in your data table. When titrations
are performed, a minimum of three trials should be completed to ensure accuracy. More trials should be completed if any volume of NaOH used differs by more than 1 mL.

10. Clean up your area properly.

11. Perform all week one calculations and obtain your instructor’s signature before leaving.

*Please refer to the Laboratory Techniques Document on the CHM151LL Course Website for more detailed techniques and images of lab equipment.*

**Week Two:**

1. Obtain three vitamin C tablets. Using a plastic weighing boat for each, weigh the exact mass of each tablet and record the mass on the report sheet. Make sure to record all of the digits!

2. Crush each tablet by placing it between two plastic weighing boats and applying firm pressure with a pestle.

3. Transfer the tablets to separate, labeled 250 mL Erlenmeyer flasks. Add 40-50 mL of deionized water to each sample. Use a hotplate at your lab bench to heat the flasks (heat setting between 3-4, or 80°C). Heat gently for about ten minutes to dissolve the vitamin C tablets. The binder in the tablet will not completely dissolve, leaving some residue. Set these solutions to the side to cool to room temperature.

4. Use the NaOH pump dispenser to deliver 60 mL of NaOH into a clean, labeled 250 mL beaker. Clean, rinse, and condition a 25.00 mL buret with a few mL of the NaOH solution, then fill the buret with the NaOH solution. See technique “Using a buret to deliver a solution”. Drain a small amount of the NaOH solution into your waste beaker so it fills the buret tip (with no air bubbles present). Record the exact initial buret reading.

5. Add 2 drops of phenolphthalein solution to each flask containing a Vitamin C tablet. Titrate each sample (i.e., 3 trials) with the NaOH solution to pink phenolphthalein endpoints. See technique “Performing a titration”. For week one, the pink color of the endpoint persisted for a long time. For the titration of the ascorbic acid in the tablets, the pink color will disappear fairly rapidly due to the slow reaction between the binder in the tablet and the sodium hydroxide. This reaction removes the base from the solution.

6. Perform all week two calculations and obtain your instructor’s initials before leaving.

*Please refer to the Laboratory Techniques Document on the CHM151LL Course Website for more detailed techniques and images of lab equipment.*

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**Clean-Up:** Combine all solutions in your waste beaker and dispose in waste container in the hood. Rinse everything well with soapy tap water followed by a quick DI water rinse. Clean your benchtop. Put all equipment back exactly where you found it.
Name: ______________________________

Ascorbic Acid Titration Lab Report
Turn in Pages 4-6 along with your TYPED lab report

Data:
Molarity of H₂SO₄: ____________________

Data Table 1: Week One Standardization of NaOH

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Buret Reading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Buret Reading</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Table 2: Week Two Mass of Ascorbic Acid in a Vitamin C Tablet

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of Vitamin C Tablet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Buret Reading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Buret Reading</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Observations:

Week One:

Week Two:

Start Week 1 Calculations Here:

Balanced Reaction for Week One: ________________________________

Calculations for Results Table 1: (volume NaOH, molarity NaOH, average molarity NaOH, percent error for NaOH)
True NaOH Value (ask Instructor AFTER you are done with your calculations): __________

Instructor’s Initials: ______

Percent Error Calculation for Average NaOH Molarity:

Start Week 2 Calculations Here:
Balanced Reaction for Week Two: ____________________________________________________

Calculations for Results Table 2: (volume NaOH, mg ascorbic acid in each tablet, average mg ascorbic acid, percent ascorbic acid in each vitamin C tablet, average percent ascorbic acid)
**Results:**

**Results Table 1: Molarity of NaOH**

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume NaOH Delivered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molarity of NaOH</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average NaOH Molarity:___________________

Percent Error:___________________

**Results Table 2: Mass of Ascorbic Acid**

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume NaOH Delivered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of Ascorbic Acid in Vitamin C Tablet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Ascorbic Acid in Vitamin C Tablet</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Average mg Ascorbic Acid:___________________

Average Percent:___________________
Grading Rubric for Ascorbic Acid Titration Lab Report (100 points)

Attach Rubric to back of report

**TYPED Formal Report (60 points)** Please complete the following in this order

1/1 Cover page
   - name
   - title
   - course and section
   - instructor

2/1 Detailed Purpose (In your own words – do not copy!)

