The Acid-base Titrations in Measuring the Equivalence Point and End Point of a Chemical Reaction using Phenolphthalein Indicator

Student Name:

Student Number:

Partner's Name and Student #:

Demonstrator's Name:

Lab Day (circle): *Tues aft* *Tues night* *Wed* *Thurs aft* *Thurs* *night* *Fri*

Lab Week (circle): *1* *2*

University of Ottawa
October 20, 2016

Introduction

Acids and bases are not only encountered for laboratory purposes, but are things that we encounter in our everyday lives. From the foods that we eat, such as citric acid, an acid that is present in citrus fruits such as berries, pineapples, tomatoes etc., to the grapes being fermented into ethanol to make wine, acids and bases define the way that we taste our foods. Although both strong acids and strong bases are corrosive, there are many other properties to distinguish them from one another. The Arrhenius definition of an acid is defined as that an 'acid behaves as a proton donor when dissolved in water', so an acid would donate a H+ proton, creating a conjugate base. For example, in the reaction of hydrochloric acid with water is

$$HCl(aq) + H_2O \longrightarrow H_3O^+ + Cl^-$$

In this reaction, HCl donates a proton to water, creating an hydronium ion, H3O+, and Cl-, making hydrochloric acid the acid in this reaction, since it donates a proton to water, and water the base in the reaction, since it accepts the proton. Hydrochloric acid is also going to be one of the acids being used in the following lab. Arrhenius also came up with a definition of a base, where a base would be any substance or compound that donates a hydroxide ion, however the definition was limited when some substances that acted as bases did not donate hydroxide ions. The most present definition that currently accounts for the behaviour of both acids and bases is the Lewis definition of acids and bases whereas acids are defined as electron pair acceptors and bases are defined as acid pair donors. This way, the behaviour of all acids and bases are accounted for despite whether or not they contain H+ protons or OH- ions, since each acid or base in a reaction will have its conjugate acid-base pair. Despite the different theories of the behaviours of acids and bases, for the purpose of this lab, Arrhenius' theory is sufficient since the acid in the experiment is HCl, which contains H+ protons and NaOH, which contains OH- hydroxide ions.

Why study acids and bases in a given chemical reaction? The purpose of this lab is to study acid-base titrations by determining the amount of acid present in an unknown sample, by adding a sample of a base solution, and when the reaction reaches the equivalence point, the unknown amount of acid is determined until exactly enough base solution is added to titrate the amount of acid in the solution. This can be observed visually, by adding an indicator solution, whose colour will change based on the number of hydronium ions present in the reaction. When the titration is complete and all of the hydroxide ions have reacted with all of the protons in the solution, and if the reaction reaches the stoichiometric point of the indicator, the colour of the acid-base solution will change colour. After recording the volume of base added to the solution until the solution changed colour, the exact amount of acid can be calculated.

Procedure

As described in the lab manual provided by the teacher (Ref).

Data and Observations/Results:

Data Tables

Table 1. Formation of a stock solution of NaOH

Volume of concentrated NaOH solution (mL)	4.20 mL
Concentration of concentrated NaOH solution (M)	6.00 mol/L
Volume of stock solution after dilution (mL)	246 mL
Approximate concentration of stock solution (M)	0.102 M

Table 2. Standardization of Stock Solution of NaOH

Data	Trial 1	Trial 2	Trial 3
Concentration of Standard Acid solution (M)	0.100 mol/L	0.100 mol/L	–
Volume of Standard Acid solution (mL)	25.0 mL	25.0 mL	–
Volume of stock solution of NaOH (mL)	23.6 mL	22.2 mL	–
Concentration of stock solution of NaOH (M)	0.0500 mol/L	0.0507 mol/L	–

Average Concentration of stock solution of NaOH (M)	0.0503 mol/L

Table 3. Determination of the Concentration of an Unknown Acid

Data	Trial 1	Trial 2	Trial 3
Sample Number of Unknown Acid	2	2	–
Volume of Unknown Acid solution (mL)	11.9 mL	10.0 mL	–
Volume of stock solution of NaOH (mL)	9.83 mL	7.96 mL	–
Concentration of stock solution of NaOH (M)	2.07 x 10^-2 M	2.00 x 10^-2 M	–
Concentration of Unknown Acid Solution (M)	5.01 x 10^-2 M	5.02 x 10^-2 M	–
Average Concentration of Unknown Acid solution (M)	1.25 x 10^-3 M		

