

Titration - Lab Report

by George Butcher

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Lab Report 2

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George Butcher

UWTSD

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concise ToC

Introduction.

This report is about the titration experiment. The purpose of this experiment is to identify the concentration of an unknown hydrochloric (HCl) acid solution. This will be done by slowly adding a standard solution of sodium hydroxide (NaOH) to the unknown hydrochloric acid solution via titration. This will proceed until the equivalence point is reached, at this point the number of moles (H^+) is equal to the number of moles of the base (OH^-). This equivalence point will be identified by the change in colour in the added indicator, enabling us to determine the concentration of the unknown sample. The procedure for this experiment can be seen in Appendix 2.

avoid 1st person writing

equivalence point well explained

Hypothesis:

The volume of NaOH required to neutralize a fixed volume of HCl can be used to determine the molarity of HCl.

this is a good hypothesis

Variables:

- Independent Variable: Volume of NaOH added.
- Dependent Variable: The point at which the indicator changes colour, signifying equalisation.
- Controlled Variables: Concentration of NaOH, volume of HCl, type and amount of indicator and equipment used.

variables correctly identified

Equations:

The equation for molarity, $M = n / v$ can be solved for n (number of moles) and we can write:

it can be written as:

$$M_A V_A = M_B V_B$$

where M_B is the molarity of the standard base solution, V_B is the volume of the base solution used to neutralise the acid, V_A is the volume of acid in the conical flask and M_A is the concentration of acid that must be calculated [1].

Results.

The data collected from the experiment can be seen in below.

FLASK	1 rough titration	2	3	4
V_{HCl} (mL) from pipette	25.0 <i>precision of pipette is 0.05 mL; sig figs!</i>	25.0	25.0	
Initial burette reading	32.00	30.11 <i>the precise reading of burette is either .00 or .05 mL</i>	30.00	
Final burette reading	49.05	46.32	46.44	
V_{NaOH} (mL)	17.05 <i>volumes of NaOH solution should differ by no more than 0.10 mL for the same volumes of HCl</i>	16.21	16.44	
Moles of NaOH	0.001701 <i>based on the 3 sig. figs. for the volume of HCl, moles should contain 3 sig figs as well</i>	0.001617	0.001640	
Moles of HCl	0.001701	0.001617	0.001640	
Molarity of HCl	0.068 <i>there should be minimum 3 sig figs</i>	0.065	0.066	

In this table it shows the Volume of HCl used (25mL), the initial burette reading and the final burette reading. These values were then used to work out the volume of NaOH used, moles on NaOH, Moles of HCl and the molarity of HCl. As can be seen above there was a slight variation on the volume of NaOH used between each titration.

The key finding of the experiment was the volume of NaOH required to neutralize 25.0 mL of HCl. The results showed a volume ranging from 16.21 mL to 17.05 mL with an average of approximately 16.57 mL. From this we can then work out the amount of moles of NaOH as we already know the molarity (0.09977 mol/L). This is done by multiplying the concentration (0.09977 mol/L) by the Volume (V_{NaOH} L). This is shown in the equation below:

1. Moles of NaOH = 0.09977 mol/L X 0.01705 L = 0.001701 mol
2. Moles of NaOH = 0.09977 mol/L X 0.01621 L = 0.001617 mol
3. Moles of NaOH = 0.09977 mol/L X 0.01644 L = 0.001640 mol

After getting the results of moles of NaOH this gives us the moles of HCl, they are the same because the solution was neutralised meaning the H^+ and OH^- have to be equal. From this we can then calculate the molarity of HCl by the equations below:

$$M_A = M_B V_B / V_A$$

$$M_A = 0.09977 \times 0.001701 / 0.025 = 0.068 \text{ mol/L 2s.f.} \quad 0.02500 \text{ L of HCl; 4 sig figs}$$

$$M_A = 0.09977 \times 0.001617 / 0.025 = 0.065 \text{ mol/L 2s.f.}$$

$$M_A = 0.09977 \times 0.001640 / 0.025 = 0.066 \text{ mol/L 2s.f.}$$

The calculated molarities of HCl ranged from 0.065 mol/L to 0.068 mol/L, with an average molarity of 0.066 mol/L. From these results it can be said that the experiment produced accurate and consistent results. *rough titration shouldn't be included in the average*

Discussion.

