



Thomas James Cresswell

Chemistry Lab Report 2 – Titration

University of Wales Trinity Saint David
Ordnance Munitions and Explosives Professional

BEng
Academic Year: 2024 - 2029

Supervisor: Emma Moseley
February 2025

Academic integrity declaration

I declare that:

- the thesis submitted has been written by me alone.
- the thesis submitted has not been previously submitted to this university or any other.
- that all content, including primary and/or secondary data, is true to the best of my knowledge.
- that all quotations and references have been duly acknowledged according to the requirements of academic research.

I understand that to knowingly submit work in violation of the above statement will be considered by examiners as academic misconduct

Acknowledgements

[Click here to enter acknowledgement text.](#)

Table of Contents

1. Introduction	1
1.1. Aim of experiment.....	1
1.2. Hypothesis.....	1
1.3. Experiment variables.....	1
1.4. Experiment equations.....	1
2. Results.....	2
2.1. Results.....	2
3. Discussion	2
3.1. Significance of results	2
3.2. Calculations – Determination of HCl molarity.....	2
3.3. Relevance to OME	4
3.4. Sources of error	4
4. Conclusions.....	4
5. References.....	5
6. Appendices	6
6.a. Annex a - Materials and methods.....	6
6.b. Annex b – Original data sheet.....	8

List of Equations

Equation 1 - Relationship between speed of light, wavelength and frequency.... 1

List of Tables

Table 1 - Results from experiment – before calculations 2

Table 2 - Results from experiment – post calculations..... 4

List of Abbreviations

OME Ordnance Munitions & Explosives

1. Introduction

1.1. Aim of experiment

The purpose of this experiment is to determine the concentration of hydrochloric acid by adding sodium hydroxide until a measured equivalence point is met.

1.2. Hypothesis

The hypothesis being tested in this experiment is that the sodium hydroxide, if added gradually, can be used to find an equivalence point where the acid is neutralised, which can then be used to calculate the acids molar concentration.

1.3. Experiment variables

Independent variable:

Solution tested and therefore the metal salts present in each solution.

Dependant variable:

Colour change threshold for phenolphthalein.

Control variables:

- Concentration of base
- Concentration and volume of phenolphthalein
- Ambient temperature: Constant room temperature.

1.4. Experiment equations

$$M_1V_1=M_2V_2 [1]$$

M_1 = Molarity of base (NaOH)

V_1 = Volume of base (NaOH)

M_2 = Molarity of acid (HCl)

V_2 = Volume of acid (HCl)

Equation 1 – Relationship between the molarity and volume of two solutions

$$n = M \times V$$

n = Number of moles (mol)

M = Molarity (M)

V = Volume (L)

frequency

2. Results

2.1. Results

Below is a table of the results gained from the experiment; four serials were completed.

FLASK	1 Rough Titration	2	3	4
V _{HCl} from pipette (ml)	25.0	25.0	25.0	10.0
Initial burette reading (ml)	0.8	0	0	14.00
Final burette reading (ml)	17.95	16.80	14.50	20.50
V _{NaOH} (ml)	17.15	16.80	14.50	6.50

Table 1 - Results from experiment – before calculations

In this experiment, it was difficult to get precise results on the equilibrium point for the 3rd test. The equilibrium point observed is when the phenolphthalein indicator starts to transition from clear to pink. The rough titration and the 1st slow titration fell within a small range of 0.35ml whereas the 3rd titration had a much different value. The final test used a smaller volume, but its ratio stayed similar to the first two results suggesting the ratio sits around 0.65:1 and 0.675:1 NaOH:HCl.

3. Discussion

3.1. Significance of results

The results in this experiment signify the quantity of NaOH required to neutralize the HCl in the flask. The recorded volume required to reach the equilibrium point can be used to calculate the molarity of the HCl in the flask since the molarity of the NaOH is known: 0.09977M.

3.2. Calculations – Determination of HCl molarity

The molar mass of the compound can be determined by combining the atomic mass of all its components, the atomic mass of each element is at the bottom of it's square in the periodic table.

Molar mass NaOH: $22.99 + 15.99 + 1.008 = 40.00 \text{ g/mol}$

Molar mass HCl: $1.01 + 34.45 = 36.46 \text{ g/mol}$

Molarity of NaOH (provided by lab): 0.9977M

Using the above molarity and the volumes of each solution, the molarity of the HCl can be determined as well as the number of moles of each substance.

