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Lab report 2 – Titration - Determining Concentrations

University of Wales, Trinity St Davids
Ordnance, Munitions and Explosives(BEng) - Chemistry

Academic Year: 2024 - 2025

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1 Introduction

The purpose of this experiment is to determine the concentration of an unknown sample of hydrochloric acid (HCL), by adding an indicator and gradually adding a known concentration of standard solution, sodium hydroxide (NaOH), until the indicator reaches the endpoint and changes colour, indicating the equivalence point in which the mixed solution is neutralized. This is method is known as titration.

This method is repeated 3 times with an expectation that each time the amount of NaOH added should be roughly the same, giving a consistent result in concentration when calculated.

This will identify the concentration to an accurate figure, as it is expected that the results will be roughly the same, to a level.

The dependant variable in this experiment is the amount of standard solution added to the unknown, which can be translated into concentration using the following equations[1]:

$$M = n/V$$

Equation 1 - Calculating Molarity

$$M_A V_A = M_B V_B$$

Equation 2 - Balance of Molarity and Volume

Where:

n is the number of moles within a substance

M is molarity of a substance

V is volume of a substance

$_A$ and $_B$ are representative of the unknown and standard solutions respectively.

2 Results

The results of the experiment were recorded in the table below:

TITRATION DATA SHEET

Molarity of the standard base solution: **M $_{NaOH}$ =** 0.09977 mol/L

FLASK	***1 (rough titration)***	***2***	***3 (different batch)***
V $_{HCl}$ (mL) from pipette	***25***	***25***	***25***
Initial burette reading	***0.10***	***16.80***	***24.70***
Final burette reading	***16.75***	***33.80***	***42.15***
V $_{NaOH}$ (mL)	***16.65***	***17.00***	***17.45***
Moles of NaOH	***1.661×10^{-3}***	***1.696×10^{-3}***	***1.741×10^{-3}***
Moles of HCl	***1.661×10^{-3}***	***1.696×10^{-3}***	***1.741×10^{-3}***
Molarity of HCl	***0.0664***	***0.0678***	***0.0696***

Table 1 - Titration Data Sheet Results

The key findings in this data sheet are that the molarity of HCl is roughly 0.067mol/L. The pattern observed is that the molarity of the HCL is consistently ±0.002mol/L.

3 Discussion

3.1 Significance of results

The results recorded allow us to accurately calculate the molarity of an unknown substance, which can be used to calculate the number of moles within a substance and understand its composition and purity better.[2]

3.2 Relevance of Titration to OME

Within the OME sector, a type of titration, known as nonaqueous titration, can be used to rapidly analyse and determine the concentrations of organic explosive materials including PETN, TNT, picric acid, HMX, RDX, Tetryl, DNT, EGDN and TNG. [3]

3.3 Limitations and possible sources of error

Limitations of this experiment are that it can only give you a rough idea of the molarity of a substance, as it cannot precisely identify the endpoint. Sources of error could include human errors such as misjudging the colour of the indicator near the end point, misreading the volume due to refraction of light through the meniscus as well as the line of sight in which the meniscus was read, and using potentially contaminated solutions could skew the results [4]. Within this experiment it could also be assumed that the exact volume of HCl within the mixture was not measured as accurately as possible, as a graduated cylinder was used to measure it out, rather than something more accurate. Another source of error was that there were different batches of HCL used between titrations 2 and 3, due to lack of availability of the original batch.

4 Conclusions

4.1 Summary and Evaluation

This experiment identified a rough level of concentration of an unknown substance down to 0.001mol/L. This supports the hypothesis that the concentration of unknown substance would be calculated consistently.

4.2 Directions for Future Research

If this experiment were to be conducted again, a possible improvement could be to include the weight of the substances and measure the change in weight, as that would allow you to more accurately measure the volume of both the unknown and standard solutions. A more accurate way of measuring out the unknown solution would also improve accuracy.

