

Titration

by Ellie Martin

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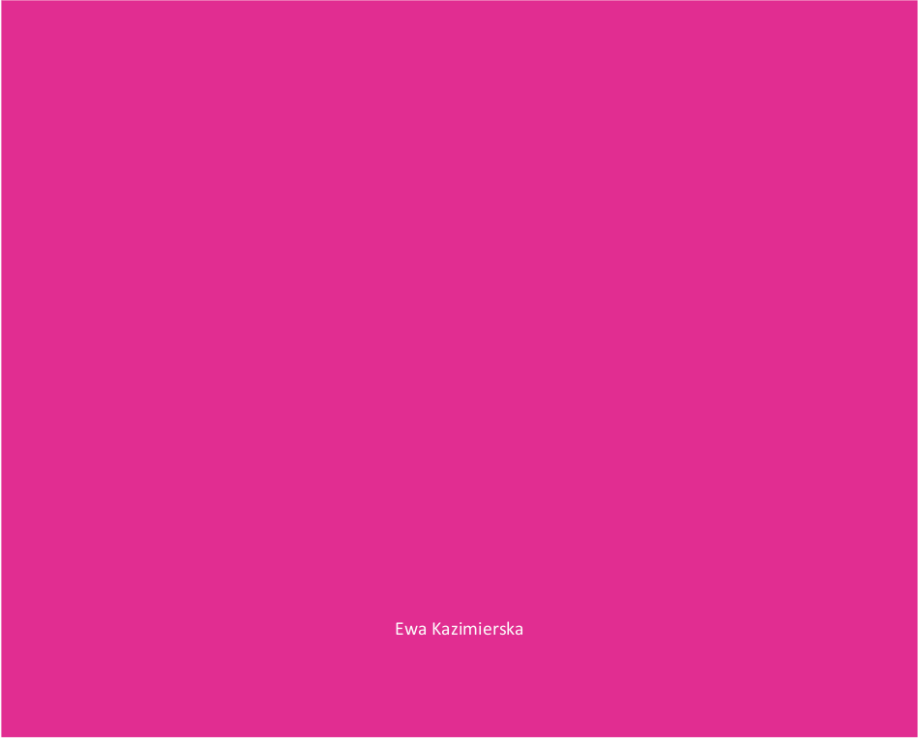
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ACDB4011: TITRATION

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Ewa Kazimierska

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Figure 1: difference in phenolphthalein colour following titration [2] **Error! Bookmark not defined.**

Table of Equations

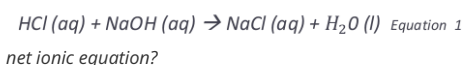
HCl (aq) + NaOH (aq) → NaCl (aq) + H2O (l) Equation 1 1

Molarity = Moles of solute (mol) / Litres of solution (L) Equation 2: Molarity 1

Concentration x volume = Moles Equation 3: Moles Calculation 2

1 Introduction

The purpose of this experiment was to determine the concentration of Hydrochloric acid (HCl) in an unknown sample required to neutralise standard solution of Sodium hydroxide (NaOH) in the process of titration. This is known as a neutralise reaction because the products which are produced are neutral as displayed in [Equation 1].



It is hypothesised that by ensuring the equivalence point is reached, the concentration of the hydrochloric acid (HCl) can be determined by a visible colour change due to the indicator which is used to establish the end point of the reaction.

Some of the variables of this reactions include ensuring that there is enough of the standard solution (NaOH) which has a known concentration to allow the accurately. The volume of the acid will be recorded as this will then be used to calculate the moles of the solution. The molarity of the acid can be calculated by using the volume of the base required for neutralisation, which allows the moles of HCl to be determined, based on the stoichiometry of the balanced reaction.[1]

$$\text{Molarity} = \frac{\text{Moles of solute (mol)}}{\text{Litres of solution (L)}} \quad \text{Equation 2: Molarity}$$

2 Results

Three titrations were conducted as outlined in the methodology in appendix 1 and have been displayed in table 1. By establishing the volume of NaOH titrated from the burette into the conical flask containing HCl caused the solution to change colour from colourless to pink, indicating the equivalence point [Figure 1].

