

A 25.0 ML Sample Of Vinegar (dilute Acetic Acid, CH₃CO₂H) Is Titrated And Found To React With 94.7 ML

Introduction

A 25.0 mL sample of vinegar (dilute acetic acid, CH₃CO₂H) is titrated and found to react with 94.7 mL of a standard base solution. This seemingly straightforward titration provides a wealth of information about the concentration of acetic acid in the vinegar sample, and it serves as a fundamental example of volumetric analysis in chemistry. Titration is a precise method used to determine the concentration of an unknown solution by reacting it with a solution of known concentration, called the titrant. In this case, the acetic acid in vinegar reacts with a base, typically sodium hydroxide (NaOH), to determine its molarity. Understanding this process involves exploring the chemistry of acetic acid, the principles of titration, and calculations to find the concentration of acetic acid in the vinegar sample.

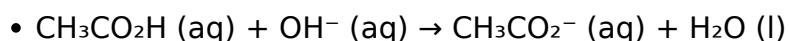
Understanding the Chemistry of Vinegar and Titration

Composition of Vinegar (Acetic Acid)

- Vinegar primarily consists of acetic acid (CH₃CO₂H) dissolved in water.
- Typical commercial vinegar contains between 4% and 8% acetic acid by volume.
- The acetic acid is a weak acid, meaning it does not fully dissociate in water.

Reaction with a Base

- The fundamental chemical reaction during titration is an acid-base neutralization:



- This reaction proceeds to completion under titration conditions, allowing the determination of the acetic acid concentration.

Significance of the Titration Volume

- The volume of the base required to neutralize the acetic acid provides a quantitative

measure of the acid's amount.

- The larger the volume of base needed, the higher the concentration of acetic acid in the sample.

Conducting the Titration: Key Steps

Preparation

- Prepare a standard solution of a strong base, such as NaOH, with a known molarity (e.g., 0.100 M).
- Fill a burette with the standard base solution.
- Measure a precise volume of the vinegar sample, here 25.0 mL, and add a few drops of an appropriate indicator (e.g., phenolphthalein).

Performing the Titration

- Slowly add the base from the burette to the vinegar sample while swirling.
- Observe the color change of the indicator, signaling the endpoint of the titration.
- Record the volume of base used, which in this scenario is 94.7 mL.

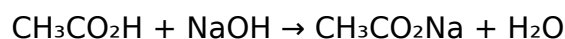
Calculating the Acetic Acid Concentration

- Use the titration data to determine the molarity of acetic acid in the original sample.

Calculations and Data Analysis

Step 1: Write the Balanced Chemical Equation

- The neutralization reaction between acetic acid and sodium hydroxide:



- The molar ratio of acetic acid to NaOH is 1:1.

Step 2: Calculate Moles of NaOH Used

- Molarity (M) = moles / volume (L)
- Given:
- Volume of NaOH = 94.7 mL = 0.0947 L
- Molarity of NaOH (assumed known, e.g., 0.100 M)

- Moles of NaOH:

$$\text{moles NaOH} = \text{Molarity} \times \text{Volume} = 0.100 \text{ mol/L} \times 0.0947 \text{ L} = 0.00947 \text{ mol}$$

Step 3: Determine Moles of Acetic Acid in the Vinegar Sample

- From the 1:1 molar ratio:

$$\text{moles CH}_3\text{CO}_2\text{H} = \text{moles NaOH} = 0.00947 \text{ mol}$$

Step 4: Calculate the Concentration of Acetic Acid in the Vinegar Sample

- The original vinegar volume:

$$V_{\text{sample}} = 25.0 \text{ mL} = 0.0250 \text{ L}$$

- Molarity of acetic acid:

$$[\text{CH}_3\text{CO}_2\text{H}] = \text{moles} / \text{volume} = 0.00947 \text{ mol} / 0.0250 \text{ L} = 0.3788 \text{ M}$$

- Therefore, the concentration of acetic acid in the vinegar is approximately 0.379 M.