Table 4. Determination of the Mass Percentage of Acid in a Juice

Data	Trial 1	Trial 2	Trial 3
Sample Number of Juice	1	1	–
Volume of Juice (mL)	13.1 mL	11.0 mL	–

Volume of stock solution of NaOH (mL)	17.3 mL	16.7 mL	–
Concentration of stock solution of NaOH (M)	7.54 x 10^-2 M	7.52 x 10^-2 M	–
Concentration of acid in Juice (M)	3.32 x 10^-2 M	3.81 x 10^-2 M	–
Average Concentration of Acid in Juice (M)		3.56 x 10^-2 M	
Density of Juice (g/mL)		1.0003 g/m^3	
Molar Mass of acid in Juice (g/mol)		192.1 g/mol	
Mass Percent of Acid in Juice (%)		0.683%	

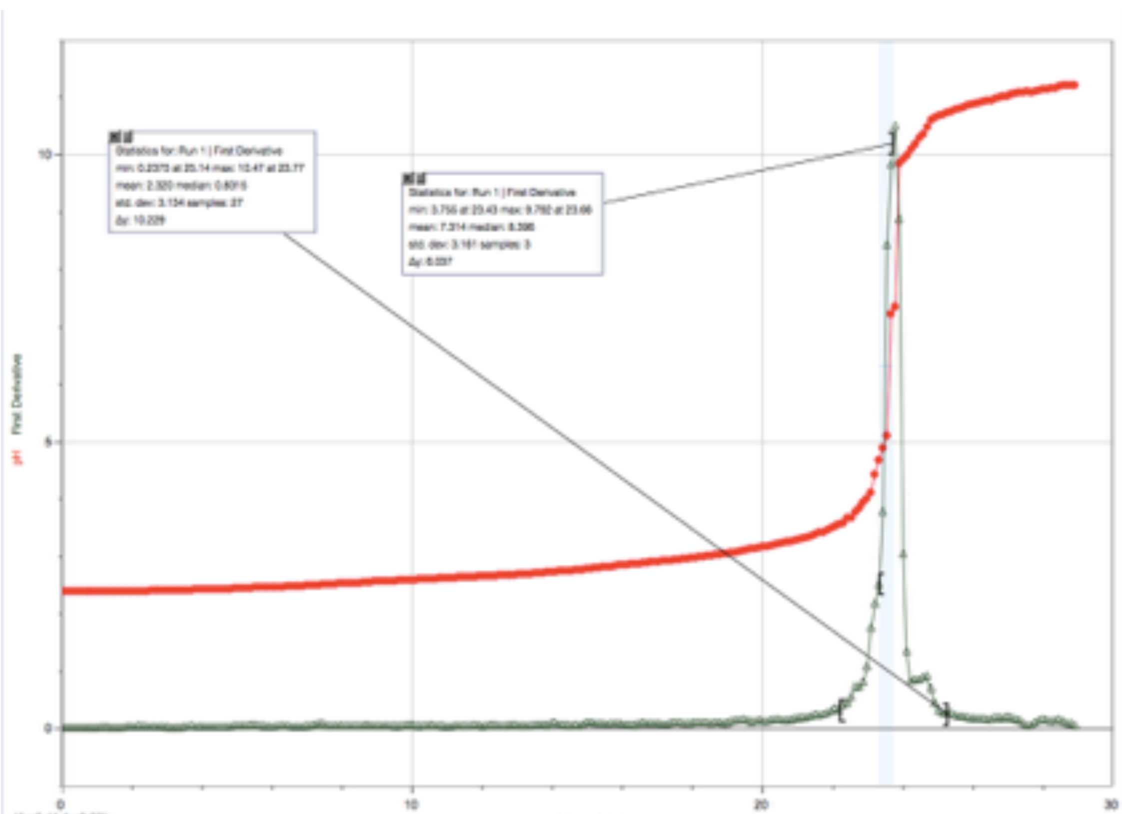
Additional Observations:

- The colour of the solution when it reached the equivalence point of the reaction was a light, faint pink.
- The magnetic spinner was spinning fast and in order simultaneously in order for the solution to mix, as the base was being dropped into the solution
- The two trials for the unknown concentration of acid was completed in a much shorter period of time for the reaction to reach its equivalence point in comparison to the monoprotic and tripotic acid trials
- The solution turned a darker pink after more NaOH was added to the solution in order to increase the pH.