Molarity equation [2]

$$M_2 = (M_1V_1)/V_2$$

Determination of number of moles

$$n = M \times V$$

Test 1:

$$M_2 = (0.9977 \times 17.15)/25 = 0.06844 \text{ M}$$

$$n_{\text{HCl}} = 0.06844 \times 0.025 = 0.001711 \text{ mol}$$

$$n_{\text{NaOH}} = 0.9977 \times 0.01715 = 0.001711 \text{ mol}$$

Test 2:

$$M_2 = (0.9977 \times 16.80)/25 = 0.06705 \text{ M}$$

$$n_{\text{HCl}} = 0.06705 \times 0.025 = 0.001676 \text{ mol}$$

$$n_{\text{NaOH}} = 0.9977 \times 0.0168 = 0.001676 \text{ mol}$$

Test 3:

$$M_2 = (0.9977 \times 14.50)/25 = 0.05787 \text{ M}$$

$$n_{\text{HCl}} = 0.05787 \times 0.025 = 0.001447 \text{ mol}$$

$$n_{\text{NaOH}} = 0.9977 \times 0.0145 = 0.001447 \text{ mol}$$

Test 4:

$$M_2 = (0.9977 \times 6.50)/10 = 0.06485 \text{ M}$$

$$n_{\text{HCl}} = 0.06485 \times 0.01 = 0.0006485 \text{ mol}$$

$$n_{\text{NaOH}} = 0.9977 \times 0.0065 = 0.0006485 \text{ mol}$$

In these calculations, test serial 3 has been identified as an outlier. The molarity of the HCl, as an average of the valid results, was calculated to be 0.06678 M.

Below is the table populated with the values from the above calculations.

FLASK	1 Rough Titration	2	3	4
V _{HCl} from pipette (ml)	25.0	25.0	25.0	10.0
Initial burette reading (ml)	0.8	0	0	14.00
Final burette reading (ml)	17.95	16.80	14.50	20.50
V _{NaOH} (ml)	17.15	16.80	14.50	6.50
Moles of NaOH	0.001711	0.001676	0.001447	0.0006485

Moles of HCl	0.001711	0.001676	0.001447	0.0006485
Molarity of HCl (M)	0.06844	0.06705	0.05787	0.06485

Table 2 - Results from experiment – post calculations

3.3. Relevance to OME

Titration's relevance to OME stretches to multiple areas, one of these areas is the identification of the explosive's purity. An example of this process is a journal entry explaining a method of non-aqueous titration to generate percentages for purity [2] for the composition, in this case FOX-7.

3.4. Sources of error

The method of this experiment allowed for a range of error sources:

- Human errors:
 - Using human eye for measurement is potentially less accurate than equipment
 - Physical conditions/dexterity can lead to less control of burette tap, potentially leading to an overshoot in values.

4. Conclusions

The results of the experiment in general are consistent and represent a calculated molarity of 0.06678 M. Although the final serial of testing was performed with a lower volume of HCl a similar molarity was calculated which further proves the method.

5. References

- [1] University of Wales Trinity Saint David, "ACDB 4011: TITRATION," 2025.
- [2] P. P. S. S. A. M. R. P. A.K. Nandi, "Assay of the Insensitive High Explosive FOX-7 by Non-Aqueous Titration," *Central European Journal of Energetic Materials*, vol. 9, no. 4, pp. 343-352, 2012.
- [3] T. Cresswell, DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS, Swansea, 2025.

6. Appendices

6.a. Annex a - Materials and methods [1]

Lab tools and supplies:

- Bunsen burner
- Heat-resistant mat
- Matches

Procedure:

1. Wash:
 - a. Pipette – clean with deionised water from the wash bottle followed by a small volume of HCl and discard.
 - b. Burette - clean with deionised water from the wash bottle followed by a small volume of NaOH and discard.
 - c. Erlenmeyer (conical flask) - with a small amount of deionised water
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.
3. Using the pipette filler place 25 mL of HCl solution in the three clean conical flasks
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
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.
6. Repeat step 5 for the next sample of HCl
7. 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)
8. 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
9. Repeat steps 6 and 7 until a satisfactory result is obtained

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

6.b. Annex b – Original data sheet [3]

University of Wales Trinity Saint David – OME Programme

DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS

STUDENT'S NAME: THOMAS GRESSWELL

PARTNERS' NAMES: JORDEN NEWMAN + JAMES BURTON

Alex Halliday

REPORT IS DUE MARCH 21, 2025 @ 3.00 pm submitted via Moodle

(DD: March 28, 2025 @ 3.00 pm)

TITRATION DATA SHEET

Molarity of the standard base solution: $M_{\text{NaOH}} = 0.09977 \text{ M}$ 4 s.f.

FLASK	1 rough titration	2	3	4
V_{HCl} (mL) from pipette	25 mL	25 mL	25 mL	~~25 mL~~ 10.0 mL
Initial burette reading	0.0 mL ~~0.20 mL~~	0 mL	0 mL	~~0 mL~~ 14.00 mL
Final burette reading	17.95 mL	16.80 mL	14.50 mL	~~0 mL~~ 20.50 mL
V_{NaOH} (mL)	17.95 mL	16.80 mL	14.50 mL	~~0 mL~~
Moles of NaOH				~~0~~
Moles of HCl				~~0~~
Molarity of HCl				~~0~~

9
4.2 mL

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.

7