

Titration Lab Report

L4 OME CHEMISTRY ACDB4011

Emalie Halifax (2222482)

UNIVERSITY OF WALES TRINITY SAINT DAVID | L4 OME CHEMISTRY ACDB4011

TABLE OF CONTENTS

1. Purpose	2
2. Theory	2
3. Chemicals and Equipment.....	3
4. Procedure	4
5. Data.....	5
6. Calculations	6
7. Results and Discussion	7
8. Conclusion	7
9. References.....	8
10. Appendix A	9
11. Appendix B	10

TABLE OF EQUATIONS, FIGURES AND TABLES

Equation 1	2
Equation 2	3
Equation 3	3
Equation 4	3
Equation 5	3
Equation 6	3
Equation 7	6
Equation 8	6
Equation 9	6
Equation 10	10
Equation 11	10
Equation 12	10
Equation 13	10
Equation 14	10
Equation 15	11
Equation 16	11
Equation 17	11
Equation 18	11
Equation 19	12
Equation 20	12
Equation 21	12
Figure 1 - Titration Apparatus	4
Figure 2 - Start of change of colour in Titration experiment.....	5
Figure 3 - Results of Titration Experiment	6
Table 1 - Experiment Results.....	5
Table 2 – Values for calculation	6

1. PURPOSE

Analytical chemistry is the process of determining the qualitative and quantitative data of a substance [1]. There are various uses and methods of analytical chemistry. One element is to calculate the unknown concentration of a solution. The concentration of a solution is defined as the quantity of a solute dissolved in a solvent. There are different ways to measure concentration. This report looks at molarity which is defined as the number of moles per litre.

This report discusses the Acid/Base titration experiment which is a form of volume analysis [1]. The aim of the titration experiment was to determine the molarity of a solution of Hydrochloric Acid using a standard solution of Sodium Hydroxide.

2. THEORY

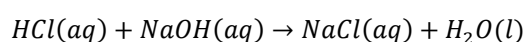
The process of titration is used to determine the quantity of a one substance by adding a quantity of another substance to the point they react, and the equivalence point it achieved [2]. The equivalence point is when neutralisation occurs – when the number of moles of substance one equates to the number of moles of substance two.

Depending on the type of chemical reaction involved a titration experiment can be categorised into the following categories:

- Acid and Base Titration
- Complexometric Titration
- Redox Titration
- Precipitation Titration [3]

Each method has its own uses. A redox titration is used to determine the quantity of an oxidising or reducing agent present in a solution, whereas an Acid/Base titration is used to determine the concentration of an Acid using a standard solution of a Base with a known concentration. Acid/Base titration is often used to determine the pH of a solution and can be seen in the pharmaceutical and water industries [4]. Whereas a Redox reaction is a form of combustion so is seen with explosives. The reaction of ammonium perchlorate and powdered aluminium inside a rocket booster is an example [5]. Redox titration can be used to determine the quantity of oxidising agent needed to perform the reaction.

This report details an Acid/Base titration. It covers the neutralisation of Hydrochloric Acid, HCl, by Sodium Hydroxide, NaOH to determine the concentration of the acid. In this experiment the base – Sodium Hydroxide – is a standard solution, where the concentration is accurately known. As both solutions are colourless, an indicator is needed to show the equivalence point. Phenolphthalein is the indicator used. It is a colourless solution that turns pink in a neutral solution. The chemical equation for this reaction is shown in equation 1.



EQUATION 1

Based on the stoichiometry of the equation we know that one mole of Hydrochloric Acid is neutralised by one mole of Sodium Hydroxide. Meaning the number of H⁺ ions provided by the acid is the same as the number of OH⁻ ions provided by the hydroxide; this balance allows the equivalence point to occur.