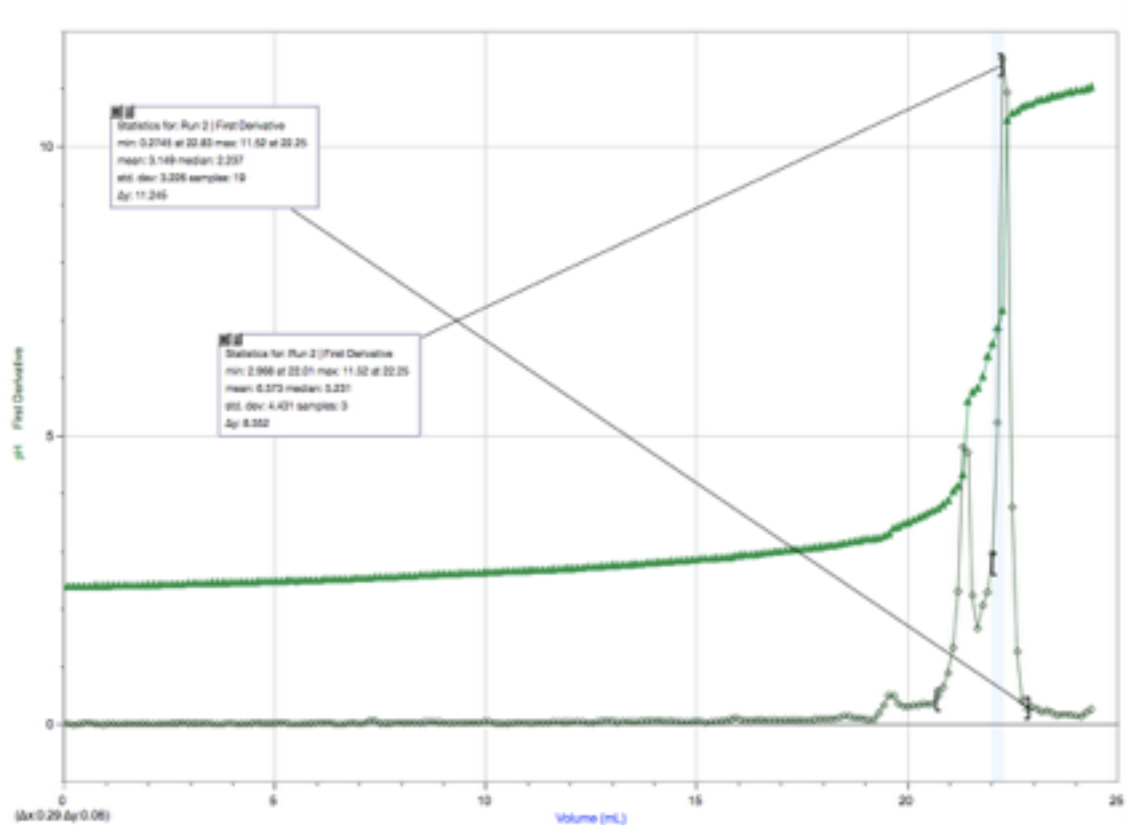
GRAPHS: Attach Logger Pro data tables AND graphs

