

University of Wales Trinity Saint David

Analysing the effectiveness of titration for an unknown solution

Ordinance Munitions and Explosives ACDB4011

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Introduction

Titration is used to measure the concentration of an unknown solution by reacting it with a solution with a known concentration. This process usually involves adding the titrant to the analyte until a base state is reached, normally indicated by a colour change. For example, when no excess titrant is added, an acidic solution may turn from pink to colourless. The chemical used as a titrant for acid is phenolphthalein.

Theory

Titration works by using the pH scale to neutralise an unknown solution, which means bringing an acid up to 7 and an alkaline down to 7. The concentration of the solution can be determined by understanding the equivalence point of the mixture, this is the point where the titrant and the analyte are added in equal proportions to completely neutralise the solution (down to a reading of 7).

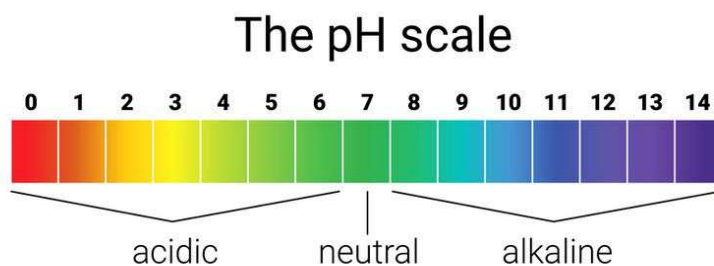


Figure 1 pH Scale [1]

Results

Table 1 Results from experiment

Flask	1 st Titration	2 nd Titration	3 rd Titration	4 th Titration
V _{HCL} (mL) From Pipette	25 mL	25 mL	25 mL	10.0
Initial burette Reading	0.8 mL	0 mL	0 mL	14.00
Final burette Reading	17.95 mL	16.80 mL	14.50 mL	20.50
V _{NaOH} mL	17.15 mL	16.80 mL	14.50 mL	n/a
Moles of NaOH	0.001711 mol	0.001676 mol	0.001446 mol	n/a
Moles of HCl	0.001711 mol	0.001676 mol	0.001446 mol	n/a
Molarity HCl	0.06844 mol/L	0.06704 mol/L	0.05784 mol/L	n/a

Molarity of standard base solution = 0.09977 (4s.f)

The molarity of the solution can be found by using the equation:

$$M = n/v$$

Where M is the molarity, n is the number of moles and v is volume. Substituting in the numbers for NaOH (Sodium Hydroxide) the equations is as follows:

$$0.09977 \times 0.01715 = 0.001711 \text{ mol}$$

The moles of HCl (Hydrochloric acid) will be the same as NaOH as this will be the equivalence point – the point at which the titrant and the analyte are the same and full neutralisation has occurred. Knowing the molarity of NaOH the molarity of HCl can be determined using the inverse of the above:

$$\frac{0.001711}{0.02500} = 0.06844$$

The rest of the results have been filled into the table using the equations as above.

Discussion

The results confirm that titration is an effective method for determining the concentration of unknown solutions, as each batch was fully neutralized without any excess titrant. However, there are limitations in how the results are recorded and interpreted. The volume of titrant added depends on the individual conducting the experiment, introducing variability and ambiguity that could affect the accuracy of the findings. The average molarity of the HCl was 0.06444 which means that the solution was weak as it was below 1M however more tests may be required to determine if the ionisation was stronger or weaker due to the presence of more H^+ ions.

Titration is a commonly used method to determine concentration of an unknown. A use of titration in the defence industry is to measure the nitrogen content in propellants using Iron(II) and Titanium(III). This method has been modified to encapsulate military-type nitrocellulose and smokeless powders. The modification uses an acetic acid – acetic anhydride solvent mixture to prevent premature precipitation of the sample during the reduction step with ferrous chloride solution and in adding the hydrobromic solution separately. [2]

Conclusions

The findings of the experiment supported the authors hypothesis that this type of experiment, given the equipment would not yield perfect results. The author was told that the HCl solution was not concentrated for safety reasons but was asked to behave as if it were completely unknown.

Appendix

The methods and apparatus have been taken from the handout sheet given in the experiment brief.

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
- 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

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.

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.

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

University of South Wales Cardiff - GML Programme

DATA SHEET TO RECORD OBSERVATIONS, CALCULATIONS AND RESULTS

STUDENT'S NAME: James Gwynne

PARTNERS' NAMES: James Gwynne + James Rennie + Alex Hilday

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: $M_{NaOH} = 0.09977 \pm 0.0001$

FLASK	1 rough titration	2	3	4
$V_{HCl}(mL)$ from pipette	25 mL	25 mL	25 mL	25 mL
Initial burette reading	0.00 mL	0.00 mL	0.00 mL	0.00 mL
Final burette reading	17.95 mL	16.80 mL	14.50 mL	10.00 mL
$V_{NaOH}(mL)$	17.95 mL	16.80 mL	14.50 mL	10.00 mL
Moles of NaOH				
Moles of HCl				
Molarity of HCl				

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 2 Titration results and observations

Acknowledgements

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Works Cited

[1] A. stock, Artist, *ph scale*. [Art]. stock.adobe.

[2] J. Grodzinski, "Application of the Iron(II) - Titanium(III) titration procedure to determine of the Nitrogen Content of propellants," Analytical Chemistry , Tel Aviv, 1957.