Acid-Base Titrations

Written by:

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For CHM1311B - Group Z
University of Ottawa

Introduction

Acids and bases are important in everyday life. They have application in food manufacturing and commercial products. As such, an understanding of the dynamics at play within acid/base reactions is important. To utilize acids and bases for everyday application, one must control the pH. To control the pH, the ratio of acid to base to that produces a certain pH must be known. One such method to quantify amounts of acid and base needed is titration. Titration is the process of taking an acid and slowly adding a base to determine the *equivalence point.* The equivalence point is when the all the acid in the solution has been used up to *neutralize* the base. A *neutralization reaction* is one where and acid and base combine to form water and a salt. The general equation of an acid-base reaction is as follows:

$$acid + base \rightarrow water + salt$$

By the *Arrhenius definition,* acids are *proton donors.* They 'give up' their hydrogen ion. The *Brønstead-Lowry definition* of acids and bases states that acids and bases are complementary: acids are proton donors and bases are proton acceptors. The reactions can be defined according to the Arrhenius definition. Since hydrogen has a single positive charge and no electrons, it is referred to as a *proton.* Whenever *proton exchange* is mentioned, it is regarding *hydrogen ion* exchange. HNO_3 dissolves in water to form its component ions:

$$HNO_3 \rightarrow H^{+}(aq) + NO_3^{-}(aq) \quad [1]$$

This can be considered a the general equation for the *dissociation* of acidic ions in water. A base follows a similar pattern, consider the reaction between NaOH and water:

$$NaOH(aq) \rightarrow Na^{+}(aq) + OH^{-}(aq) \qquad [2]$$

The base/acid breaks apart or *ionizes*. Ionization is the process through which a substance breaks down into its component ions. An acid or base is called strong when it ionizes fully. That is, it breaks completely apart into its component ions. However, the *concentration* of an acid/base also influences its strength. Concentration is measured in mols/litre. It is calculated according to the following equation:

$$concentration(mol/L) = \frac{amount\ of\ solute(mol)}{volume\ of\ solvent(L)}$$

A general equation to find the volume, mass, and mols of the acid/base is:

$$c_{base} g V_{base} = \frac{b}{a} c_{acid} g V_{acid} \qquad [7]$$

Where V is volume, b is moles of base, a is moles of acid, and c is concentration.

When performing a titration, the *end-point* and *equivalence point* must be close. The end-point in a titration is when the *indicator* changes color[1]. An indicator is a weak acid that will produces a color when it dissociates in a certain pH. The endpoint must be close to the equivalence point to know how much base is needed to neutralize the acid.

Prediction

It will take more base to neutralize the diprotic acid than to neutralize the monoprotic acid.

Procedure:

(2018) "Oh How Bitter A Thing It Is…" Acid Base Titrations. *Lab Manual.* Experiment 4, all pages.

Sources of Error

When performing the experiment, one such source was measurement. The human eye is not equipped to make precise conclusions. The volumes of water used to dilute the base and acids is an approximation, as such, the calculated concentration of acid and base are not highly accurate. Also, the drop counter stopped working and recalibration of the drop counter was required. As such, the second half of the experiment used a drop calibration of

Data

Preparing a solution of NaOH by dilution

Substance	Volume (ml)
NaOH	4.8

[1] Gillespie, Claire. "Definition of Endpoint Titration."

Water	250
Diluted NaOH	4.8 + 250 = 254.8 255.

Calibrating the drop counter

Calibration	Volume (ml)	Drops	Volume per drops
1	5.0-3.0 = 2.0	38	0.053ml/drop
2	8.4-6.7 = 1.7	33	0.052ml/drop

Standardizing the diluted NaOH

Run	Substance	Concentration (M)	Volume (ml)	Volume of water used to dilute the solution (ml)
1	HCl	0.100	10.00	100.0
2	HCl	0.100	10.00	100.0
3	HCl	0.100	10.00	100.0
1	Unknown acid	Unknown	10.00	110.0
2	Unknown acid	Unknown	10.00	110.0
3	Unknown acid	Unknown	10.00	110.0

Volume of NaOH in plastic burette:

The molar concentration of NaOH is 6.0 M

Run 1: titrating HCl	1	2	3
Volume (ml)	41.00	41.00	40.00

Run 2: titrating unknown acid	1	2	3

Volume (ml)	40.00	40.00	40.00

Qualitative data:

Substance	Observations
NaOH	• Clear • Colorless • Odorless
HCl	• Clear • Colorless • Odorless
Unknown acid	• Clear • Colorless • Odorless

Graphs

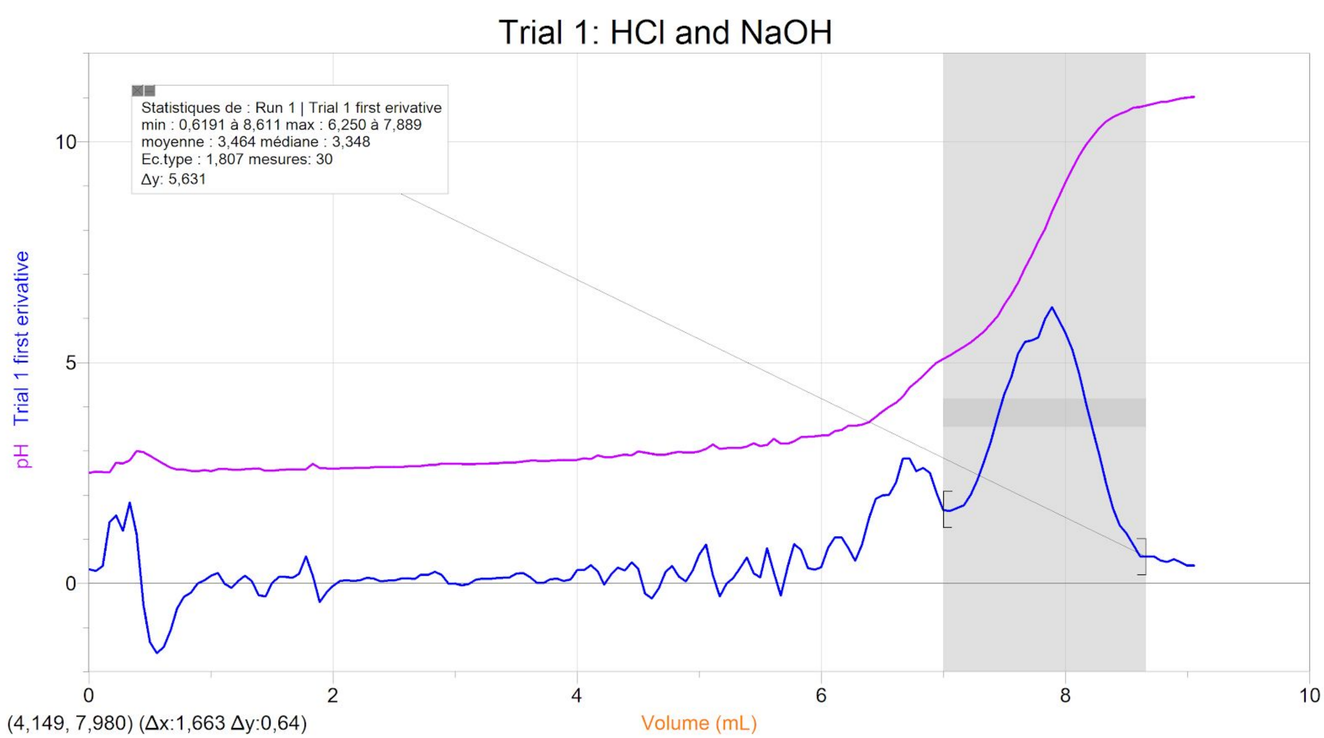


Figure 1.1

