

Titration of Vinegar

Objectives

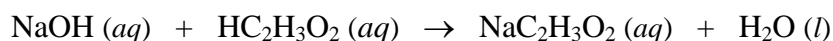
The objectives of this laboratory are to determine the molarity and percent by mass of acetic acid in vinegar.

Background

Vinegar is essentially a solution of acetic acid ($\text{HC}_2\text{H}_3\text{O}_2$) in water. The concentration of acetic acid in vinegar may be expressed as a molarity (in mol/L) or as a mass percent, where:

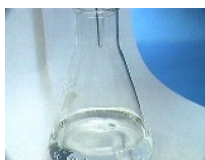
$$\begin{aligned}\text{Molarity} &= \text{Moles of Acetic Acid} / \text{Volume of Vinegar (in L)} \\ \text{Mass \%} &= [\text{Mass of Acetic Acid} / \text{Mass of Vinegar}] \times 100\end{aligned}$$

In this experiment, a technique known as a titration will be used to determine the concentration of acetic acid in vinegar. A titration involves performing a controlled reaction between a solution of known concentration (the titrant) and a solution of unknown concentration (the analyte). Here, the titrant is an aqueous solution of $\sim 0.1 \text{ M}$ sodium hydroxide (NaOH) and the analyte is vinegar. When mixed, a neutralization reaction occurs between sodium hydroxide and the acetic acid in vinegar:



The sodium hydroxide will be gradually added to the vinegar in small amounts from a burette. A burette is a device that allows the precise delivery of a specific volume of a solution. The NaOH will be added to the vinegar sample until all the acetic acid in the vinegar has been exactly consumed (reacted away). At this point the reaction is completed, and no more NaOH is required. This is called the *equivalence point* of the titration.

In order to know when the equivalence point is reached, an *indicator solution* called phenolphthalein is added to the vinegar at the beginning of the titration. Phenolphthalein is a pH sensitive organic dye. Phenolphthalein is colorless in acidic solutions like vinegar, and deep pink in basic solutions like sodium hydroxide. At the equivalence point of the titration, just one drop of NaOH will cause the entire solution in the Erlenmeyer flask to change from colorless to a very pale pink.



In acidic solution



In basic solution



equivalence point

As the titration is performed, the following data will be collected: (1) the molarity of NaOH (*aq*) used, (2) the volume of NaOH (*aq*) used to neutralize the vinegar, and (3) the volume of vinegar used. Using this data, the molarity and mass percent of acetic acid in vinegar can be determined by performing a series of solution stoichiometry calculations (see Calculations Section).

Procedure

Safety

Be especially careful when handling the sodium hydroxide base (NaOH), as it is corrosive and can cause chemical burns to the skin. If any NaOH spills on you, rinse immediately under running water for up to 15 minutes and report the accident to your instructor.

Materials and Equipment

50-mL burette*, 5-mL volumetric pipette*, pipette bulb*, ~ 0.1 M NaOH (aq), vinegar, phenolphthalein, burette stand, two 250-mL (or 125 mL) Erlenmeyer flasks, wash bottle with distilled water, funnel

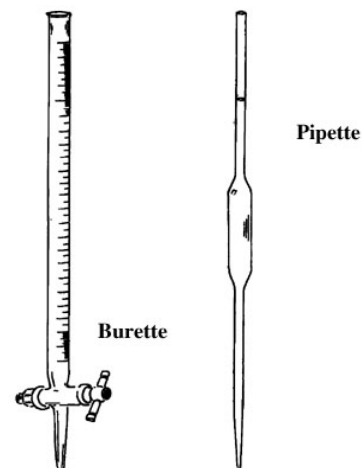
Titration Procedure

Your instructor will demonstrate the correct use of the volumetric pipette and burette at the beginning of the lab session. Detailed instructions on how to use a pipette are also found on the last page of this handout. Note that three titrations must be performed.