	Run 1		Run 2		Run 3		Run 4		Run 5		Run 6	
	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH
1	0.000	2.40	0.000	2.36	0.000	2.77	0.000	2.97	0.000	3.26	0.000	3.31
2	0.114	2.40	0.117	2.37	0.117	2.78	0.117	2.96	0.117	3.25	0.117	3.30
3	0.229	2.40	0.234	2.37	0.234	2.77	0.234	2.96	0.234	3.25	0.234	3.31
4	0.343	2.40	0.351	2.36	0.351	2.76	0.351	2.95	0.351	3.24	0.351	3.30
5	0.457	2.40	0.468	2.37	0.468	2.77	0.468	2.90	0.468	3.24	0.468	3.31
6	0.571	2.40	0.585	2.37	0.585	2.76	0.585	2.90	0.585	3.24	0.585	3.32
7	0.686	2.40	0.703	2.37	0.703	2.77	0.703	2.90	0.703	3.25	0.703	3.32
8	0.800	2.40	0.820	2.37	0.820	2.77	0.820	2.90	0.820	3.28	0.820	3.34
9	0.914	2.40	0.937	2.37	0.937	2.77	0.937	2.90	0.937	3.27	0.937	3.34
10	1.029	2.39	1.054	2.37	1.054	2.78	1.054	2.90	1.054	3.26	1.054	3.34
11	1.143	2.40	1.171	2.38	1.171	2.78	1.171	2.91	1.171	3.27	1.171	3.35
12	1.257	2.40	1.288	2.38	1.288	2.79	1.288	2.92	1.288	3.30	1.288	3.36
13	1.371	2.40	1.405	2.38	1.405	2.79	1.405	2.91	1.405	3.30	1.405	3.37
14	1.486	2.40	1.522	2.38	1.522	2.80	1.522	2.93	1.522	3.30	1.522	3.38
15	1.600	2.40	1.639	2.38	1.639	2.80	1.639	2.95	1.639	3.30	1.639	3.40
16	1.714	2.39	1.756	2.39	1.756	2.80	1.756	2.94	1.756	3.32	1.756	3.39
17	1.829	2.40	1.874	2.39	1.874	2.81	1.874	2.94	1.874	3.32	1.874	3.41
18	1.943	2.40	1.991	2.39	1.991	2.81	1.991	2.95	1.991	3.34	1.991	3.42
19	2.057	2.40	2.108	2.39	2.108	2.82	2.108	2.95	2.108	3.37	2.108	3.43
20	2.171	2.40	2.225	2.39	2.225	2.83	2.225	2.96	2.225	3.42	2.225	3.45
21	2.286	2.41	2.342	2.40	2.342	2.83	2.342	2.97	2.342	3.45	2.342	3.47
22	2.400	2.41	2.459	2.40	2.459	2.84	2.459	2.97	2.459	3.54	2.459	3.47
23	2.514	2.41	2.576	2.40	2.576	2.84	2.576	2.98	2.576	3.53	2.576	3.48
24	2.629	2.41	2.693	2.40	2.693	2.85	2.693	2.98	2.693	3.53	2.693	3.51
25	2.743	2.41	2.810	2.41	2.810	2.85	2.810	2.99	2.810	3.57	2.810	3.51
26	2.857	2.42	2.927	2.41	2.927	2.86	2.927	3.00	2.927	3.57	2.927	3.53
27	2.971	2.42	3.044	2.41	3.044	2.87	3.044	3.01	3.044	3.58	3.044	3.56
28	3.086	2.42	3.162	2.42	3.162	2.87	3.162	3.02	3.162	3.60	3.162	3.59
29	3.200	2.42	3.279	2.42	3.279	2.88	3.279	3.03	3.279	3.77	3.279	3.59
30	3.314	2.42	3.396	2.42	3.396	2.89	3.396	3.04	3.396	3.74	3.396	3.61
31	3.429	2.42	3.513	2.43	3.513	2.89	3.513	3.05	3.513	3.69	3.513	3.62
32	3.543	2.42	3.630	2.43	3.630	2.90	3.630	3.06	3.630	3.71	3.630	3.65
33	3.657	2.42	3.747	2.43	3.747	2.91	3.747	3.07	3.747	3.68	3.747	3.66
34	3.771	2.43	3.864	2.43	3.864	2.91	3.864	3.08	3.864	3.72	3.864	3.67
35	3.886	2.43	3.981	2.44	3.981	2.93	3.981	3.09	3.981	3.83	3.981	3.68

