

Appendix 7: SAMPLE OF A FORMAL LAB REPORT

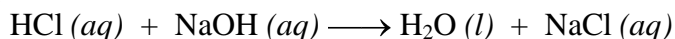
Follow this format meticulously whenever you are asked to turn in a formal lab report.

Chem 124
Section CM1
Spring 2007

Name: John Doe
Name of Partner: Jane Smith
Date of Expt: 2/3/07
Date of Submission: 2/10/07

Experiment #17: DETERMINATION OF THE CONCENTRATION OF AN AQUEOUS SOLUTION OF HCl

Abstract: The purpose of the experiment was to determine the concentration of an aqueous solution of HCl.



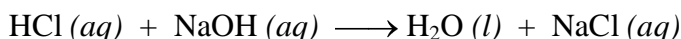
A known volume of HCl solution was pipetted into a flask and a few drops of phenolphthalein were added. To this was added a solution of NaOH of known concentration through a buret until the solution changed to a pale pink. The molarity of the HCl was then calculated based on the volume and molarity of the NaOH solution and volume of HCl solution used in the titration.

Three trials were performed and the average concentration was found to be 0.1475 M with relative standard deviation of 0.1% and an error of -2.9%.

Note to Students: The Cover Page should contain nothing else. Begin a new page for the next section.

Below is a sample of the rest of the Formal Lab Report. It must include the headings as shown (Introduction, Procedure, Data & Observations, Calculation & Results, Summary of Results & Discussion, Error Analysis, Conclusion, Answers to Post-Lab Questions, References).

Introduction: The concentration of an unknown solution of HCl was to be determined. This was done by titrating a sample of the HCl solution against a solution of NaOH of known concentration. The reaction involved is as follows:



Phenolphthalein was used as the indicator, which changes from colorless when acidic to pink when basic. With the HCl solution in the flask with the phenolphthalein, the solution would be colorless initially. When just enough of the NaOH solution has been added to neutralize the HCl solution, the solution would change to a pale pink. This is the endpoint of the titration. It is close to the stoichiometric point, where the number of moles of HCl that were present in the flask is equal to the number of moles of NaOH added. By measuring the volume of the NaOH solution needed to neutralize the HCl solution, and noting the concentration of the NaOH solution, the number of moles of NaOH added to the flask can be calculated. At the end point, this is also the number of moles of HCl, and in conjunction with the volume of HCl solution used, the molarity of the HCl solution can be calculated.

Experimental Procedure: The procedure described in Ref. 1 was followed, with the exception that four trials were performed instead of three. The results of Trial #2 are not included in the calculations because the endpoint was too pink. In addition, a magnetic stirrer was used.

Data & Observations:

HCl Unknown # = 159

Volume of HCl solution used in each titration = 25.00 mL

Concentration of NaOH solution = 0.1000 M

| Trial # | # 1 | # 2 | #3 | #4 |
|-------------------------------|-----------|-------------|-----------|-----------|
| Final Buret Reading of NaOH | 35.38 mL | 36.90 mL | 36.26 mL | 35.81 mL |
| Initial Buret Reading of NaOH | 0.10 mL | 1.12 mL | 1.06 mL | 0.55 mL |
| Volume of NaOH soln used | 35.28 mL | 35.78 mL | 35.20 mL | 35.26 mL |
| Color at endpoint | pale pink | bright pink | pale pink | pale pink |

Trial #2 was obviously past the end point.

Calculations & Results:

(See attached Calculation & Results pages from the lab manual.)

Below are additional calculations not shown on the attached calculation pages.

Standard Deviation in Molarity of HCl

$$\begin{aligned}\sigma &= \sqrt{\frac{\sum_{i=1}^N (x_i - \bar{x})^2}{(N-1)}} = \\ &= \sqrt{\frac{(0.1411 - 0.1410)^2 + (0.1408 - 0.1410)^2 + (0.1410 - 0.1410)^2}{(3-1)}} \\ &= \sqrt{\frac{(0.0001)^2 + (-0.0002)^2 + (0.0000)^2}{2}} \\ &= \sqrt{\frac{1 \times 10^{-8} + 4 \times 10^{-8} + 0}{2}} = \sqrt{\frac{5 \times 10^{-8}}{2}} = 0.0002\end{aligned}$$

$\sigma = 0.0002 \text{ M HCl}$

$$\text{Relative standard deviation} = \frac{0.0002 \text{ M}}{0.1410 \text{ M}} \times 100 = 0.1\%$$