1. Obtain a 50-mL burette, 5-mL volumetric pipette and a pipette bulb from the stockroom.

Setting up the burette and preparing the NaOH

2. Rinse the inside of the burette with distilled water. Allow the distilled water to drain out through the tip in order to ensure that the tip is also rinsed.
3. Now rinse the burette with a small amount of NaOH (aq). To do this, add about 5-mL of NaOH (aq) to the burette, then twirl the burette on its side (over the sink) to rinse its entire inner surface. Then allow the NaOH (aq) to drain out through the tip.
4. Fill the burette with NaOH (aq) up to the top, between 0-mL and 5-mL. Use a funnel to do this carefully, below eye-level, and preferably over the sink. After this you will need to flush the tip of the burette – your instructor will show you how to do this. Now measure the volume at the level of the NaOH precisely, and record it as the “Initial Burette Reading” on your report. Also record the exact molarity of the NaOH (aq), which is labeled on the stock bottle.

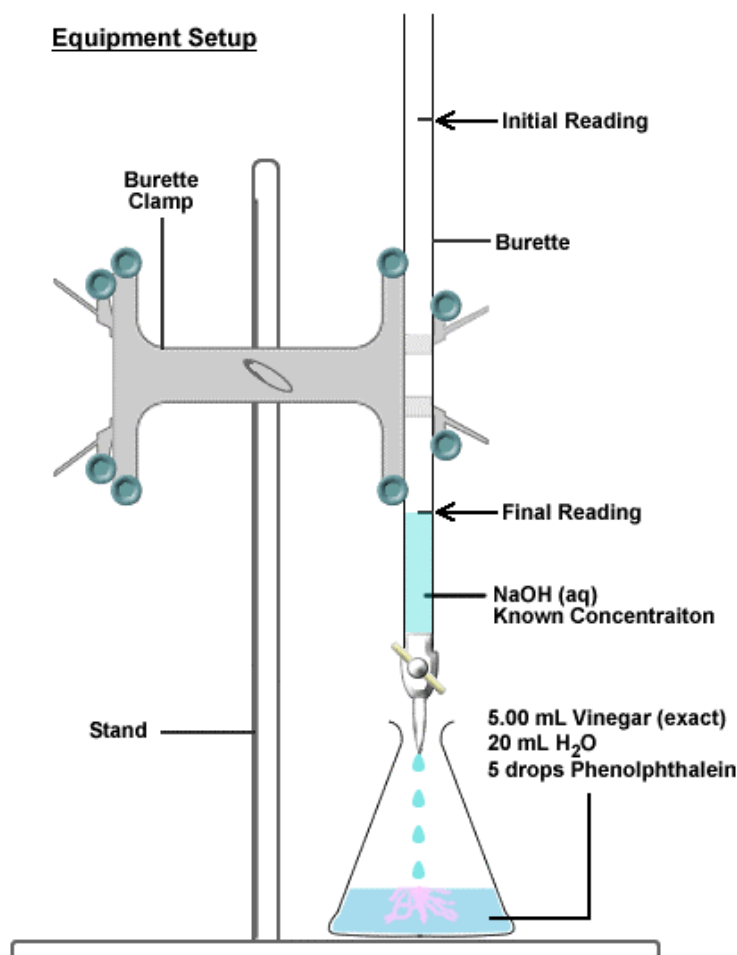


Preparing the vinegar sample

5. The volumetric pipette used in this lab is designed to measure and transfer exactly 5.00 mL of solution. First, rinse the inside of the volumetric pipette with distilled water. Using the pipette bulb, draw the water into the pipette up above the 5-mL mark, then allow it to drain out through the tip. You may want to do this several times for practice. Then perform a final rinse, but this time use vinegar.
6. Now use the volumetric pipette to transfer 5.00-mL of vinegar into a clean 250-mL Erlenmeyer flask (see instructions on page 4). Record this volume of vinegar (precise to two decimal places) on your report. Then add about 20-mL of distilled water and 5 drops of phenolphthalein to this Erlenmeyer flask.