Implications and Applications of the Titration Results

Determining Acetic Acid Content in Vinegar

- The molarity calculated reflects the concentration of acetic acid in the vinegar sample.
- To express this as a weight percentage, additional calculations are necessary.

Converting Molarity to Weight Percentage

- Molar mass of acetic acid ($\text{CH}_3\text{CO}_2\text{H}$):

- C: $12.01 \text{ g/mol} \times 2 = 24.02 \text{ g/mol}$
- H: $1.008 \text{ g/mol} \times 4 = 4.032 \text{ g/mol}$

- O: $16.00 \text{ g/mol} \times 2 = 32.00 \text{ g/mol}$
- Total = $24.02 + 4.032 + 32.00 = 60.05 \text{ g/mol}$

- Mass of acetic acid in the 25.0 mL sample:

$$\text{mass} = \text{moles} \times \text{molar mass} = 0.00947 \text{ mol} \times 60.05 \text{ g/mol} \approx 0.569 \text{ g}$$

- Concentration in weight percent:

$$\text{Weight \%} = (\text{mass of acetic acid} / \text{mass of vinegar sample}) \times 100\%$$

- Assuming the density of vinegar is approximately 1.00 g/mL:

$$\text{mass of vinegar} = 25.0 \text{ mL} \times 1.00 \text{ g/mL} = 25.0 \text{ g}$$

- Therefore:

$$\text{Weight \%} \approx (0.569 \text{ g} / 25.0 \text{ g}) \times 100\% \approx 2.28\%$$

- This value suggests the vinegar contains approximately 2.28% acetic acid by weight, which is somewhat lower than typical commercial vinegar but illustrates the calculation process.

Factors Affecting Titration Accuracy

Potential Sources of Error

- Inaccurate measurement of sample volume or titrant volume.
- Impurities in the vinegar sample affecting the reaction.
- Incorrect endpoint detection due to subtle color changes.
- Degradation or contamination of titrant solution.

Strategies for Improving Precision

1. Use calibrated volumetric equipment such as burettes and pipettes.

2. Perform multiple titrations to obtain consistent results.
3. Use a suitable indicator that provides a clear endpoint.
4. Ensure the titrant is standardized accurately before use.

Broader Implications of the Titration Study

Quality Control in Food Industry

- Titration allows manufacturers to verify the acetic acid content in vinegar, ensuring product consistency and compliance with standards.

Educational Significance

- Demonstrates fundamental principles of acid-base chemistry, stoichiometry, and volumetric analysis.

Research and Development

- Helps in formulating new vinegar products with targeted acetic acid concentrations for flavor and preservation qualities.

Conclusion

The titration of a 25.0 mL vinegar sample with a known base volume of 94.7 mL exemplifies a classic analytical chemistry procedure to quantify acetic acid content. Through careful measurement, calculation, and understanding of acid-base reactions, chemists can determine the concentration of acetic acid in vinegar, which has practical applications in quality assurance, regulatory compliance, and scientific research. The process underscores the importance of precise laboratory techniques and the power of stoichiometric calculations to interpret experimental data. Whether for industrial purposes or educational demonstrations, titration remains an essential tool in the chemist's arsenal for analyzing solutions and ensuring product standards.

Frequently Asked Questions

What is the significance of the titration volume in

determining the concentration of acetic acid in vinegar?

The titration volume indicates how much titrant (usually a base like NaOH) is needed to neutralize the acetic acid, allowing calculation of the acetic acid concentration in the sample.

How can the molarity of acetic acid in the vinegar be calculated from the titration data?

Using the titrant's molarity, the titration volume, and the volume of vinegar, you can apply the molarity equation to find the acetic acid concentration: $M_{\text{acetic acid}} = (M_{\text{titrant}} \times V_{\text{titrant}}) / V_{\text{vinegar}}$.

Why is it important to know the titration volume when analyzing vinegar samples?

It helps determine the acetic acid content, which is essential for quality control, nutritional labeling, and understanding the vinegar's potency.

What assumptions are typically made during the titration of vinegar with a strong base?