Table one

Flask	1 rough titration	2	3
V HCL (ML)	25	25	25
Initial burette reading	0	16.61	26.89
Final burette reading	16.61	33.24	43.41
V NaOH (ML)	16.61	16.60	16.52

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Moles of NaOH	0.01657	0.01656	0.01648
Moles of HCL	0.01657	0.01656	0.01648
Molarity of HCL Mol/Litre	0.0649	0.064	0.0653

The patterns which were identified in the titration was that when approaching the equivalence point there is a very small volume of NaOH required to neutralise the solution. This could cause you to over titrate the solution giving you a deep pink colour opposed to a faint pink. When the solution was titrated with 16ml of NaOH the colour of the solution began to change however, when this was mixed the colour dissipated thus requiring more NaOH to be added to the solution and depending on the droplet size and how much the tap of the burette was opened meant overshooting the equivalence point of the neutralisation.

The Key finding was establishing the volume of a known concentration of NaOH required to fully neutralise HCl allowing the Molarity and the moles of both chemicals to be determined. To be able to calculate the molarity, the moles used first needs to be determined- this is done by multiplying the concentration of the base solution and the volume:

$$\text{Concentration} \times \text{volume} = \text{Moles} \quad \text{Equation 3: Moles Calculation}$$

- 1) $0.09977 \times 0.01661 = 0.00165 \text{ mol}$
- 2) $0.09977 \times 0.001660 = 0.001656 \text{ mol}$
- 3) $0.09977 \times 0.001652 = 0.001652 \text{ mol}$

The equation for molarity [Equation 2] can be solved for the moles of the solute by writing it as shown below.

$$M_A V_A = M_B V_B$$

$$M_A = \frac{M_B V_B}{V_A} \text{ mol/litre}$$

$$M_A = \text{concentration of HCl}$$

$$V_A = \text{Volume of HCl}$$

$$M_B = \text{Molarity of base (NaOH)}$$

$$V_B = \text{Volume of base (NaOH)}$$

This equation can then be used to determine the molarity is equal to the moles of the solute multiplied by the volume as shown for each titration below. The moles of NaOH which was found from multiplying the concentration and the volume are then used to calculate the molarity of HCl using [Equation 2] as seen from the balance chemical equation there is an number of moles there is a 1:1 ratio.

- 1) $M_A = \frac{0.09977 \times 0.01661}{0.025} = 0.066 \text{ mol/litre}$
- 2) $M_A = \frac{0.09977 \times 0.0160}{0.025} = 0.064 \text{ mol/litre}$
- 3) $M_A = \frac{0.09977 \times 0.01652}{0.025} = 0.065 \text{ mol/litre}$

i like this picture :-)

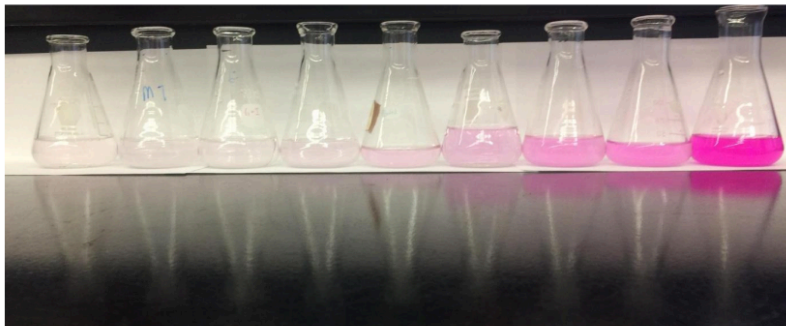


Figure 2: difference in phenolphthalein colour following titration [2]