To calculate the concentration of the acid, a volume of the hydroxide is dripped into the solution until the indicator turns it pink. This will allow the number of moles of the hydroxide to be calculated and using stoichiometry of the reaction the number of moles of the acid is found. Using the formula derived below the concentration of the acid can be calculated.

$$\begin{aligned} &\text{At equivalence point} \\ &\text{Number of Moles in Acid } (n_A) = \text{Number of Moles in Base } (n_B) \end{aligned}$$

EQUATION 2

$$\begin{aligned} &\text{And} \\ &\text{Number of Moles } (n) = \text{Molarity of Solution } (M) \times \text{Volume of Solution } (V) \end{aligned}$$

EQUATION 3

$$\begin{aligned} &\text{Therefore} \\ &M_A V_A = M_B V_B \end{aligned}$$

EQUATION 4

$$M_A = \frac{M_B V_B}{V_A}$$

EQUATION 5

$$\text{Where } V_B = V_{\text{initial}} - V_{\text{final}}$$

EQUATION 6

Where M_A is the Molarity of the acid – HCl – and M_B is the Molarity of the base – NaOH – both measured in Moles per Litre (mol L^{-1}). V_B is the volume of the base and V_A is the volume of the acid in Litres (L).

3. CHEMICALS AND EQUIPMENT

To perform the titration experiment, the equipment required is listed below.

- Burette of 50ml capacity attached to a Burette stand
- Pipette of 10ml capacity with a pipette filler
- Small funnel to fill the Burette
- Beaker for waste
- Erlenmeyer (conical) flask
- White tile to go under the Erlenmeyer flask

Figure 1 shows how the equipment was set up [6]. In the titration experiment undertaken the standard solution used was Sodium Hydroxide (NaOH) with a Molarity of 0.1002mol/L and a volume of 25mL of Hydrochloric acid (HCl) was used per titration.

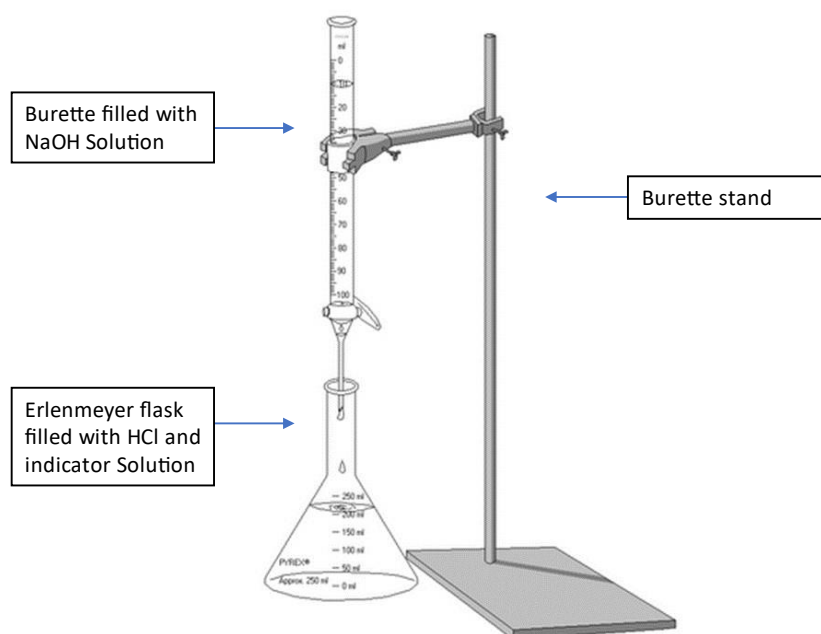


FIGURE 1 - TITRATION APPARATUS

Before starting the experiment, all equipment was washed. A small volume of HCl was ran through the pipette and a small volume of NaOH was poured through the Burette. Both quantities were discarded in the waste jar once used. The Erlenmeyer flask was rinsed with a small quantity of distilled water. This water was emptied out, but the flask was not needed to be entirely dry before use as the experiment was interested in the moles present in the solutions and water will not affect this value.

4. PROCEDURE

Using the small funnel, the burette was filled until the bottom of the meniscus sat at 0.0mL. This value was the initial volume reading for the rough titration. Using the pipette and the pipette filler 25mL of HCl was added to the Erlenmeyer flask, along with 4 drops of the phenolphthalein indicator. The Erlenmeyer flask was swirled gently to ensure the indicator was mixed into the acid.