After looking at the results from the titration experiment all the values were fairly accurate. The last two results were only 0.23 mL difference. ^{should be 0.1 mL} This shows that our titration was a reliable and accurate experiment. The significance of the results is that we used them to work out that the molarity of HCl, which was 0.065 mol/L to 0.068 mol/L, with an average molarity of 0.066 mol/L. This is important because by knowing the molarity of a solution it allows for accurate chemical analysis and reaction control. It allows the user to have proper reactant concentrations, meaning there will be no excess or inefficiency when reacting two solutions together.

** not really, because the difference was more than 0.1 mL*

Titration is relevant to OME because it is a highly accurate procedure. This is important when dealing with explosives or propellants because even small variations in acid or base concentrations can impact the stability and sensitivity of a compound. Furthermore, by using titration, it ensures the correct chemical balance, preventing unintended reactions [2]. An example of this is the purification of TNT (trinitrotoluene). Titration is used to find the presence of acidic impurities within TNT and to monitor the success of the cleaning process. TNT production involves nitration reactions, meaning acidic by products like sulfuric and nitric acid are left over. Titration can be used to work out the quantity of these acids by neutralising the acids with an alkaline solution. After the TNT has been neutralised, titration can be used again to confirm all acidic by products have been removed, ensuring chemical stability [3]. *very good examples*

The main limitation of titration is inaccurate readings of the burette from the user. The user needs to make sure they are eye level with the meniscus and is taking the reading from the bottom of the curve. If these steps aren't taken then the readings could be inaccurate and produce inaccurate results. Another limitation could be the use of the indicator, currently the user has to wait for the mixture to turn pink to identify neutralisation, which can produce inaccuracy due to human error. To improve this a pH meter could be used to accurately identify when the solution has been neutralised [4].

Conclusions.

In conclusion, the results of the titration experiment were used to confirm the molarity and an unknown HCl solution. The molarity found had a range of 0.065 mol/L to 0.068 mol/L, with an average molarity of 0.066 mol/L. These results support the hypothesis. The experiment also demonstrated the reliability and precision of titration, with minimal variation between the repeated experiments.

In future experiments, different indicators or a digital pH meter could be used to improve the endpoint accuracy and reduce human error. Furthermore, the results would be more accurate if multiple people took readings on the burette and pipette. In future research, it may be beneficial in measuring the impact of the temperature on the acid or base. I believe this would give more information and provide better understanding of this method in different environments [4].

References

- [1] U. Moodle, "Log in to the site | Home," *Uwtsd.ac.uk*, 2025.
<https://moodle.uwtsd.ac.uk/mod/resource/view.php?id=652879> (accessed Mar. 27, 2025).*not a reference*
- [2] J. Clifton, "What is Titration Used For in Real Life? - The Chemistry Blog," *ReAgent Chemical Services*, Feb. 14, 2024. <https://www.chemicals.co.uk/blog/what-is-titration-used-for-in-real-life?srsId=AfmBOoqEmxuQr0uInMP62o89RfMXKQu05Dv06Zfa04OQ23c2Wy7E1YQR> (accessed Mar. 27, 2025).
- [3] H. Muraour and C. Munroe, "The Purification of TNT," *Ordnance*, vol. 5, no. 26, pp. 507–511, 1924, Accessed: Mar. 27, 2025. [Online]. Available:
https://www.jstor.org/stable/pdf/45484735.pdf?refreqid=fastly-default%3A9b8d849203338770c36dc0a6e517fd20&ab_segments=&initiator=&acceptTC=1
- [4] I. Kalkman, "How to avoid titration errors in your lab," *Metrohm.com*, 2024.
https://www.metrohm.com/en_gb/discover/blog/2024/avoid-titration-errors.html

Appendix

Appendix 1 - Materials and Equipment.

Chemicals:

- ~ 100 mL of **standard** NaOH solution, $M_B = 0.09977 \text{ mol/L}$ in a labelled beaker
- ~ 100 mL HCl solution with an unknown concentration in a labelled beaker
- Phenolphthalein indicator (colourless in acidic solution, pink in basic solution)

Equipment:

- 1x Burette, 50 mL attached to a burette stand with clamp
- 1x Pipette, 10 mL OR 5 mL, with pipette filler
- 3x Erlenmeyer (conical) flasks, 100 mL
- 1x Small funnel to fill the burette
- 1x Plastic pipette
- 1x Wash bottle with deionised water
- 1x Graduated cylinder, 100 mL
- 1x White tile or white paper to go under the titration flask
- 1x Beaker for the waste

Appendix 2 – Procedure.