5 References

[1] University of Wales Trinity Saint David. ND. *ACDB 4011: Titration.*

[2] ReAgent Chemical Services. 1999-2025. *What is Titration Used For in Real Life.* Available at: https://www.chemicals.co.uk/blog/what-is-titration-used-for-in-real-life?srsltid=AfmBOopoIg-P5xhZ4tgUjmK6VHNTgAAHWWjCnSh5TBuFoeTDf84Mpbhf. Accessed 20250314.

[3] T.J.Chem. 20220225. *Development and Valisation of a New RP-HPLC Method for Organic Explosive Compounds. Available at:* https://pmc.ncbi.nlm.nih.gov/articles/PMC10503966/#:~:text=The%20rapid%20analytical%20techniques%20such,validation%20parameters%20were%20successfully%20employed. Accessed 20250314.

[4] Chembuddy. 2009-2022. Sources of Errors in Titration. Available at: http://www.titrations.info/titration-errors#:~:text=First%2C%20there%20is%20an%20intrinsic%20error%20of,color%20changes%20of%20indicators%20are%20not%20instant.&text=This%20can%20be%20due%20to%20incorrect%20standardization%2C,bottle%20and%20partially%20evaporated%20and%20so%20on. Accessed 20250314.

6 Appendices

6.1 Appendix 1 – Materials and methods

6.1.1 Materials and equipment

The following equipment and materials were used during this experiment:

Chemicals:

- 100 mL of Standard NaOH solution, M_B = 0.09977 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:

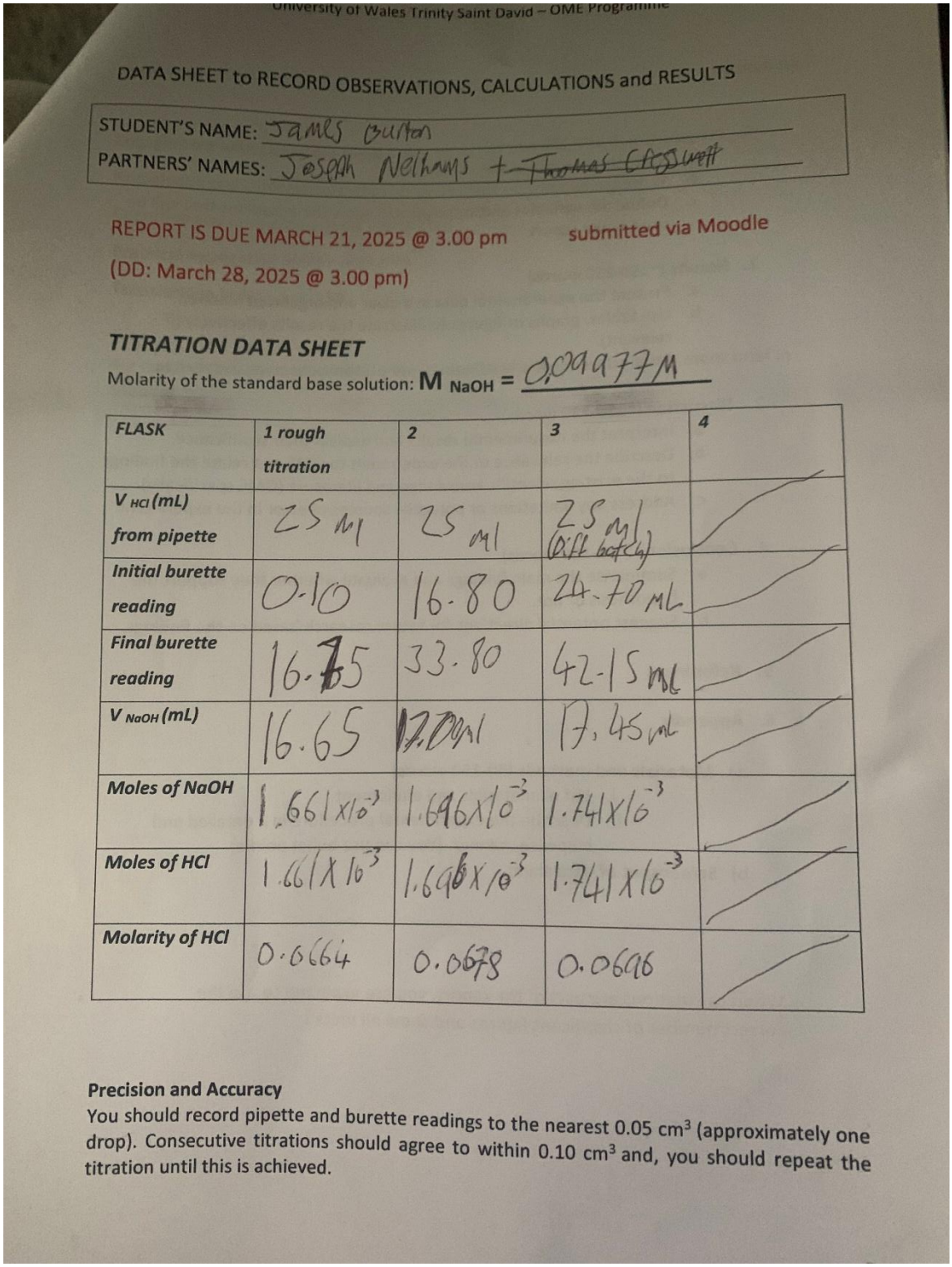
- 1x Burette, 50 mL attached to a burette stand with clamp
- 1x Pipette, 10 mL OR 5 mL, with pipette filler
- 3x Erlenmeyer (conical) flasks, 100 mL capacity
- 1x Small funnel to fill the burette
- 1x Plastic pipette
- 1x Wash bottle with deionised water
- 1x Graduated cylinder, 100 mL
- 1x White tile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

