



Ministry
of Defence



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LAB REPORT ON THE TITRATION OF HYDROCHLORIC ACID WITH SODIUM HYDROXIDE

References. See footnotes and embedded documents section at end of document.

Abstract

This report details the process and results from the Titration experiment conducted by the student on 07th February 2023. The experiment was to determine the concentration of hydrochloric acid in an unknown sample provided by the lecturer.

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2. Introduction and Background

The process of titration is used to determine the concentration of an unknown solution. Titration can often also be referred to as Titrimetry and volumetric analysis due to its reliance on volume measurements.

The process of titration involves the use of a titrant, a solution of known concentration often referred to as the standard solution, and an analyte, a solution of unknown concentration. By adding a known volume of titrant to the known volume of analyte until the reaction is complete the unknown concentration of the analyte can be calculated. In the case of this experiment Phenolphthalein was used as a reaction indicator. Other indicators can be used but it is common with an acid-base titration to either use Phenolphthalein or Methyl Orange. Phenolphthalein is an organic indicator that will show pink when the solution is above a pH 8. This means that when a slight pink hue is observed the base has neutralised the acid.

The Chemical equation for this experiment is below.



To calculate the unknown variable in the experiment we can use Equation 2.

$$\text{Equation 2 - } \text{Moles} = \text{Molarity (M)} \times \text{Volume (V)}$$

When the reaction is complete the amount of base added has ideally neutralised the unknown acid. At this point the solution should ideally be pH 7.

Assuming all the acid has been neutralised we can then draw equivalence between the moles of the Acid and Moles of the base, see Equation 3.

$$\text{Equation 3 - } \text{Moles}_{\text{Acid}} = \text{Moles}_{\text{Base}}$$

Substituting in Equation 2.

$$\text{Equation 4 - } M_{\text{Acid}} \times V_{\text{Acid}} = M_{\text{Base}} \times V_{\text{Base}}$$

Rearranged for Molarity (concentration) of the Acid.

$$\text{Equation 5 - } M_{\text{Acid}} = \frac{M_{\text{Base}} \times V_{\text{Base}}}{V_{\text{Acid}}}$$

Titration in OME

There are few recorded examples of titration in OME this is largely due to the inaccuracy and applicability of accurate titrations in explosives. The main area that Titrations are used are to determine chemical synthesis of particular reactions in explosive Research and Development (R&D). This allows a quick and immediate understanding of reaction results and how these might change over time. [1]

Photometric titration can also be used with substances like black powder to sensitivity. This is a complex process that uses ion mobility spectrometry. [2]

3. Materials and Setup

PPE

Safety Goggles
Lab Coat
Nitrile Gloves

Materials

100mL Sodium Hydroxide (NaOH) of a known concentration mol/L
100mL Hydrogen Chloride (HCL) of an unknown concentration
1-2mL Phenolphthalein indicator

Equipment

1x 50mL Burette with Retort stand and clamp
1x Small Funnel
1x 10mL Pipette with filler
1x 250mL Waste Beaker
1x White background for under the titration flask.
3x 250mL Erlenmeyer Flask
1x 1L Commercial Waste container