Step 1: wash

- Pipette - with deionised water from the wash bottle followed by a small volume of HCl; discard the washings
- Burette - with deionised water from the wash bottle followed by a small amount of NaOH (discard); use the funnel to pour a few mL of NaOH
- Erlenmeyer (conical flask) - with a small amount of deionised water

Step 2: Using a small funnel, fill the burette with standard NaOH solution, running some of the solution through the tap, until the bottom of meniscus is just on the zero level. Ensure that there are no air bubbles trapped.

RECORD THE INITIAL READING

Step 3: Using the pipette filler place 25 mL of HCl solution in the three clean conical flasks

Step 4: Add 3-4 drops of phenolphthalein indicator to each flask with acid and swirl gently, then add approximately 10 mL of deionised water using a graduated cylinder

Step 5: Using the tap of the burette run the NaOH solution in the first conical flask, mixing thoroughly, until the solution changes colour to pink. This step is called rough titration and should allow you to estimate the volume of NaOH needed to neutralise the measured volume of HCl.

RECORD THE FINAL READING

Step 6: Repeat step 5 for the next sample of HCl

Step 7: This time:

- Run the NaOH into the acid /indicator/water mix until the volume of NaOH is within 2 mL of what it was in the rough titration (Step 5)
- At this point run the base at a slower rate (dripping it slowly and shaking the solution in the flask) so you can read the volume of HCl required to neutralise the solution to one drop (0.05 mL). Note: Take an accurate reading within 0.05 mL and take the reading at the first colour change in the solution

STEP 8: Repeat steps 6 and 7 until a satisfactory result is obtained

- Two volumes of NaOH solution differ by no more than 0.10 mL for the same volumes of HCl

Appendix 3 – Results

FLASK	1 rough titration	2	3	4
<i>V_{HCl} (mL)</i> <i>from pipette</i>	25.0	25.0	25.0	
<i>Initial burette reading</i>	32.00	30.11	30.00	
<i>Final burette reading</i>	49.05	46.32	46.44	
<i>V_{NaOH} (mL)</i>	17.05	16.21	16.44	
<i>Moles of NaOH</i>	0.001701	0.001617	0.001640	
<i>Moles of HCl</i>	0.001701	0.001617	0.001640	
<i>Molarity of HCl</i>	0.068	0.065	0.066	

Titration - Lab Report

GRADEMARK REPORT

FINAL GRADE

67 / 100

GENERAL COMMENTS

Engagement with Literature Skills 10/15

The report uses correctly numbered in-text citations in IEEE format. It includes four sources, two of which are highly relevant to titration in OME. Moodle resource and commercial blog are less academically rigorous.

The integration of literature is fair, particularly the TNT purification example.

Feedback: Good use of relevant sources with proper in-text IEEE formatting;

Knowledge and Understanding Skills 15/20

The introduction defines the experiment clearly and identifies variables correctly. The chemical equation is included, and the explanation of titration purpose and theory is accurate. Molarity is calculated using the correct formulas and the logic of mole equivalence is clearly communicated. However, a net ionic equation is not provided.

Feedback: Strong foundational knowledge; include ionic equations for completeness.

Cognitive and Intellectual Skills 16/25

The report shows awareness of precision and repeats, with an average molarity calculated and results discussed. It correctly identifies key sources of error (e.g. meniscus reading, endpoint detection). The explanation of TNT purification via titration is a well-chosen OME example. However, the report could offer deeper critical analysis of specific anomalies.

Feedback: Sound reasoning and error discussion; include comparisons or improvements based on titration theory for better insight.

Practical Application Skills 16/25

The data is well presented, with consistent use of units but there are errors in significant figures. Calculations are shown step-by-step but the average is not correctly computed.

Feedback: Great calculation accuracy; pay more attention to the precision of specific glassware.

Transferable/Professional Skills 10/15

The report is mostly well-written and formatted. Passive voice is used appropriately but 1st person writing is occasionally present which reduce professionalism. Data tables clearly labelled.

Feedback: Solid structure; thorough avoidance of 1st person writing would enhance professionalism.

PAGE 1

Text Comment. professional title page

PAGE 2

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PAGE 3

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