Assumptions include complete reaction between acetic acid and the base, no side reactions, and that the titrant's concentration is accurately known.

If the titration volume for the vinegar sample is 94.7 mL, how does this relate to the acidity of the vinegar?

A larger titration volume generally indicates higher acetic acid concentration, meaning the vinegar is more acidic.

What role does the indicator play in the titration process of vinegar?

The indicator signals the endpoint of the titration, typically by changing color, indicating that neutralization is complete.

How can errors in measurement affect the determination of acetic acid concentration in vinegar?

Measurement errors, such as inaccurate titrant volume or misreading the endpoint, can lead to incorrect calculations of acetic acid concentration, affecting the reliability of the analysis.

What safety precautions should be taken when performing a vinegar titration in the laboratory?

Wear appropriate personal protective equipment like gloves and goggles, handle chemicals carefully, and dispose of waste properly to prevent accidents and skin irritation.

Additional Resources

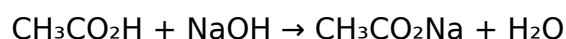
A 25.0 mL sample of vinegar (dilute acetic acid, $\text{CH}_3\text{CO}_2\text{H}$) is titrated and found to react with 94.7 mL of a titrant—likely a standardized sodium hydroxide solution. This experiment offers a comprehensive insight into acid-base titrations, the chemistry of vinegar, and the importance of precise analytical techniques in determining acetic acid concentration. This article delves into the detailed analysis of this titration process, exploring the chemistry involved, calculations, potential sources of error, and real-world applications.

Understanding the Titration Process of Vinegar

Titration is a fundamental laboratory technique used to determine the concentration of an unknown solution by reacting it with a solution of known concentration. In this case, the vinegar sample, which contains acetic acid, is titrated with a base—most commonly sodium hydroxide (NaOH). The titration process involves gradually adding the titrant to the vinegar until the reaction reaches its equivalence point, where both reactants have reacted in stoichiometrically equivalent amounts.

Principles of Acid-Base Titration

Acetic acid ($\text{CH}_3\text{CO}_2\text{H}$) is a weak acid, partially dissociating in aqueous solution, while sodium hydroxide (NaOH) is a strong base, dissociating completely. The reaction is:



At the equivalence point, the amount of acetic acid present in the vinegar sample is exactly neutralized by the sodium hydroxide. Monitoring the pH change via an appropriate indicator (like phenolphthalein) helps to pinpoint this point accurately.

Key features of titration:

- Precise measurement of volumes: Using volumetric pipettes and burettes ensures accuracy.
- Choice of indicator: Phenolphthalein is commonly used because it changes color around pH 8.2–10, suitable for titrations involving weak acids and strong bases.
- Calculation of concentration: The titration data allows calculation of the acetic acid concentration in the vinegar sample.

Calculations Based on Titration Data

Given data:

- Vinegar sample volume = 25.0 mL
- Titrant volume (NaOH) = 94.7 mL

Assuming the titrant is a standardized NaOH solution with a known molarity (say, 0.100 M), we can calculate the molarity of acetic acid in the vinegar sample.

Step 1: Calculate moles of NaOH used

$$\text{Moles of NaOH} = M_{\text{NaOH}} \times V_{\text{NaOH}}$$

$$= 0.100 \, \text{mol/L} \times 94.7 \, \text{mL} \times \frac{1 \, \text{L}}{1000 \, \text{mL}} = 0.00947 \, \text{mol}$$

Step 2: Determine moles of acetic acid in the sample

From the balanced chemical equation, the molar ratio of acetic acid to NaOH is 1:1, so:

$$\text{Moles of acetic acid} = 0.00947 \, \text{mol}$$

Step 3: Calculate molarity of acetic acid in the vinegar sample

$$M_{\text{CH}_3\text{CO}_2\text{H}} = \frac{\text{moles of acetic acid}}{\text{volume of vinegar sample in liters}}$$

$$= \frac{0.00947 \, \text{mol}}{25.0 \, \text{mL} \times \frac{1 \, \text{L}}{1000 \, \text{mL}}} = \frac{0.00947}{0.025 \, \text{L}} \approx 0.379 \, \text{M}$$

Result: The concentration of acetic acid in the vinegar is approximately 0.379 mol/L, which is typical for household vinegar.

