Estimation of the Ethanoic Acid Content of Vinegar

Yiyang Gao

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1 Aim

Estimate the concentration of $\underset{\text{ethanoic acid}}{CH_3COOH}$ in vinegar.

2 Introduction

Commercial vinegar is $\underset{\text{ethanoic acid}}{CH_3COOH}$ produced by the oxidation of $\underset{\text{ethanol}}{C_2H_5OH}$. Traditionally vinegar was produced by exposing wine to $\underset{\text{oxygen}}{O_2}$ in air. Modern industries produce vinegar synthetically by oxidizing $\underset{\text{ethanol}}{C_2H_5OH}$.

3 Materials

1. Vinegar (Concentration: 5% $\underset{\text{ethanoic acid}}{CH_3COOH}$)
2. Standard $\underset{\text{sodium hydroxide}}{NaOH}$ solution ($0.1\text{mol}\,\text{dm}^{-3}$)
3. Phenolphthalein Indicator
4. Distilled Water

4 Apparatus

1. $20\text{cm}^3 \pm 0.05\text{cm}^3$ Burette
2. $20\text{cm}^3 \pm 0.05\text{cm}^3$ Volumetric Pipette
3. 250cm^3 Conical Flask
4. $250\text{cm}^3 \pm 0.12\text{cm}^3$ [**?**] Volumetric Flask
5. 250cm^3 Beaker

5 Safety Measures

Ethanoic acid is flammable and may causes severe skin burns and eye damage [**?**]. Avoid inhaling the substance and contact with the skin.

6 Procedure

1. Using the pipette to add 20cm^3 of vinegar to the $250\text{cm}^3 \pm 0.12\text{cm}^3$ volumetric flask.
2. Add the distilled water to the vinegar until the mixture reaches the mark on the base of the stem of the flask.
3. Mix the flask thoroughly by shaking it carefully, without spilling out the liquid inside.
4. Then add more distilled water to the 250cm^3 mark and mix again.

   The one may want to use the pipette at the last several drops in order to achieve a higher precision of the resulting solution.
5. Cap the lid to minimize the side effect that liquid evaporation may bring.
6. Fill the burette to the zero label with $\underset{\text{sodium hydroxide solution}}{\text{NaOH(aq)}}$
7. Record the burette reading as the "Initial Volume".
8. Set the burette in Step **??** on the stand
9. Pipette out 20cm^3 of the diluted vinegar solution in Step **??** into the 250cm^3 conical flask
10. Add two drops of phenolphthalein indicator into the conical flask in Step **??**
11. Hold the conical flask under the burette and,
12. Slowly add the $\underset{\text{sodium hydroxide solution}}{\text{NaOH(aq)}}$ to the diluted vinegar solution
13. Shake the conical flask continuously
14. When the reacting mixture in the conical flask turns pink, stop the burette tap
15. Record the burette reading as the "Final Volume".
16. Clean and rinse the apparatuses thoroughly, and use a tissue paper to wipe out the water remains on the apparatuses to reduce error
17. Repeat from Step **??** at least 6 times in order to reduce error

7 Data Collection

Table 1: Data

Trial	Final Volume ($\pm 0.05\text{cm}^3$)	Initial Volume ($\pm 0.05\text{cm}^3$)	NaOH(aq) used ($\pm 0.10\text{cm}^3$)
1	13.7	0.0	13.7
2	13.8	0.0	13.8
3	13.9	0.0	13.9
4	13.6	0.0	13.6
5	13.6	0.0	13.6
6	13.6	0.0	13.6
			Average NaOH(aq) used: 13.7 cm^3

8 Calculation

$$\frac{M_{(\text{NaOH})} \times V_{(\text{NaOH})}}{M_{(\text{CH}_3\text{COOH})} \times V_{(\text{CH}_3\text{COOH})}} = \frac{1}{1} \tag{1}$$

where

$$\begin{aligned} M_{(\text{NaOH})} &= 0.1\text{mol}\,\text{dm}^{-3} \\ V_{(\text{NaOH})} &= 13.7\text{cm}^3 = 0.0137\text{dm}^3 \\ V_{(\text{CH}_3\text{COOH})} &= 20\text{cm}^3 = 0.02\text{dm}^3 \end{aligned}$$

thus, we can calculate the molarity of $\underset{\text{ethanoic acid}}{\text{CH}_3\text{COOH}}$ (denoted as $M_{(\text{CH}_3\text{COOH})}$) as:

$$\begin{aligned} M_{(\text{CH}_3\text{COOH})} &= \frac{M_{(\text{NaOH})} \times V_{(\text{NaOH})}}{V_{(\text{CH}_3\text{COOH})}} \\ &= \frac{0.1\text{mol}\,\text{dm}^{-3} \times 0.0137\text{dm}^3}{0.02\text{dm}^3} \\ &= 0.0685\text{mol}\,\text{dm}^{-3} \end{aligned}$$

8.1 Error Analysis

- *Error in Volumetric Pipette* $\quad 20 \pm 0.05\text{cm}^3 \rightarrow 100 \times \dfrac{0.05\text{cm}^3}{20.0\text{cm}^3} = 0.25\%$
- *Error in Burette* $\quad 100 \pm 0.05\text{cm}^3 \rightarrow 100 \times \dfrac{0.05\text{cm}^3}{13.7\text{cm}^3} = 0.36\%$
- *Total Percentage Error* $\quad 0.25\% + 0.36\% = 0.61\%$

Total Absolute Error: $0.0685\text{mol}\,\text{dm}^{-3} \times 0.61\% = 0.000418$

The molarity of $\underset{\textbf{ethanoic acid solution}}{\text{CH}_3\text{COOH(aq)}}$ **is** $0.0685 \pm 0.000418\text{mol}\,\text{dm}^{-3}$

9 Conclusion

By titrating using the standard $\underset{\text{sodium hydroxide solution}}{\text{NaOH(aq)}}$ into the given solution we found that the concentration of the given $\underset{\text{ethanoic acid solution}}{\text{CH}_3\text{COOH(aq)}}$ is $0.0685 \pm 0.000418 \text{mol}\,\text{dm}^{-3}$.

References

[1] National Center for Biotechnology Information. PubChem Database. Acetic acid, CID=176, `https://pubchem.ncbi.nlm.nih.gov/compound/Acetic-acid` (accessed on Nov. 9, 2019)

[2] American Society for Testing and Materials. United States Navel Academy. Equipment Precision, `https://www.usna.edu/ChemDept/_files/documents/manual/apdxE.pdf` (accessed on Nov. 9, 2019)