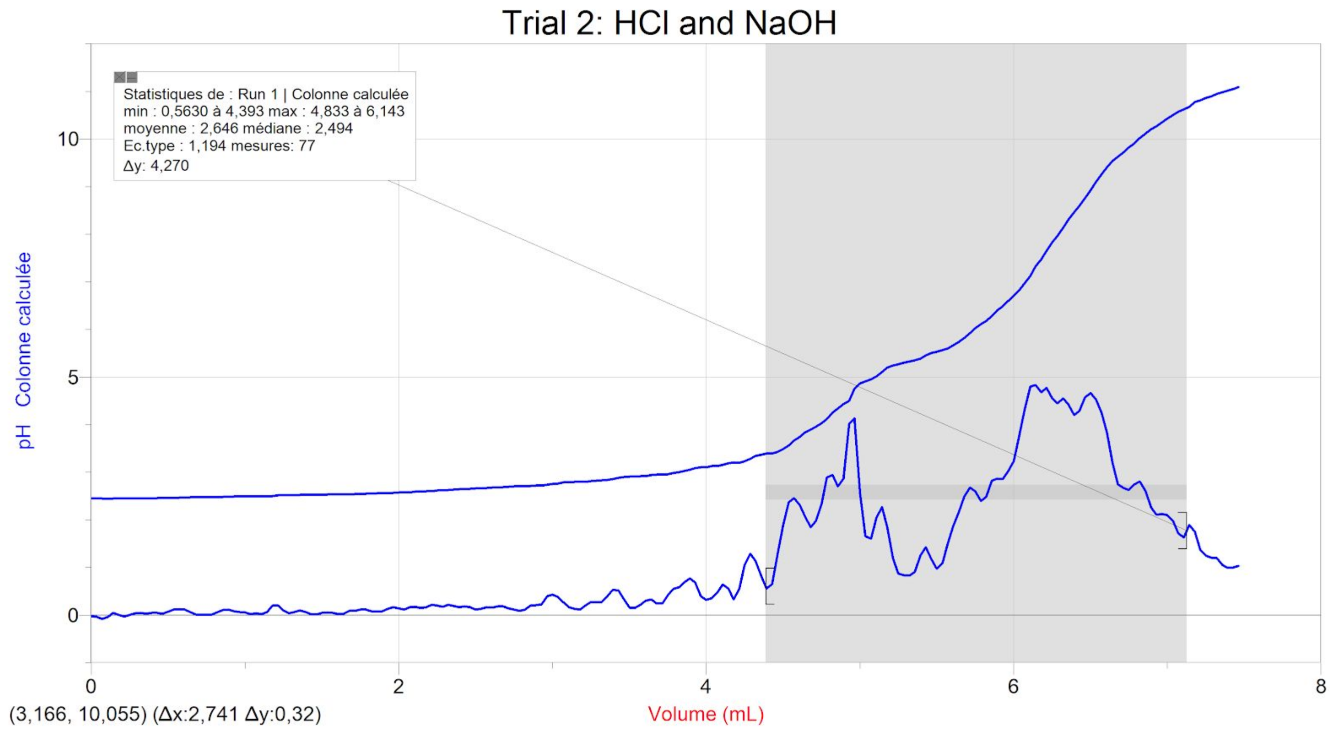


Figure 1.2

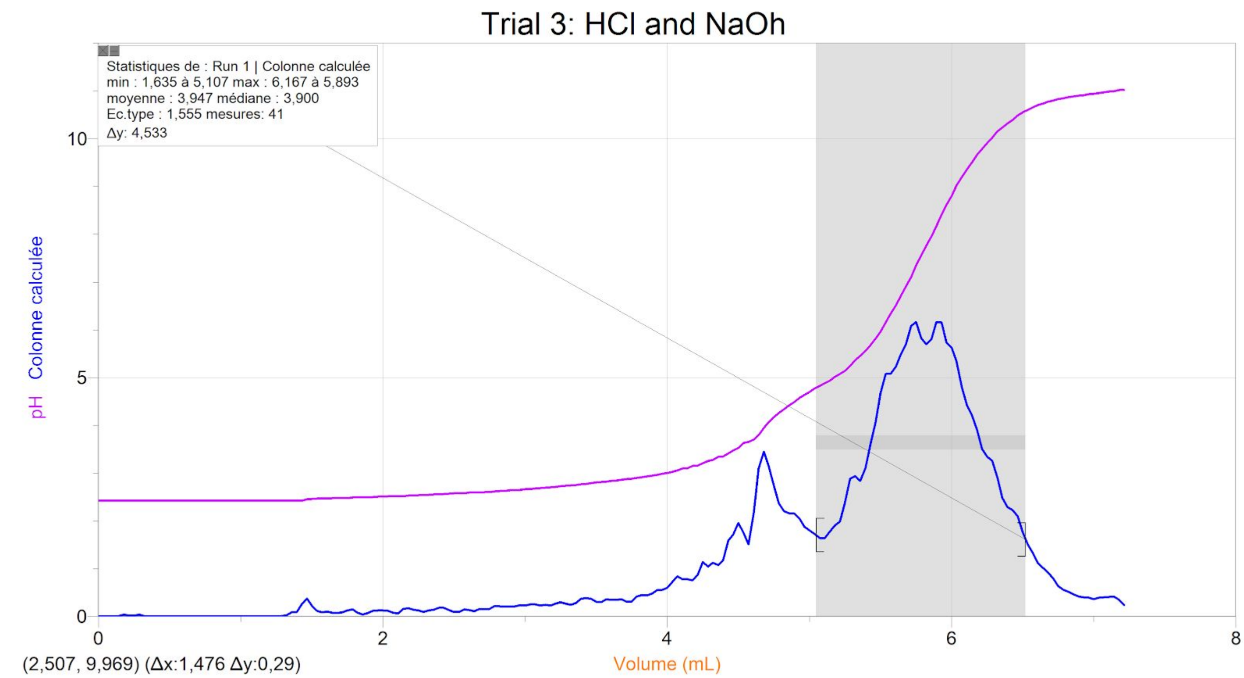


Figure 1.3

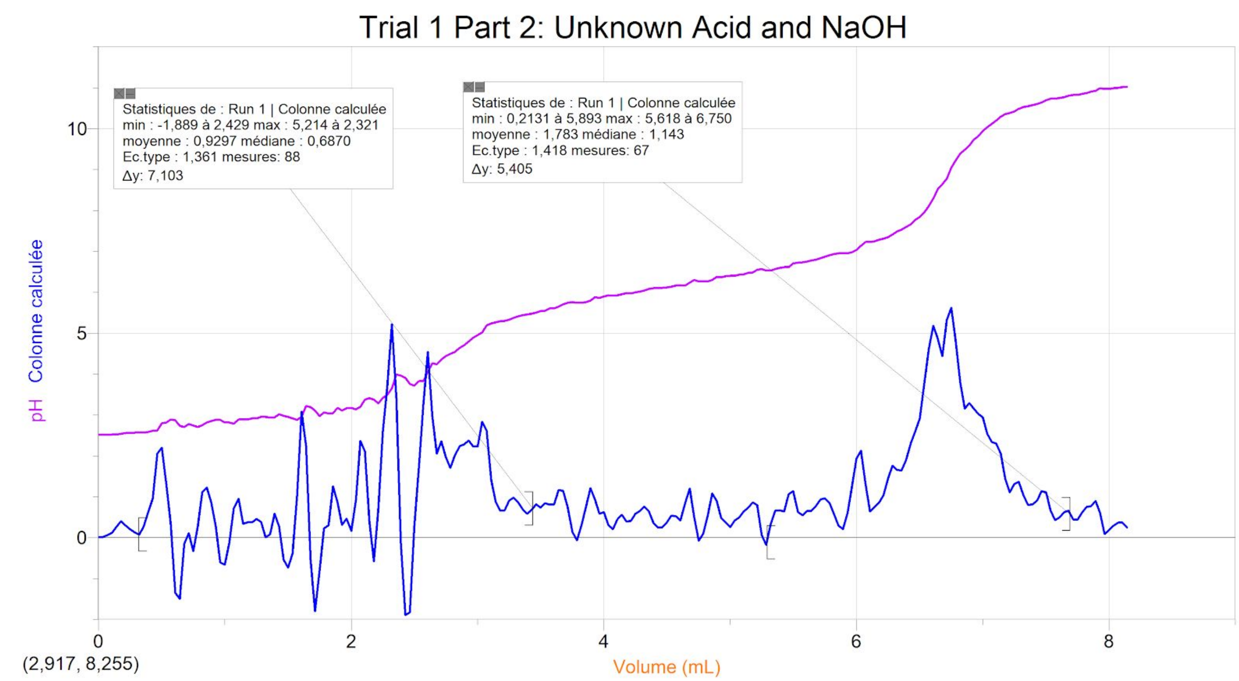


Figure 2.1

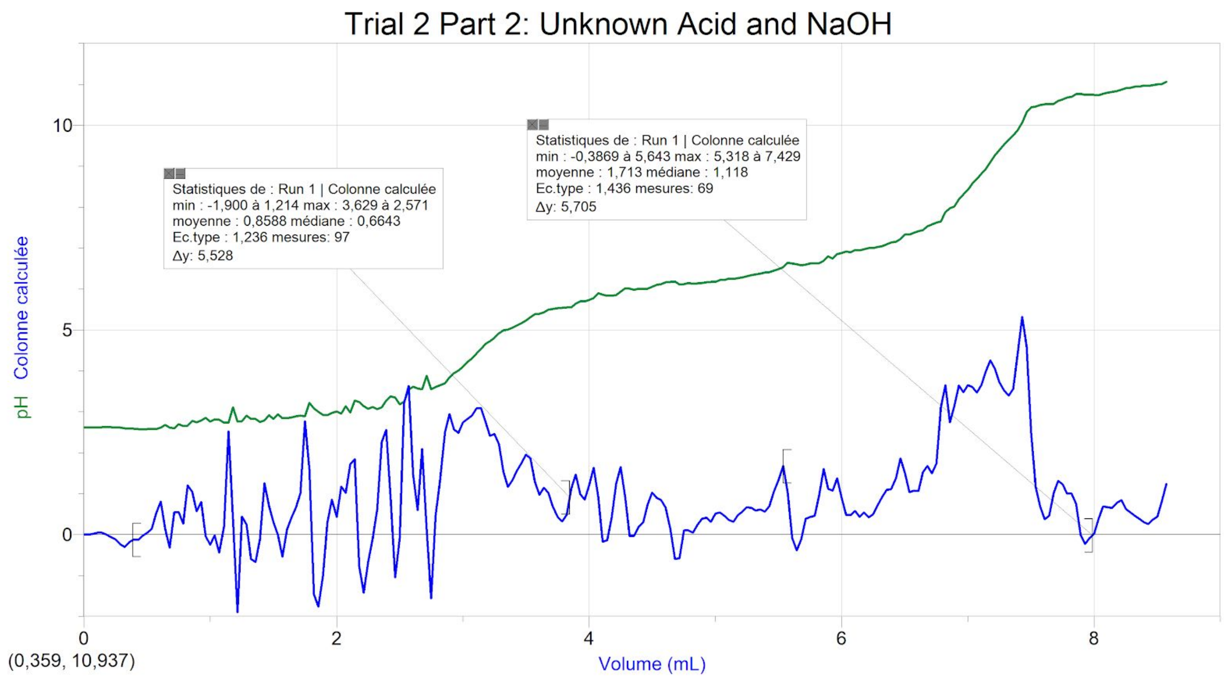

Trial 2 Part 2: Unknown Acid and NaOH
Statistiques de : Run 1 | Colonne calculée
min : -1,900 à 1,214 max : 3,629 à 2,571
moyenne : 0,8588 médiane : 0,6643
Ec.type : 1,236 mesures: 97
Δy: 5,528
Statistiques de : Run 1 | Colonne calculée
min : -0,3869 à 5,643 max : 5,318 à 7,429
moyenne : 1,713 médiane : 1,118
Ec.type : 1,436 mesures: 69
Δy: 5,705
pH Colonne calculée
Volume (mL)
(0,359, 10,937)