Significance of the Titration Results

The titration not only confirms the acetic acid concentration but also serves as a standard method to assess the quality and consistency of vinegar products. Commercial vinegars often contain between 4-8% acetic acid by volume; converting this to molarity confirms whether the vinegar meets commercial standards.

Conversion to weight percent:

The molar mass of acetic acid is approximately 60.05 g/mol.

$$\text{Mass of acetic acid in 1 L} = 0.379 \text{ mol} \times 60.05 \text{ g/mol} \approx 22.77 \text{ g}$$

The density of vinegar is close to that of water (~1 g/mL), so:

$$\text{Mass of vinegar in 1 L} \approx 1000 \text{ g}$$

Thus,

$$\text{Percent acetic acid} = \frac{22.77 \text{ g}}{1000 \text{ g}} \times 100\% \approx 2.28\%$$

This indicates the vinegar contains approximately 2.28% acetic acid by weight, which falls within the typical range for culinary vinegar but is slightly lower than the common commercial strength (~5%).

Features and Reliability of the Titration Method

Titration is regarded as a reliable and straightforward technique for quantitative analysis, but it has its features, pros, and cons.

Features:

- High accuracy when performed correctly
- Relatively simple and inexpensive
- Requires minimal specialized equipment
- Provides direct measurement of analyte concentration

Pros:

- Allows precise determination of acetic acid content
- Useful for quality control in food industries
- Can be adapted for various weak acids and bases
- Suitable for educational demonstrations

Cons:

- Sensitive to human error in reading endpoints
- Requires careful standardization of titrant solutions
- Potential interference from other acidic or basic impurities
- Weak acids like acetic acid may require careful indicator selection for clear endpoint detection

Potential Sources of Error and How to Minimize Them

No laboratory method is free from potential error, and titration is no exception.

Common errors:

- Incorrect reading of the endpoint: Using a magnifying glass or a colorimeter can improve accuracy.
- Impure reagents: Ensure titrant is properly standardized and reagents are of high purity.
- Inaccurate pipetting: Use calibrated pipettes and burettes.
- Incomplete reaction: Mix thoroughly during titration to ensure complete reaction.
- Volume miscalculations: Convert all volumes carefully and double-check calculations.

Strategies to minimize errors:

- Perform multiple titrations and average results.
- Use freshly prepared titrant solutions.
- Employ appropriate indicators and confirm endpoint accuracy.
- Maintain consistent titration techniques across trials.

Real-World Applications of Vinegar Titration

The titration of vinegar has practical significance beyond academic labs.

- Quality control: Ensuring vinegar products meet labeled acetic acid concentrations.
- Food industry standards: Adjusting formulations to achieve desired acidity.
- Environmental testing: Monitoring acetic acid levels in environmental samples.
- Educational demonstrations: Teaching students about acid-base chemistry and titration

techniques.

Conclusion

The titration of a 25.0 mL vinegar sample with a total reactant volume of 94.7 mL exemplifies the core principles of analytical chemistry. It highlights how titration can effectively determine acetic acid concentration, providing insights into the composition and quality of vinegar. While the process is straightforward, attention to detail, precise measurement, and understanding of the underlying chemistry are crucial for accurate results. The data obtained from such titrations serve vital roles in quality assurance, regulatory compliance, and educational contexts, reaffirming titration's status as a cornerstone technique in chemical analysis.

This experiment underscores the importance of analytical precision and offers a window into the fascinating chemistry underlying everyday substances like vinegar. Whether for industrial quality control or academic learning, titration remains an invaluable tool in the chemist's arsenal.

[A 25 0 Ml Sample Of Vinegar Dilute Acetic Acid Ch3co2h Is Titrated And Found To React With 94 7 Ml](#)

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