Performing the titration

7. Begin the titration by slowly adding NaOH (aq) from the burette to the vinegar in the Erlenmeyer flask. Swirl Erlenmeyer flask as you add the base in order to efficiently mix the chemicals. Some pinkness may appear briefly in the flask as the base is added, but it will quickly disappear as the flask is swirled.
8. As the equivalence point is approached, the pink color will become more pervasive and will take longer to disappear. When this occurs, start to add the NaOH (aq) **drop by drop**. Eventually the addition of just one drop of NaOH (aq) will turn the solution in the Erlenmeyer flask a pale pink color that does not disappear when swirled. This indicates that the equivalence point has been reached. **Do not add any more NaOH (aq) at this point**. Measure this volume of NaOH (aq) precisely, and record it as the “Final Burette Reading” on your report. Then show the resulting solution in the flask to your instructor so s/he can record the final color on your report form.
9. Refill your burette with NaOH (aq), and then repeat this procedure for a second sample of vinegar, and then a third sample of vinegar. You do not need to flush the tip of the burette again. Note that if you use less than 25-mL of NaOH (aq) for the second titration, you do not need to refill the burette for the third titration; also that you will need to clean out and re-use one of your Erlenmeyer flasks for the third titration. You and your partner should take turns performing these titrations.
10. When finished, dispose of your chemical waste as instructed.



Pipetting Instructions

- Get the appropriate amount of the solution you wish to pipette in a clean, dry beaker. Never pipette directly out of the stock bottles of solution. This creates a contamination risk.
- Insert the tip of the pipette into the beaker of solution so that it is about a quarter inch from the bottom. Be sure not to press the tip against the bottom of the container.
- If you are right handed, hold the pipette in your right hand, leaving your index finger free to place over the top of the pipette. With your left hand, squeeze the pipette bulb. Press it firmly over the top of the pipette, but **DO NOT INSERT THE PIPET DEEP INTO THE BULB!**
- Release the pressure on the bulb and allow the solution to be drawn up into the pipette until it is above the volume mark. Do not allow the solution to be sucked into the bulb itself.
- Quickly remove the bulb and place your index finger firmly over the top of the pipette. Then remove the pipette tip from the beaker of solution.
- Slowly roll your finger to one side and allow the liquid to drain until the bottom of the meniscus is aligned with the volume mark. With practice you will be able to lower the liquid very, very slowly.
- When the bottom of the meniscus is even with the volume mark, press your index finger firmly on the top of the pipette so no liquid leaks out. Touch the tip once to the side of the beaker to remove any hanging drops.
- To transfer the solution, place the tip of the pipette against the wall of the receiving container at a slight angle. Then allow the liquid to drain from the pipette.
- When the solution stops flowing, touch the pipette once to the side of the receiving container to remove any hanging drops. **DO NOT** blow out the remaining solution. The pipette has been calibrated to deliver the appropriate amount of solution with some remaining in the tip.

Calculations

Molarity of Acetic Acid in Vinegar

- First, using the known molarity of the NaOH (*aq*) and the volume of NaOH (*aq*) required to reach the equivalence point, calculate the moles of NaOH used in the titration.
- From this mole value (of NaOH), obtain the moles of HC₂H₃O₂ in the vinegar sample, using the mole-to-mole ratio in the balanced equation.
- Finally, calculate the molarity of acetic acid in vinegar from the moles of HC₂H₃O₂ and the volume of the vinegar sample used.

Mass Percent of Acetic Acid in Vinegar

- First, convert the moles of HC₂H₃O₂ in the vinegar sample (previously calculated) to a mass of HC₂H₃O₂, via its molar mass.
- Then determine the total mass of the vinegar sample from the vinegar volume and the vinegar density. Assume that the vinegar density is 1.000 g/mL (= to the density of water).
- Finally, calculate the mass percent of acetic acid in vinegar from the mass of HC₂H₃O₂ and the mass of vinegar.