3 Discussion

This experiment is relevant to OME as the method of titration can be used to determine the concentration of nitric acid used for form nitrocellulose. This is a highly flammable substance which is made from cellulose being treated with highly concentrated nitric acid [3]. Gun cotton can be formed by pure nitric acid or from a mixture of sulphuric acid and nitric acid and this was done to increase the weight of the gun cotton [4]. This material was used to replace gun powder as a propellant for munitions a low order explosive, this means that the decomposition is propagated through deflagration.[4] Due to the acids being in a mixture, the process of a titration is important to accurately determine the concentration of the acids, to ensure the formulation of the explosive will possess the desired characteristics for the propellant and also ensure that the explosive will be consistent.

Some of the limitations of this experiment relate to the accuracy of the precision of measurements. Even though the precision of the glassware (burette and pipette) is $\pm 0.05 \text{ Ml}$ this means that the readings are only accurate to this point. Additionally, inaccuracies in reading the volumes from the glassware due to human error, such as misreading the burette or pipette; could introduce small errors in the volume measurements, leading to slight inaccuracies in the calculated concentration of HCl. Another limitation of this process is effectively determining the end point (equivalence point) of the reaction, as the colour change as shown in figure 1 is very slight and requires the apparatus to be used very carefully to ensure the most accurate volume of NaOH is used. Another area of limitation is identifying and converting the measurements for volume from millilitres to litres to allow for the accurate calculations.

4 Conclusion

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This titration was used to determine the concentration of HCl by following the titration process using a NaOH standard solution. When the equivalence point was reached as indicated by the colour change of the indicator phenolphthalein, and the volume of NaOH required to neutralise the HCl was then recorded. The molarity of the HCl was then calculated by using the known concentration and volume of NaOH- it was calculated that the average molarity of 0.065 mol/L for HCL. This type of experimental technique is effective at determining the concentration of an unknown acid- the limitations of this technique are due to precision inaccuracies due to the glassware and human error. The results gathered supports the hypothesis which suggests the equivalence point can be used to calculate the molarity. When conducting experiments, the use of more precise equipment and techniques to minimise the human error which would allow for more accurate determination of the equivalence point.

5 References

[1]

A. Raviolo, A. S. Farré, and N. T. Schroh, "Students' understanding of molar concentration," *Chemistry Education Research and Practice*, vol. 22, no. 2, pp. 486–497, Apr. 2021, doi: <https://doi.org/10.1039/D0RP00344A>.

[2]

S. Schmidt, "Classic acid and base titration in pink," *Chem13 News Magazine*, Dec. 03, 2018. <https://uwaterloo.ca/chem13-news-magazine/december-2018-january-2019/feature/classic-acid-and-base-titration-pink>

[3]

R. Rennie and J. Law, *A Dictionary of Chemistry*, 8th ed. Oxford University Press, 2016.

[4]

F. A. Abel, "XIV. Researches on gun-cotton.—On the manufacture and composition of gun-cotton," *Philosophical Transactions of the Royal Society of London*, vol. 156, pp. 269–308, Dec. 1866, doi: <https://doi.org/10.1098/rstl.1866.0014>.

6 Appendix – Methodology

6.1 Chemicals:

- 100 mL of standard NaOH solution 0.09977 mol/litre
- 100ml of HCL solution – unknown concentration
- Phenolphthalein indicator

6.2 Equipment

- Burette 50ml attached to stand with clamp
- Pipette 10ml
- Conical flask 100ml
- Pipette
- Wash bottle with deionised water

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- Graduated cylinder 100ml
- White tile to go under the titration flask
- Beaker for waste