Set up the equipment as shown in figure x

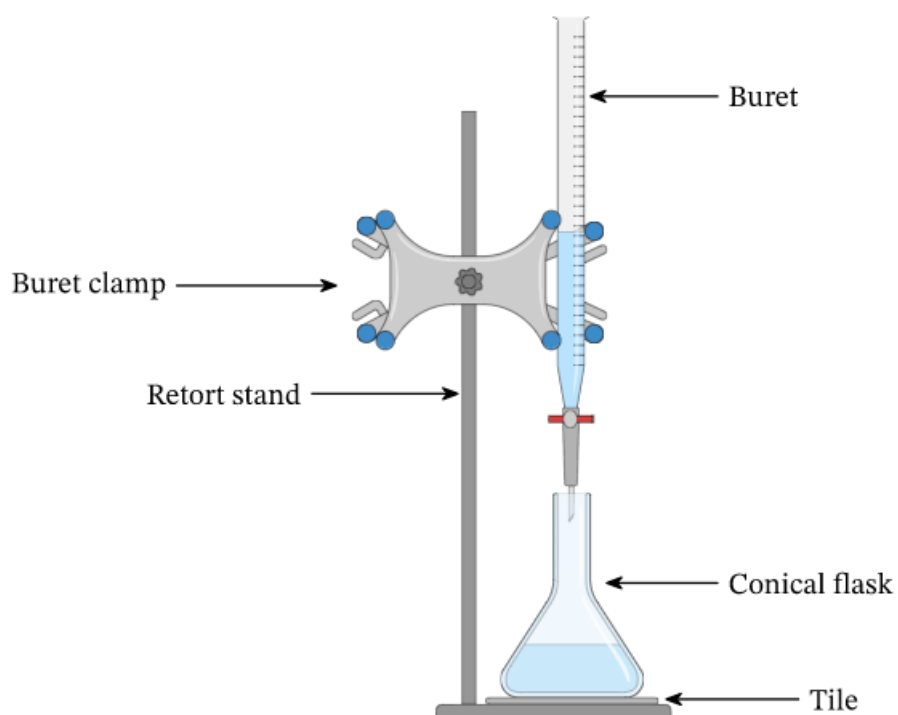


Figure 1 – Setup [3]

5. Procedure

5.1. Washing

Pipette

Washout the pipet with a small amount of HCL and discard into the waste beaker.

Burette

Wash out the burette with a small amount of NaOH and discard in to the waste beaker

Erlenmeyer Flask

Wash out the flask with a small amount of distilled water and discard into the waste beaker. Discard as much of the water as you can but any remnants will not effect the results.

5.2. Preparation

Using a small funnel fill the burette with the standard solution of NaOH. If the measurement is below the 0mL level that this can be your starting measurement. If the burette is overfilled drain the NaOH in to the waste beaker until it is filled to the 0 mL line or lower. Ensure no air bubbles are trapped by gently tapping the burette with a finger.

To prepare the conical flasks for the titration add 25ml of HCL solution to the flasks. This will be done in multiple stages as the maximum volume of the pipet is 10ml. the suggested method for this is 9mL, 9mL, 7mL as this reduces error around the minimum value. To finish preparing each flask add 3-4 drops of phenolphthalein to the flask.

5.3. Rough Titration.

Initially a rough titration will be performed. This will enable a rough value for the next titration to zero in on and refine the result.

To start note an initial reading of the level in the burette to 4 significant figures. With the flask under the burette, add NAOH slowly, whilst swirling, until the solution remains pink for 30 mins. Finally note the reading on the burette. Calculate the difference in the burette readings to get a general value for the titrations.

5.4. Finer Titrations

Using the same method as detailed in the rough titration add NaOH to the flask until you are within 2mL of the previous titration. Reducing the rate of addition to drops or a very slow dribble add NaOH until a light pink remains in the flask for 30s or more. At this stage it is good to ensure that any drops don't run down the inside of the flask and instead fall in to the solution. This will ensure the best result.

Repeat the above steps until two results are achieved within 0.06mL of each other and 3 results are within 0.10mL of each other.

7. Raw Results

The below is a direct copy of the results achieved during the experiment. See Annex 1 for the original.

STUDENT'S NAME: Charles Hadley _____

PARTNERS' NAMES: Sam Hawkins _____

TITRATION DATA SHEET

Molarity of the standard base solution: **M_{NaOH} = 0.1002 mol/L**

Flask	Titration Number			
	1	2	3	4
Volume of HCl (mL)	25	25	25	25
Initial Burette Reading (mL)	0	17	13.40	19.90
Final Burette Reading (mL)	16.90	33.60	30.20	36.80
Calculated Volume of NaOH (mL)	16.90	16.60	16.80	16.90
Moles of NaOH	$= 0.1002 \times 0.001 \times 16.9 = 1.69 \times 10^{-3}$	$= 0.1002 \times 0.001 \times 16.6 = 1.66 \times 10^{-3}$	$= 0.1002 \times 0.001 \times 16.8 = 1.68 \times 10^{-3}$	$= 0.1002 \times 0.001 \times 16.9 = 1.69 \times 10^{-3}$
Moles of HCl	$= 1.69 \times 10^{-3}$	$= 1.66 \times 10^{-3}$	$= 1.68 \times 10^{-3}$	$= 1.69 \times 10^{-3}$
Molarity of HCl (mol/l)	= 0.0677	= 0.0665	= 0.0673	= 0.0677

Colour of the titrations;

Flask	Titration Number			
	1	2	3	4
Colour	Bright Pink	Lightest Pink	Middle Pink	Bright Pink
Example colour				

During titrations 1 and 4 it was observed that a couple of drops of NaOH landed outside the flask and therefore introduced error in to these stages this likely accounts for the bright pink colour.