For the rough titration, the NaOH was added to the HCl solution by opening the tap of the burette. The flask was gently swirled while the base was added, until the solution turned pink and stayed pink for 30s (Figure 2). The white tile enabled the colour to be seen easier. The volume of NaOH remaining in the burette was recorded as the final volume.

These steps were repeated for the main titrations. When the volume of the base added was within 2mL of the result of the rough titration, the NaOH was added at a slower rate. This slower rate enabled the volume to neutralise the HCl to be recorded to the drop. A drop equated to 0.05mL.

The process was repeated for each titration – accurately recording the initial and final volume of the base. To provide an accurate result the experiment was repeated until there were three concordant results found within 0.1mL or two within 0.05mL.



FIGURE 2 - START OF CHANGE OF COLOUR IN TITRATION EXPERIMENT

5. DATA

The results of the experiment are shown in Table 1. Flasks 3 and 4 were the concordant results as they were within 0.05mL of each other. The average of these two – 16.23mL – was used in the calculations to determine the molarity of the Hydrochloric Acid. Figure 3 shows the flasks with the pink indicator which highlighted the neutralisation of the acid.

	FLASK 1 - ROUGH TITRATION	FLASK 2	FLASK 3	FLASK 4
VOLUME OF HCL (ML)	25.00	25.00	25.00	25.00
INITIAL BURETTE READING	0.20	17.25	24.20	21.40
FINAL BURETTE READING	17.25	33.30	40.40	37.65
VOLUME OF NAOH (ML)	17.05	16.05	16.20	16.25

TABLE 1 - EXPERIMENT RESULTS

Molarity of Base - NaOH (Mol/L)	0.1002
Average Volume of Base - NaOH (L)	0.01623
Volume of Acid - HCl (L)	0.0250

TABLE 2 – VALUES FOR CALCULATION



FIGURE 3 - RESULTS OF TITRATION EXPERIMENT

6. CALCULATIONS

Using the data from table 1 and the values in table 2 the molarity of HCl can be calculated using equation 5 derived in section one.

$$M_A = \frac{M_B V_B}{V_A}$$

EQUATION 7

$$M_A = \frac{0.1002 \times 0.01623}{0.02500}$$

EQUATION 8

$$M_A = 0.06505 \text{ MolL}^{-1}$$

EQUATION 9

Where M_A is the Molarity of the acid – HCl – and M_B is the Molarity of the base – NaOH – both measured in Moles per Litre (MolL^{-1}). V_B is the volume of the base and V_A is the volume of the acid in Litres (L).

Appendix A shows the original data sheet used in the experiment with the calculated results for each titration. Appendix B shows the calculations made for each flask. The answers to the calculations are shown to four significant figures.

7. RESULTS AND DISCUSSION

The final calculation, using the two concordant results, calculated the molarity to be $0.06505 \text{ Mol L}^{-1}$. Based on the molarity of the base, $0.1002 \text{ Mol L}^{-1}$, the hypothesis was for the molarity of the acid to be low. These calculations provided a result that supported the hypothesis.

The experiment was conducted with high accuracy being able to provide a volume to 0.05 mL . This was due to slowing down the rate of the addition of Sodium Hydroxide to one drop at a time. However, to provide an even more accurate result further titrations could be conducted to achieve more concordant results.

This method of titration used a visual indicator to determine the equivalence point. The colour change provided a subjective element to the experiment as the visualisation of the pink colour occurring can be difficult to analyse. Improvements could include a digital probe in the solution to measure the pH change in the solution.

Further limitations include the inconsistency with the method of swirling of the solution while the base was being added. This provided a difference in interpreting the equivalence point. Future experiments could include a more accurate method of mixing the solution, such as a magnetic stirrer. This equipment would allow the solution to be stirred at a consistent rate across all titrations.

8. CONCLUSION

The titration experiment provided a method to determine the unknown concentration of the Hydrochloric Acid used. While areas of improvement have been identified, including the method of determining the equivalence point and the mixing of solutions, the experiment was performed with accuracy. This provided concordant results of the volume of Sodium Hydroxide used to 0.05 mL , allowing the concentration to be calculated to four significant figures. The calculated molarity of Hydrochloric acid was $0.06505 \text{ Mol L}^{-1}$.