6.1.2 Experimental procedure

1. Equipment washed:
   -
2. Using a small funnel, the burette was filled with standard NaOH solution, running some of the solution through the tap, until the bottom of meniscus was just on the zero level. It was ensured that there were no air bubbles trapped. The initial reading was then recorded.

3. Using the pipette filler, 25 mL of HCl solution was added to the three clean conical flasks.
4. 3-4 drops of phenolphthalein indicator was added to each flask with acid, then swirled gently, with approximately 10 mL of deionised water added using a graduated cylinder.
5. Using the tap of the burette, the NaOH solution was run into the first conical flask, mixing thoroughly, until the solution changed colour to pink. This step was the rough titration and allowed estimation of the volume of NaOH needed to neutralise the measured volume of HCl. The Final reading was recorded.
6. Step 5 was repeated for the next sample of HCl
7. This time:
    - The NaOH was run into the acid /indicator/water mix until the volume of NaOH was within 2 mL of what it was in the rough titration (Step 5)
    - At this point the base was run at a slower rate (dripping it slowly and shaking the solution in the flask) so to read the volume of NaOH required to neutralise the solution to one drop (0.05 mL). A reading within 0.05 mL was taken and then the reading at the first colour change in the solution was also taken.
8. Steps 6 and 7 were repeated for each sample of HCL, with results recorded in the table.

6.2 Screenshot of Data Sheet



University of Wales Trinity Saint David – OME Programme

DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS

STUDENT'S NAME: James Burton

PARTNERS' NAMES: Joseph Nelhams + ~~Thomas Crossnell~~

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** $_{NaOH}$ = 0.09977M

FLASK	*1 rough titration*	*2*	*3*	*4*
V $_{HCl}$ (mL) from pipette	25 ml	25 ml	25 ml (diff bottle)	
Initial burette reading	0.10	16.80	24.70 mL	
Final burette reading	16.75	33.80	42.15 mL	
V $_{NaOH}$ (mL)	16.65	17.00 ml	17.45 ml	
Moles of NaOH	1.661×10^{-3}	1.696×10^{-3}	1.741×10^{-3}	
Moles of HCl	1.661×10^{-3}	1.696×10^{-3}	1.741×10^{-3}	
Molarity of HCl	0.0664	0.0678	0.0696	

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.