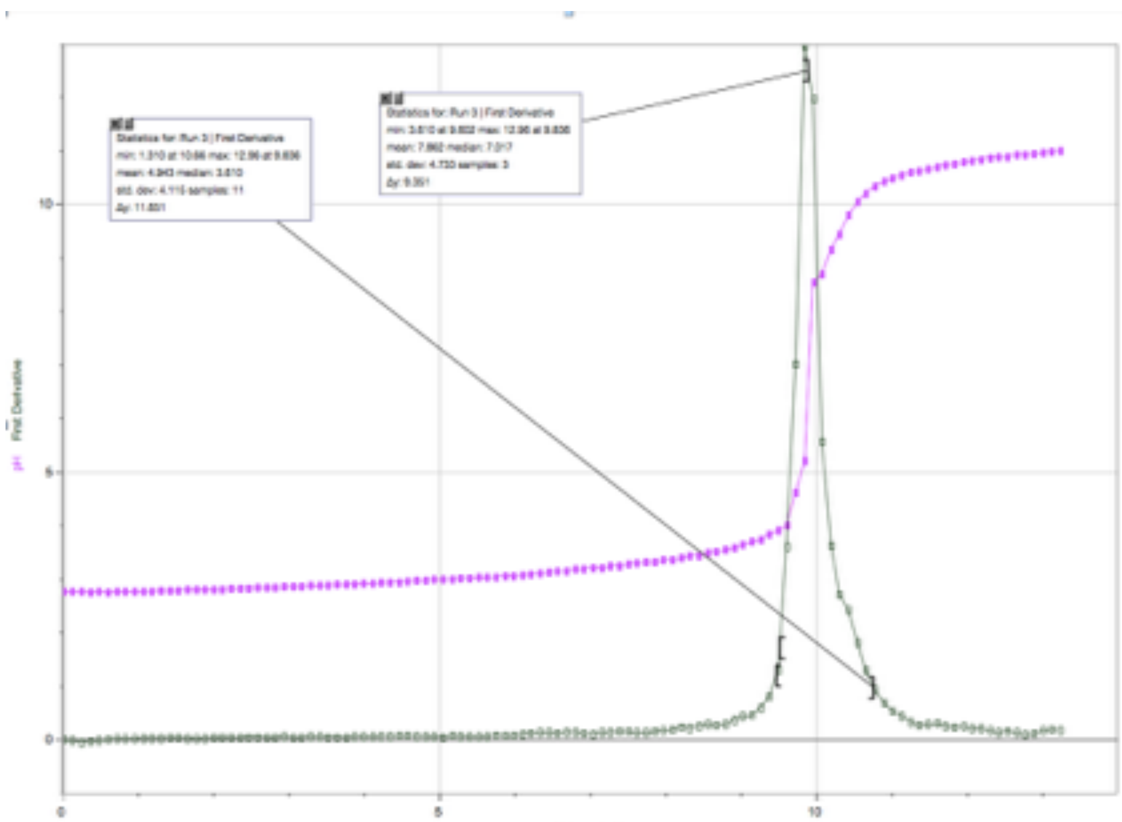
Graph 1. Standardization of Stock Solution of NaOH (Run 1)



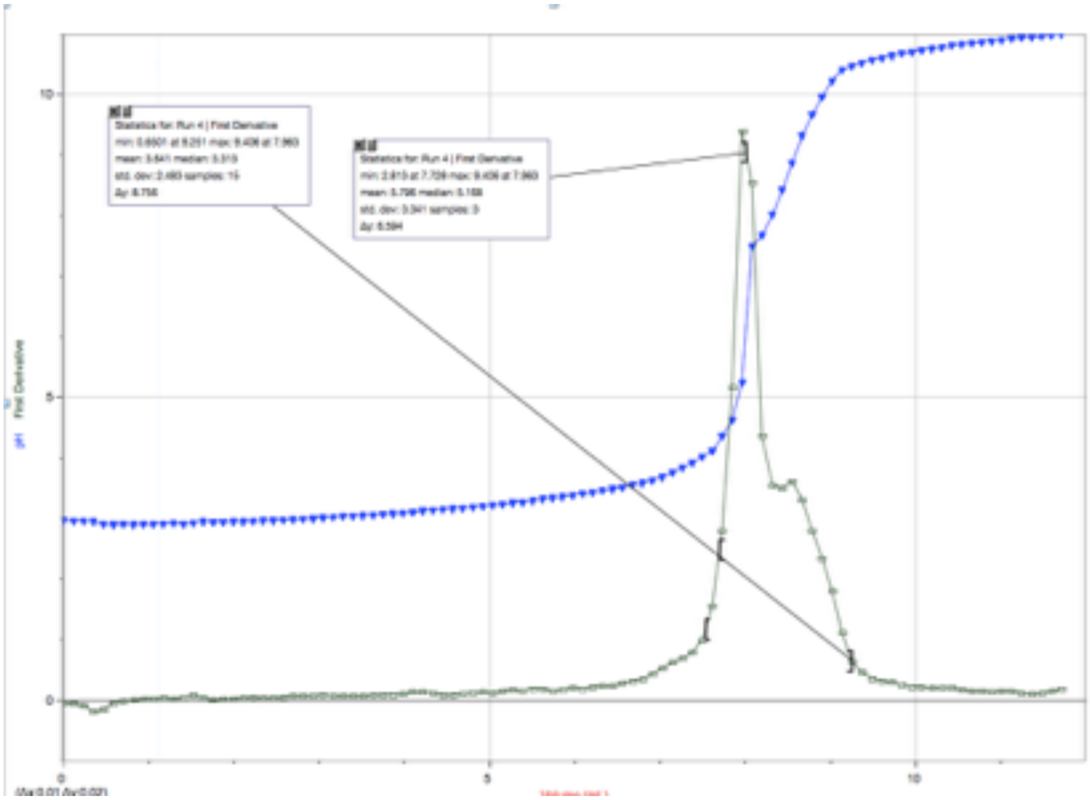
Graph 2. Standardization of Stock Solution of NaOH (Run 2)