6.3 Methodology

- Wash the pipette deionised water and a small amount of HCl before then discard washings
- Wash the burette deionised water and a small amount of NaOH before then discard washings
- Wash the conical flask with small amount of deionised water
- Use the funnel and fill the burette with the standard NaOH solution- run some of the solution through the tap until bottom of meniscus is at zero ensuring there are no bubbles trapped
- Using the pipette place 25ml of HCl into three conical flasks
- Add 3-4 drops of the phenolphthalein indicator to each conical flask and swirl then add 10ml of deionised water using graduated cylinder
- Using tap of burette run the NaOH solution in one of the conical flasks, mixing until the solution changes colour from colourless to pink. This step is used as a rough titration to estimate the volume of NaOH needed to neutralise the measure volume of HCl. Record the final reading.
- Repeat the above step for the next sample of HCl however when the volume is within 2ml of the rough titration run the base at a slower rate (dripping slowly and shaking the solution in the flask) so you can read the volume of NaOH to neutralise the solution. Record the volume used.
- Repeat the steps until two volumes of NaOH solution differ by no more than 0.10ml for the same volume of HCl.

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University of Western Australia - OMS Programme

DATA SHEET TO RECORD OBSERVATIONS, CALCULATIONS AND RESULTS

STUDENT'S NAME: Elise Martin

PARTNER'S NAME: Joe Tawadla

REPORT IS DUE MARCH 23, 2025 @ 3.00 pm submitted via Moodle

(DO: March 28, 2025 @ 3.00 pm)

TITRATION DATA SHEET

Molarity of the standard base solution: $M_{NaOH} = 0.09977 \text{ mol/L}$

FLASK	1 rough	2	3	4
V _{NaOH} (mL)				
Pipette	2.5	2.5	2.5	
Initial burette reading	0	16.61	26.99	
Final burette reading	16.61	53.24	45.41	
V _{NaOH} (mL)	16.61	16.60	16.52	
Moles of NaOH	0.001657	0.001656	0.001648	
Moles of HCl	0.001657	0.001656	0.001648	
Molarity of HCl	0.0657	0.0656	0.0652	
Molarity of HCl	0.0657	0.0656	0.0652	

Precision and Accuracy

You should record pipette and burette readings to the nearest 0.05 cm³ (approximately one drop). Consecutive titrations should agree to within 0.10 cm³ and, you should repeat the titration until this is achieved.

Titration

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

67/100

Engagement with Literature – 10/15

The report references four relevant sources, clearly linked to OME. IEEE style is correctly applied. Literature is integrated well but could be more analytically connected to the experiment.

Feedback: Strong use of sources. Aim to connect references more directly to your analysis rather than describing them.

Knowledge and Understanding – 11/20

The aim, theory, and chemical equation are clearly stated, and the hypothesis is relevant, though more descriptive than predictive. The net ionic equation is missing, and variables are not clearly defined.

Feedback: Include the net ionic equation and state independent, dependent, and controlled variables.

Cognitive and Intellectual Skills – 17/25

The report demonstrates good reflection on error sources and links the experiment to OME (e.g. nitrocellulose production). The discussion is clear but remains mostly descriptive, with no quantified uncertainty or comparison to theoretical values.

Feedback: Include uncertainty estimates or comparisons to strengthen your analysis.

Practical Application Skills – 17/25

The procedure is well described, and calculations are shown with correct unit conversions. However, volumes like “25 mL” should be “25.00 mL,” and controlled variables are not listed.

Feedback: Report all volumes to two decimal places and list controlled variables clearly.

Transferable/Professional Skills – 12/15

The report is clearly structured and professionally presented. Language is mostly formal and passive, with only minor informal expressions.

Feedback: Maintain the strong tone; refine occasional phrasing for greater formality.

PAGE 1

Text Comment. title page should contain your name

PAGE 2

Text Comment. add subsections to make the ToC more detailed

PAGE 3

PAGE 4

Text Comment. net ionic equation?

Text Comment. pipette and burette should be read to the 0.00 or 0.05 mL

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PAGE 5

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Comment 4

avoid personal pronouns; use passive voice

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PAGE 6

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