Figure 2.2

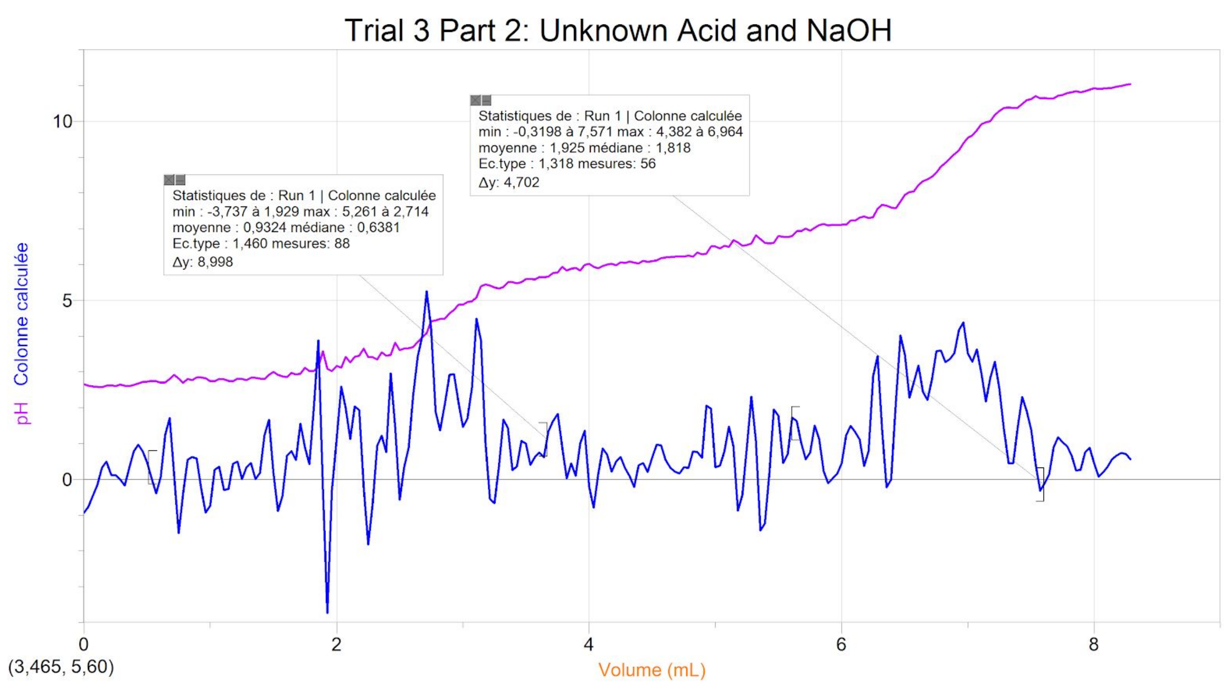

Trial 3 Part 2: Unknown Acid and NaOH
Statistiques de : Run 1 | Colonne calculée
min : -3,737 à 1,929 max : 5,261 à 2,714
moyenne : 0,9324 médiane : 0,6381
Ec.type : 1,460 mesures: 88
Δy: 8,998
Statistiques de : Run 1 | Colonne calculée
min : -0,3198 à 7,571 max : 4,382 à 6,964
moyenne : 1,925 médiane : 1,818
Ec.type : 1,318 mesures: 56
Δy: 4,702
pH Colonne calculée
Volume (mL)
(3,465, 5,60)

Figure 2.3

Calculations

1. $c_1 v_1 = c_2 v_2 \rightarrow 6.0M(4.8ml) = c_2(250ml) \rightarrow c_2 = 1.2 \times 10^{-1} M\ NaOH$

2. $c_{base} g V_{base} = \frac{b}{a} c_{acid} g V_{acid}$

   $c_{base} = 1.2 \times 10^{-1}, V_{base} =$

   a. Trial 1: $c_1 v_1 = c_2 v_2 \rightarrow c_1 7.889 = 10.00ml \circ 0.100M \rightarrow c_1 = 1.27 \times 10^{-1} M$

   b. Trial 2: $c_1 v_1 = c_2 v_2 \rightarrow c_1 6.143ml = 10.00ml \circ 0.100M \rightarrow c_1 = 1.63 \times 10^{-1} M$

   c. Trial 3: $c_1 v_1 = c_2 v_2 \rightarrow c_1 5.893ml = 10.00ml \circ 0.100M \rightarrow c_1 = 1.70 \times 10^{-1} M$

Average concentration of NaOH: $\frac{1.27\times10^{-1}+1.63\times10^{-1} 1.70\times10^{-1}}{3} = 1.53 \times 10^{-1} M$

3. $H_2A\ (aq) + 2NaOH\ (aq) \rightarrow 2H_2O\ (l)\ + 2NaA\ (aq)$

   $c_{base} g V_{base} = \frac{b}{a} c_{acid} g V_{acid}$

   a. $1.53 \times 10^{-1} M \circ 6.750ml = \frac{2}{1} c_{acid} 10.00ml \rightarrow 5.16 \times 10^{-2} M$

   b. $1.53 \times 10^{-1} M \circ 7.429ml = \frac{2}{1} c_{acid} 10.00ml \rightarrow 5.68 \times 10^{-2} M$

   c. $1.53 \times 10^{-1} M \circ 6.964ml = \frac{2}{1} c_{acid} 10.00ml \rightarrow 5.33 \times 10^{-2} M$

Average concentration of unknown acid: $\frac{5.16\times10^{-2}+5.68\times10^{-2} 5.33\times10^{-2}}{3} = 5.39 \times 10^{-1} M$