9. REFERENCES

- [1] L. Bell-Young, "What Is Analytical Chemistry," 28 October 2020. [Online]. Available: <https://www.chemicals.co.uk/blog/what-is-analytical-chemistry#:~:text=Analytical%20chemistry%20is%20a%20specialised%20discipline%20that%20deals,and%20structure%20at%20both%20atomic%20and%20molecular%20levels..> [Accessed 13 March 2023].
- [2] A. Townshend, "Titrimetry, Overview," in *Encyclopedia of Analytical Science*, Elsevier, 2005, pp. 105-113.
- [3] Author of Website, "Titrimetry," [Online]. Available: <https://www.eag.com/techniques/titrimetry/>. [Accessed 08 March 2023].
- [4] L. Bell-Young, "What is Titration Used For in Real Life?," 20 October 2021. [Online]. Available: <https://www.chemicals.co.uk/blog/what-is-titration-used-for-in-real-life>. [Accessed 10 March 2023].
- [5] Mostafa, "9 Most Effective Applications of Redox Titration," 5 September 2022. [Online]. Available: https://blog.praxilabs.com/2021/03/16/applications-of-redox-titration/#Applications_of_Redox_Titration. [Accessed 10 March 2023].
- [6] "Titration Facts for Kids," 16 July 2021. [Online]. Available: <https://kids.kiddle.co/Titration>. [Accessed 8 March 2023].

10. APPENDIX A

STUDENT'S NAME: Emalie Halfax

PARTNERS' NAMES: Libby Jones

TITRATION DATA SHEET

Molarity of the standard base solution: $M_{\text{NaOH}} = \underline{0.1002 \text{ mol/L}}$

FLASK	1 rough titration	2	3	4
$V_{\text{HCl}}(\text{mL})$ from pipette	25	25	25	25
Initial burette reading	0.20	17.25	24.20	21.40
Final burette reading	17.25	33.30	40.40	37.65
$V_{\text{NaOH}}(\text{mL})$	17.05	16.05	16.20	16.25
moles of NaOH	1.754×10^{-3}	1.608×10^{-3}	1.623×10^{-3}	1.628×10^{-3}
Moles of HCl	1.754×10^{-3}	1.608×10^{-3}	1.623×10^{-3}	1.628×10^{-3}
Molarity of HCl mol L^{-1}	~~0.0716~~ 0.07016	0.06432	~~0.06512~~ 0.06492	0.06512

Accuracy

You should record pipette and burette readings to the nearest 0.05 cm^3 (approximately one drop). Consecutive titrations should agree to within 0.10 cm^3 and, you should repeat the titration until this is achieved.

11. APPENDIX B

Calculations for Flask 1

Known Values and Results from Experiment:

$$M_B = 0.1002 \text{ MolL}^{-1}$$

$$\begin{aligned} V_B &= V_{\text{final}} - V_{\text{initial}} \\ &= 17.25 \times 10^{-3} - 0.20 \times 10^{-3} \\ &= 17.05 \times 10^{-3} \text{ L} \end{aligned}$$

$$V_A = 25.00 \times 10^{-3} \text{ L}$$

Part One – Calculate the number of moles of NaOH

$$\begin{aligned} n_B &= M_B \times V_B \\ &= 0.1002 \times 17.05 \times 10^{-3} \\ &= 1.754 \times 10^{-3} \text{ Mol} \end{aligned}$$

EQUATION 10

Part Two – Calculate the number of moles of HCl

$$\begin{aligned} n_B &= n_A \\ 1.754 \times 10^{-3} \text{ mol} &= 1.754 \times 10^{-3} \text{ mol} \end{aligned}$$

EQUATION 11

Part Three – Calculate the Molarity of HCl

$$\begin{aligned} M_A &= \frac{n_A}{V_A} \\ &= \frac{1.754 \times 10^{-3}}{25.00 \times 10^{-3}} \\ &= \mathbf{0.07016 \text{ MolL}^{-1}} \end{aligned}$$