Calculation of Error in Average Molarity:

The correct molarity of the HCl solution = 0.1452 M (Ref. 2)

$$\begin{aligned} \text{error} &= \text{average value} - \text{correct value} \\ &= 0.1410 \text{ M} - 0.1452 \text{ M} = -0.0042 \text{ M} \end{aligned}$$

$$\begin{aligned} \% \text{ error} &= \frac{\text{error}}{\text{correct value}} \times 100 \\ &= \frac{-0.0042 \text{ M}}{0.1452 \text{ M}} \times 100 \\ &= -2.9 \% \text{ error} \end{aligned}$$

Summary of Results and Discussion: Below is a table showing the results from the three trials calculated in the manner shown above.

| Trial # | #1 | #3 | #4 | Average |
|------------------------|----------|----------|----------|-----------|
| Concentration of HCl | 0.1411 M | 0.1408 M | 0.1410 M | 0.1410 M |
| Deviation from Average | 0.0001 M | 0.0002 M | 0.0000 M | 0.0001 M* |

*Average of the deviations of the three trials.

standard deviation = 0.0002 M

relative standard deviation = 0.1%

Trial #2 was discarded because the endpoint was much too pink. In addition, the volume of NaOH solution needed to bring it to the endpoint was much larger than the others. A decision was made to perform a 4th trial in place of Trial #2.

When the result of Trial #2 is discarded, the relative standard deviation is only 0.1%, which shows that the precision is quite good.

The percent error of -2.9% shows that the accuracy is good, but could be improved upon. The negative sign tells us that reported molarity is lower than the correct value. Perhaps the error is due to the pipet used to deliver the HCl solution was not properly calibrated. This would explain why the precision was excellent and yet the accuracy was as good as expected. If the pipet was wet the first time it was used, it would not explain why all the trials gave results that were consistently low.

Error Analysis: One of the likely sources of error in this experiment would be in pipeting exactly 25.00 mL of the unknown HCl solution into each Erlenmeyer flask. It was not easy controlling the level of the HCl solution in the pipet. This source of error can affect the calculated molarity of the HCl both ways. If less than 25.00 mL was actually delivered, it would have taken less NaOH to neutralize the solution, and therefore the calculated molarity of HCl would be too low. If more than 25.00 mL was delivered, then the calculated molarity of HCl would be too high.

A second likely source of error would be the process of reaching the correct endpoint. It was not easy to control how much NaOH solution to add to reach the pale pink endpoint. If the end point is too pink, that would mean too much NaOH was added (as was the case in Trial #2). It would seem that there is more HCl in the flask than is actually there. This would make the molarity of HCl too high.

Another possible error could be the equipment used being contaminated by water, in the equipment used. If the buret holding the NaOH was not rinsed properly with the NaOH solution and it still contained a small amount of water left from the previous user, then the NaOH solution would be diluted, and the molarity of NaOH would be lower than as shown on the label. It would therefore take a larger volume of NaOH solution to reach the endpoint, and it would make the molarity of the HCl appear to be higher than it actually is.

Similarly, if the pipet used to deliver the HCl was contaminated by water left by the previous user, the HCl solution in the pipet would become diluted, and the molarity of the HCl would appear to be lower than it actually is.

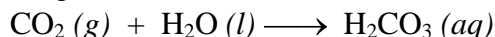
Conclusion: The concentration of Unknown # 159 has been determined to be 0.1411 M HCl, based on three trials, with a relative standard deviation of 0.1% and -2.9% error.

References:

1. CCBC Chem Faculty & Staff *Chem 124 Experiments in General Chemistry II Laboratory*, 2nd Ed.; Academx: Virginia Beach, VA, 2007; pp 235-239.
2. Yau, C. CCBC-Catonsville, personal communication, 2007

Answers to Post-Lab Questions:

1. If the pink endpoint remains after less than 30 seconds of swirling, we would not know whether it is pink because we have truly reached the endpoint, or whether the HCl and NaOH have not fully reacted due to insufficient time allowed.
2. If the pink goes away after having swirled it much longer than 30 seconds, we would not know whether it is because we truly have not reached the endpoint yet, or whether it is due to the CO₂ that has been absorbed from the air. Carbon dioxide when dissolved in water produces a small amount of carbonic acid as shown in the equation below. As an acid it can be competing with the HCl in the reaction with NaOH.



(Remember to attach the Calculations & Results page from the lab manual, and any other appropriate material, such as graphs and chromatograms.)