Discussion

The goal of the experiment was to:

A. Determine the concentration of HCl and unknown acid that was neutralized by the NaOH.

B. The volume at which the equivalence point was reached during the titration of HCl and the unknown diprotic acid.

To determine the concentration of HCl, the initial and final volume and the initial molar concentration were used to find the final molar concentration. The calculations show that as the final volume increased, the molar concentration decreased. The concentration of the unknown diprotic acid was determined by using a stoichiometric ratio of mols of base to mols of acid. The concentration, and volume of NaOH and the volume of diprotic acid were used to find the concentration of the diprotic acid. Initial, the expected

In acid-base titrations, the endpoint is reached faster with a monoprotic acid as opposed to a diprotic acid. This is based on the *Arrhenius definition* of acids and bases which stipulates that acids are proton donors. In a monoprotic acid, one proton is donated. Thus, protons are used up faster in monoprotic acid and base titration. This means that less base was used to reach the equivalence point. When performing the experiment, the equivalence point was reached when the solution turned dark pink due to the indicator.

More base was needed to reach the equivalence point of the unknown acid because the acid was diprotic. The titration of a diprotic acid undergoes two stages. The first is when the acid donates its first proton which neutralizes the base. As more base is added, the acid gives up its second proton. Thus, it took more base to reach the equivalence point of the diprotic acid. Loggerpro© was used to determine the volume of NaOH used to neutralize each acid. As expected, the average concentration of base used to neutralize the HCl was less than the average concentration of base used to neutralize the diprotic acid.

Acid	HCl	Unknown diprotic acid
Average amount of base used to reach equivalence point.	$\frac{7.889+6.143+5.893}{3} = 6.642ml$	$\frac{6.750+7.429+6.964}{3} = 7.048ml$

Conclusion

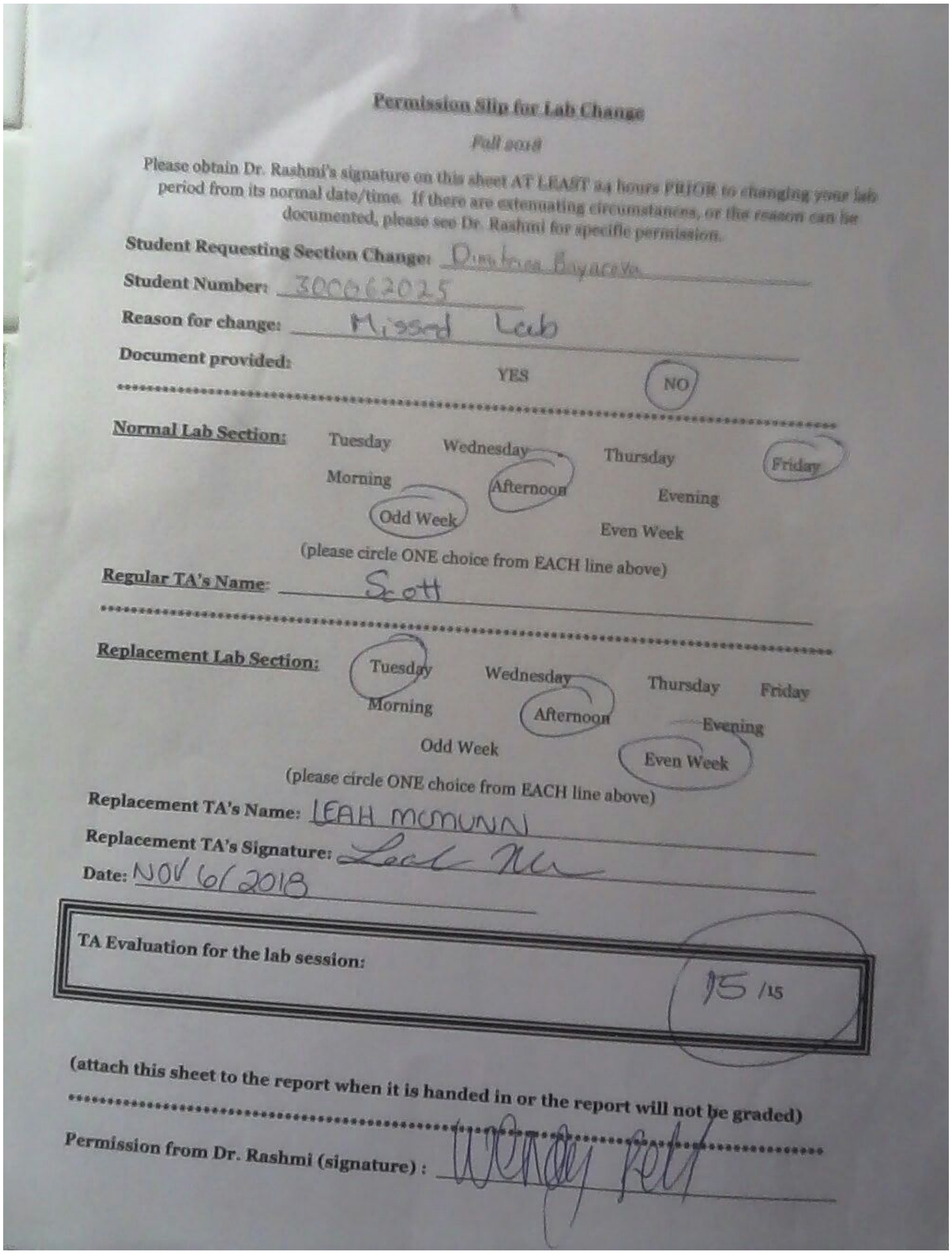
The data show that when titrating a diprotic acid, it takes more base to reach the equivalence point. This is based on the theory of acids that states that acids are a proton donor. Therefore diprotic acids have more protons to donate thus need more base to neutralize all the extra protons.