Figure 1 - Titration Data Sheet Original

6.3 Photos of Lab Equipment and Setup

Figure 2 - Lab Equipment Setup

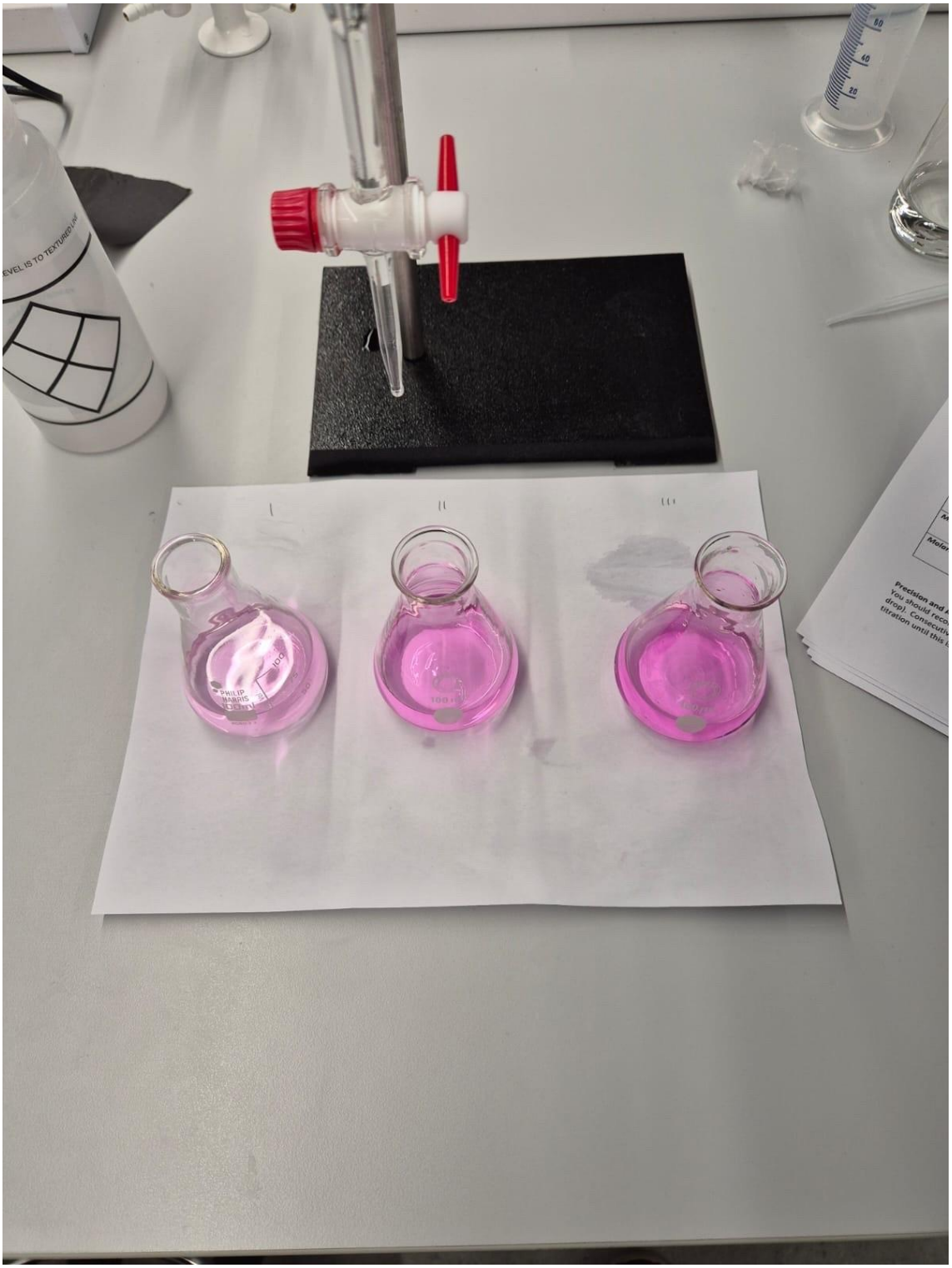


Figure 3 - Resultant Solution Post-Titration