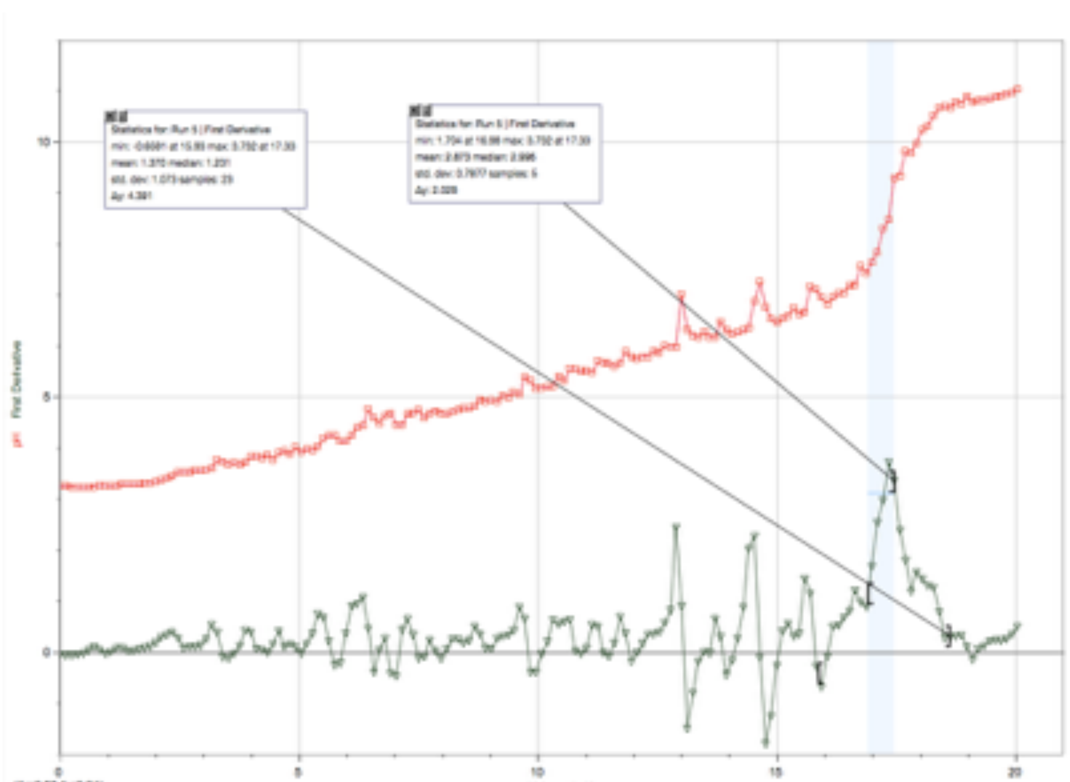
Graph 3. