Determination of the Amount of Acetic Acid in Vinegar

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Aim: To determine the amount of acetic acid in vinegar. This should be done by titration against sodium hydroxide.

Table of Content

Design

Research Question: What amount of acetic acid is there in vinegar?

Table 1 - Variables

Variables	
Independent	Volume of Vinegar
Dependent	Amount of Acetic Acid in Vinegar
Control	1 Temperature 2. Pressure 3. Number of Measurements 4. Amount of Phenolphthalein 5. Concentration of NaOH 6. Volume of NaOH

Materials:

50 cm3 Burette with Precision of 0.1 cm3
A 25 cm3 Pipette with Precision of 0.1 cm3
A 250 cm3 beaker
3cm3 Dropper with Precision of 0.1 cm3
Weighing Scale with Precision of 0.01 g
A Funnel
Chemicals:
Phenolphthalein
1.00 mol dm^{-3} solution of NaOH
Vinegar

Procedure:

Titration was chosen to be performed during this practical, because it is the most safest, easiest, and most accessible way to obtain the required result.

1) Weigh the beaker and tare the scale.
2) Pour 10 cm^3 of vinegar to the beaker with use of a 25cm^3 pipette and then weigh it.
3) Add 3 drops of phenolphthalein using a 3m^3 dropper.
4) Install the burette on a stand and fill it with 1.00 mol $\mathbf{dm^{-3}}$ solution of NaOH.
5) Titrate the vinegar against NaOH. Wait and observe the colour change. Pour the base very slowly and carefully until the colour of the solution turn from transparent to pinkish.
6) Record the amount of volume of the base required to neutralise the vinegar.
7) Repeat the procedure 5 times to obtain proper results.

Safety Rules:

All necessary safety precautions were undertaken, the performers were wearing lab coats, rubber gloves and protecting glasses. All the safety rules were followed and no mistake was made, and everything went according to planned.

Data Collection and Processing

Table 2 - Data Collection of Vinegar

Volume of Vinegar (cm^3) $\pm 0.1\ cm^3$	Average Volume of Vinegar (g) m_{av}	Standard Deviation, (g), $\triangle m_{av}$
10.2	**10.1**	**0.07**
10.1		
10.0		
10.0		
10.1		

Table 3 - Data Collection of NaOH

Volume of NaOH (cm^3) $\pm 0.1\ cm^3$	Average Volume (cm^3), V_{av}	Average Volume (cm^3), $\triangle V_{av}$	Percentage Uncertainty, %
17.1	**17.4**	**0.23**	**1.3%**
17.5			
17.3			
17.8			
17.4			

The standard deviation of the result was calculated by using this formula:

$$\sqrt{\frac{\Sigma(X - \bar{X})^2}{(n - 1)}}$$

where:

X = each score
$\bar{X}$ = the mean or average
n = the number of values
Σ means we sum across the values

Having determined the volume of NaOH needed to neutralise the given amount of vinegar, the amount in moles of the base can or must be calculated.

(C NaOH stands for the concentration of sodium hydroxide) :

Number of moles of sodium hydroxide ($\mathbf{n_{NaOH}}$)

$\mathbf{V_{av} \times c_{NaOH}} =$

$= 0.0174\ \mathbf{dm^3} \times \mathbf{1.00\ mol\ dm^{-3}}$

$= 0.0174$ mole

The Reaction occurs due to the following equation:

$$\mathbf{CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow CH_3COOHNa_{(aq)} + H_2O_{(l)}}$$

The molar ratio of the acid to the base is 1:1. The amount of acid neutralized is equal to the value calculated on the top. Therefore, we can conclude that:

$\mathbf{n_{acid}} = 0.0174$ mole

Now the mass of acetic acid present in the sample of vinegar can be calculated:

Molar mass of acid $(\boldsymbol{M_{acid}}) = 60.05\ \text{g} \cdot \boldsymbol{mole^{-1}}$

Mass of acid $(\boldsymbol{m_{acid}}) = \boldsymbol{n_{acid}} \times \boldsymbol{M_{acid}} = 0.0174 \times 60.05\ \text{g} \cdot \boldsymbol{mol^{-1}} = 1.04\text{g}$

The uncertainties of the results above must also be calculated:

Uncertainty of molar quantity calculations:

$$\Delta\, \boldsymbol{n_{acid}} = \boldsymbol{n_{acid}} * \left(\frac{\Delta \mathbf{V_{av}}}{\mathbf{V_{av}}}\right) = 0.0174\ \boldsymbol{mole} * \left(\frac{0.23\ \boldsymbol{cm^3}}{17.4\ \boldsymbol{cm^3}}\right) = 0.00023\ \boldsymbol{mole}$$

Uncertainty of mass calculations:

$$\Delta\, \boldsymbol{m_{acid}} = \boldsymbol{m_{acid}} * \left(\frac{\Delta \mathbf{n_{acid}}}{\mathbf{n_{acid}}}\right) = 1.04\ \boldsymbol{g} * \left(\frac{0.00023\ \boldsymbol{cm^3}}{0.0174\ \boldsymbol{cm^3}}\right) = 0.0137\ \boldsymbol{g}$$

Hence, the final result can be expressed as:

$$\boldsymbol{(m_{acid}) = (1.04 \pm 0.01)g}$$

To see clearly the obtained mass should be compared to the mass of the whole sample:

1.04g/ 10.1g = 10.3 %

This result also has an uncertainty:

$$\left(\frac{\Delta m_{av}}{m_{av}} + \frac{\Delta m_{acid}}{m_{acid}}\right) \times 10.2\,\% = \left(\frac{0.07g}{10.1} + \frac{0.01}{1.04}g\right) \times 10.2\,\% = 0.168\,\%$$

$$\sim 0.17\%$$

Finally the amount of acetic acid can be said to be:

$(10.3\% \pm \mathbf{0.17\%})$ % of the sample of vinegar

Conclusion and Evaluation

The result obtained in this experiment of practicals shows us that in 10 cm^3 of vinegar there is about 10.4 g of acetic acid, which is more than about 10% of the value (the value overall can range from 10.03 up to 10.37 due to the uncertainties in the experiment) of the mass of the vinegar. This is consistent with the label on the bottle of vinegar, which says that the concentration of acetic acid is also about 10%. So what we did, and what we found out, is in our favour and it works.

Therefor is can easily be concluded that the undertaken examination of the experiment was somewhat on a high level accurate and it was shown that the vinegar which can be bought in the shop is already prepared cautiously. Moreover, the method uses some proves to be of great use in determinations. Due to the fact that we did our best in precision and accuracy, that is why we manage to get this proper result with all numbers and calculations.

From the tables on the top in the Data collection part of the report, we can see that all the measurements involve not a very high random error, what resulted in somewhat fair standard deviation as well as percentage uncertainty, they were below 0.5%. This is because of the precise weighing machine as well as other measuring devices as well as precision in

undertaking the titration process itself. You have to be very careful during the titration process, because as soon as the colour starts to turn light pink, on the brink of the dot you have to stop it. Moreover, it is almost certain that both the scale and the burette don't have a zero offset error, and therefor can be no systematic error resulting from this as well.

Table 4: Error and Improvement

Error	Improvement
Over-Titrating - continuing to add the base even after the required colour change has taken place	The person has to be watchful, and watch the time when it neutralises, and be very careful otherwise over-titrating can damage the results.
Imperfection of Observer - Similar to the one on top	This can introduced slight errors, but they cannot be neglected.
Repetition of Amount of Experiment	The amount of times it is repeated is critical, due to the fact that the more times you do it, the more effective average results can be made
Systematic Errors	There were no systematic error during the experiment, but there always are uncertainties of every aspect of the experiment
Random Errors	Random errors were not found in the experiment, but the most basic one can be copying numbers down, but all of these were neglected.

Possibilities of Error

However, to increase the precision of the experiment to even a better level, it can be suggested that more trials can be done, in order to reduce those random errors and make them completely negligible, which is very essential in the experiment. When there are reliable results, there is a possibility of making proper conclusions and thoughtful graphs. Every aspect and every material of the experiment should be clean, as well as the burette, it should be ensured that the burette does not include any impurities that could introduce undetectable systematic error to the experiment. In order to avoid this, the burette should be rinses throughly with distilled water before the practical experiment.

As it is impossible to eliminate the human factor in titration process it can be as advised to try to make it easier to find the exact moment in the titration process. This can be done any many simple ways. First way is having more than one person to be looking at it, because attention spans and reaction time one a person can be faster than the other person. Second way, is having a dark piece of cardboard underneath the breaker, which would allow for greater accuracy when looking at the solution at the right angle to its surface. Thirdly, the solution should be stirred during the titration to allow the based spread evenly. The third solution of stirring, which was actually applied to our experiment and it worked properly.

Apart from that distilled water can be spread on the walls of the beaker from time to time in order to ensure that no drops of base are left outside of the solution. After the acid is thought to be fully neutralised, it is advisable to consult the colour change with other experimenters. Finally, in order to reduce the random errors, the reading from the burette as well as the weights can be repeated several times and average to get proper results and more data. The more data you have the more you can work with it.

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