3/1 Materials list (In your own style – do not copy)

3/3 Outline of Procedure (In your own words – do not copy!)

12/12 Data/Results
   - Observations
   - Data Table 1
   - Data Table 2
   - Results Table 1
   - Results Table 1
   - Average results (molarity, mass ascorbic acid, and percent ascorbic acid)

2/2 Balanced chemical equations

20/20 Calculations
   - sample volume calculation
   - sample molarity calculation
   - average molarity calculation
   - percent error calculation
   - sample mass of ascorbic acid calculation
   - sample mass percent calculation
   - average mass percent calculation

12/12 Discussion (1-2 paragraphs each and a paragraph is typically 5-6 complete sentences)
   - analysis of results and standardization of NaOH process
   - discussion of titration (what it is, how you do it, equivalence point, end point)
   - discussion of mass percent ascorbic acid in vitamin C
   - description of errors, improvements

5/5 Conclusion with data to support, 3rd person

2/2 Overall style, lack of misc. errors, 3rd person

**Worksheet data: (40 points)** Attach Pages 4-6 to the back of the TYPED formal report

3/3 Data Table 1

9/9 Data Table 2

2/2 Observations Week 1 and 2

2/2 Balanced chemical equations

4/4 Molarity of NaOH calculations

1/1 Average molarity calculation

2/2 Percent error calculation

3/3 Results Table 1

9/9 Results Table 2

3/3 Mass of ascorbic acid calculations

2/2 Mass percent calculation (with average)
Post-Lab Questions – These questions will not be graded as part of your lab report grade. You will be responsible for the information in these questions and able to answer these or similar questions on the post-lab quiz at the start of next week’s lab period. Questions will also be similar to your lab report data, observations, calculations, and results.

1. In acidic solutions, phenolphthalein is: (Circle one)  pink  colorless
   In basic solutions, phenolphthalein is: (Circle one)  pink  colorless

2. Acidic solutions contain what ions, specifically?  ________________
   Basic solutions contain what ions, specifically?  ________________

3. Hydrochloric acid can also be titrated with sodium hydroxide using phenolphthalein indicator to determine the endpoint. The Erlenmeyer flask on the left below shows that the only ions present at the start of the titration are $\text{H}^+(aq)$ and $\text{Cl}^-(aq)$. Indicate the color of the solution at the start. For the second flask, write the chemical formulas for the substances present (other than water) at the endpoint of the titration between hydrochloric acid and sodium hydroxide. Also indicate (by circling) the color of the solution at the endpoint.

   Before any NaOH(aq) is added,  the solution is:  pink  colorless
   At the endpoint of the titration,  the solution is:  pink  colorless

4. Explain, in terms of substances present, why the solution in the flask turns pink and stays pink at the endpoint.

5. A student performs a neutralization reaction between calcium hydroxide and phosphoric acid. What is the molarity of Ca(OH)$_2$ if 18.2 mL of Ca(OH)$_2$ is required to neutralize 25.0 mL of 0.3770 M H$_3$PO$_4$ based on the given, unbalanced reaction below? Show all work.
   
   \[
   \text{Ca(OH)}_2 (aq) + \text{H}_3\text{PO}_4 (aq) \rightarrow \text{Ca}_3(\text{PO}_4)_2 (s) + \text{H}_2\text{O} (l)
   \]
6. How does the average milligrams of ascorbic acid that you calculated compare with the manufacturer’s claim of 500 mg of ascorbic acid per tablet? Describe at least three sources of error in your lab techniques that could have resulted in different amounts of ascorbic acid than the manufacturer’s claim.

1. 

2. 

3. 

7. How would the calculated molarity for NaOH be affected (higher, lower, or no change) if the following procedural errors occurred? Explain why in each case.
   a. While pipetting the H₂SO₄ solution, several drops of H₂SO₄ drip out of your pipet onto the bench top and miss the Erlenmeyer flask.
      NaOH molarity (circle one): high or low

      Why?

   b. The buret tip is not filled with NaOH at the beginning of the titration.
      NaOH molarity (circle one): high or low

      Why?