References

- Gillespie, Claire. "Definition of Endpoint Titration." *Sciencing*, 15 May 2018, sciencing.com/definition-endpoint-titration-5172167.html.
- Freiser, H. (1963). *Ionic Equilibria in Analytical Chemistry*. Kreiger. ISBN 0-88275-955-8.

Lab Quest Data

See Additional Attached Documents



Permission Slip for Lab Change

Fall 2018

Please obtain Dr. Rashmi's signature on this sheet AT LEAST 24 hours PRIOR to changing your lab period from its normal date/time. If there are extenuating circumstances, or the reason can be documented, please see Dr. Rashmi for specific permission.

Student Requesting Section Change: Dimitrova Bayarova

Student Number: 300062025

Reason for change: Missed Lab

Document provided: YES NO

****

Normal Lab Section: Tuesday Wednesday Thursday Friday

Morning Afternoon Evening

Odd Week Even Week

(please circle ONE choice from EACH line above)

Regular TA's Name: Scott

****

Replacement Lab Section: Tuesday Wednesday Thursday Friday

Morning Afternoon Evening

Odd Week Even Week

(please circle ONE choice from EACH line above)

Replacement TA's Name: LEAH MCMUNN

Replacement TA's Signature: [signature]

Date: NOV 6/2018

TA Evaluation for the lab session: 15 /15

(attach this sheet to the report when it is handed in or the report will not be graded)

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Permission from Dr. Rashmi (signature) : [signature]

[illegible]9-356-3480
[illegible] Eastham

* [illegible] #2

Preparing Solution of NaOH

Step: 3. 250 mls 10. [illegible] ml
2. 4.8

Initial pH: 12.93

refilled plastic burret to 41 mls

filled plastic beaker with 3 mls
5 mls final volume in graduated cylinder
38 drops

Recalibration · 8 mls initially
6.2
7

25 mls HCl, .1 M

Initial burret reading: 3 ml

[illegible] burret reading: 13

13 - 3 = 10 ml

3 drops indicator
100 mls water added to reach
light pink pH
~~darker~~ pink
final pink at pH 8

Trial 2: 40 mls initially
glass burret: 13 mls initially 23 mls final, 10 mls
100 mls water

1. 321 ml (38 drops)
2nd try = 0.[illegible] ml (38 drops)

6.0 M NaOH

Step 24: filled it to 41 mls
Initial pH: 2.91

* Recalibration for trial 2

[illegible] mls initially
initial 0.1 final
initial [illegible] 4 mls
33 drops 1.[illegible] is 33 drops

Trial 3

Diprotic acid:
Trial 1: 6 ml in glass burret
11 final
Trial 2: initial glass 11 mls
final: 21 mls

Trial 3 glass start @ 1, end @ 11