8. Calculations and Discussions

Calculating the molarity of HCl using Equation 5 the below results are achieved.

Flask	Titration Number			
	1	2	3	4
Molarity of HCl (<i>mol/l</i>)	= 0.0677	= 0.0665	= 0.0673	= 0.0677

Taking a mean average of these results provides an Average molarity = 0.0673 *mol/l*

Error Calculations

During this experiment there are 4 main areas that error is accumulated, 3 of which can be calculated. These are, error in the burette readings, error in the HCL readings, error in missed drops as experienced in titrations 1 and 4 and lastly error in the Phenolphthalein indicator.

Error in the burette readings: As the burette was graduated at 1ml the finest possible reading was 0.5ml. Therefore, the error in each reading is $\pm 0.5\text{ml}$ on both readings. Leading to a $\pm 1\text{ml}$ error overall. Assuming a measured amount of 16.8ml (average) this equates to a $\pm 5.95\%$ error.

Error in the HCL readings: As the pipette was graduated at 0.1ml the finest possible reading was 0.05ml. Therefore, the error in each reading is $\pm 0.05\text{ml}$ on all 6 readings for each 25ml. Leading to a $\pm 0.3\text{ml}$ error overall. Assuming a measured amount of 25ml this equates to a $\pm 1.20\%$ error.

Error in missed drops: When conducting the experiment it was observed that one drop from the burette equalled around 0.5ml of NaOH. For every drop missed or accidentally added this introduced an error of $\pm 0.5\text{ml}$ overall. Assuming a measured amount of 16.8ml (average) this equates to a $\pm 2.97\%$ error where observed.

By adding these percentages together an estimated error can be achieved for these results.

Flask	Titration Number			
	1	2	3	4
Molarity of HCl (<i>mol/l</i>)	= 0.0677	= 0.0665	= 0.0673	= 0.0677
Base Error	$\pm 7.15\%$	$\pm 7.15\%$	$\pm 7.15\%$	$\pm 7.15\%$
Drops Missed	1	0	0	2
Calculated Error	$\pm 10.12\%$	$\pm 7.15\%$	$\pm 7.15\%$	$\pm 13.09\%$

Error in the Phenolphthalein indicator occurs as the transition of the indicator is in the pH range of 8.3-10 this means that when the indicator is a slight pink it is already over the balance and has turned the solution alkaline. This is any the lightest pink possible is aimed for. There is little that can be done to mitigate this apart from using a different indicator which is not always possible.

9. Conclusions

In conclusion the estimated value for the molarity of the HCl solution is

$$HCl = 0.0673 \frac{mol}{l} \pm 9.38\%.$$

This was the first time that either of the participants have conducted a titration experiment and therefore much was learnt about the proper way and best practice for this experiment. During the exercise unnecessary error was introduced that could be mitigated through modified procedures. Due to time constraints the experiment could not be completed more times. This would have enabled reduction in error and implementation of best practice.

10. References

- [1] P. D. Sharma, "Mining and Blasting," [Online]. Available: https://miningandblasting.files.wordpress.com/2009/09/explosives_chemistry.pdf. [Accessed 26 03 2023].
- [2] "Sensitive Detection of Black Powder by a Stand-Alone Ion Mobility Spectrometer with an Embedded Titration Region," *Analytical Chemistry*, vol. 10, no. 85, pp. 4849-4852, 2013.
- [3] Nagwa, "Lesson Explainer: Titration Experiments," Nagwa, [Online]. Available: <https://www.nagwa.com/en/explainers/237120757373/>. [Accessed 13 03 2023].

11. Annex 1

STUDENT'S NAME: Charles HadleyPARTNERS' NAMES: Sam Hawkins**TITRATION DATA SHEET**Molarity of the standard base solution: $M_{\text{NaOH}} = 0.1002 \text{ mol l}^{-1}$

FLASK	1 rough titration	2	3	4
V_{HCl} (mL) from pipette	25 mL	25 mL	25 mL	25 mL
Initial burette reading	0 mL	17 mL	13.40 mL	19.90 mL
Final burette reading	16.90 mL	33.6 mL	30.2 mL	36.8 mL
V_{NaOH} (mL)	16.90 mL	16.60	16.8	16.9
moles of NaOH				
Moles of HCl				
Molarity of HCl				

~ 0.0687 0.0665 ~ 0.0673 0.0677

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.

Don't forget mL to L