EQUATION 12

Calculations for Flask 2

Known Values and Results from Experiment:

$$M_B = 0.1002 \text{ MolL}^{-1}$$

$$\begin{aligned} V_B &= V_{\text{final}} - V_{\text{initial}} \\ &= 33.30 \times 10^{-3} - 17.25 \times 10^{-3} \\ &= 16.05 \times 10^{-3} \text{ L} \end{aligned}$$

$$V_A = 25.00 \times 10^{-3} \text{ L}$$

Part One – Calculate the number of moles of NaOH

$$\begin{aligned} n_B &= M_B \times V_B \\ &= 0.1002 \times 16.05 \times 10^{-3} \\ &= 1.608 \times 10^{-3} \text{ Mol} \end{aligned}$$

EQUATION 13

Part Two – Calculate the number of moles of HCl

$$\begin{aligned} n_B &= n_A \\ 1.608 \times 10^{-3} \text{ mol} &= 1.608 \times 10^{-3} \text{ mol} \end{aligned}$$

EQUATION 14

Part Three – Calculate the Molarity of HCl

$$\begin{aligned}M_A &= \frac{n_A}{V_A} \\&= \frac{1.608 \times 10^{-3}}{25.00 \times 10^{-3}} \\&= \mathbf{0.06432 \text{ MolL}^{-1}}\end{aligned}$$

EQUATION 15

Calculations for Flask 3

Known Values and Results from Experiment:

$$\begin{aligned}M_B &= 0.1002 \text{ MolL}^{-1} \\V_B &= V_{final} - V_{initial} \\&= 40.40 \times 10^{-3} - 24.20 \times 10^{-3} \\&= 16.20 \times 10^{-3} \text{ L} \\V_A &= 25.00 \times 10^{-3} \text{ L}\end{aligned}$$

Part One – Calculate the number of moles of NaOH

$$\begin{aligned}n_B &= M_B \times V_B \\&= 0.1002 \times 16.20 \times 10^{-3} \\&= 1.623 \times 10^{-3} \text{ Mol}\end{aligned}$$

EQUATION 16

Part Two – Calculate the number of moles of HCl

$$\begin{aligned}n_B &= n_A \\1.623 \times 10^{-3} \text{ mol} &= 1.623 \times 10^{-3} \text{ mol}\end{aligned}$$

EQUATION 17

Part Three – Calculate the Molarity of HCl

$$\begin{aligned}M_A &= \frac{n_A}{V_A} \\&= \frac{1.623 \times 10^{-3}}{25.00 \times 10^{-3}} \\&= \mathbf{0.06492 \text{ MolL}^{-1}}\end{aligned}$$

EQUATION 18

Calculations for Flask 4

Known Values and Results from Experiment:

$$\begin{aligned}M_B &= 0.1002 \text{ MolL}^{-1} \\V_B &= V_{final} - V_{initial} \\&= 37.65 \times 10^{-3} - 21.40 \times 10^{-3} \\&= 16.25 \times 10^{-3} \text{ L} \\V_A &= 25.00 \times 10^{-3} \text{ L}\end{aligned}$$

Part One – Calculate the number of moles of NaOH

$$\begin{aligned}
 n_B &= M_B \times V_B \\
 &= 0.1002 \times 16.25 \times 10^{-3} \\
 &= 1.628 \times 10^{-3} \text{ Mol}
 \end{aligned}$$

EQUATION 19

Part Two – Calculate the number of moles of HCl

$$\begin{aligned}
 n_B &= n_A \\
 1.628 \times 10^{-3} \text{ mol} &= 1.628 \times 10^{-3} \text{ mol}
 \end{aligned}$$

EQUATION 20

Part Three – Calculate the Molarity of HCl

$$\begin{aligned}
 M_A &= \frac{n_A}{V_A} \\
 &= \frac{1.628 \times 10^{-3}}{25.00 \times 10^{-3}} \\
 &= \mathbf{0.06512 \text{ MolL}^{-1}}
 \end{aligned}$$

EQUATION 21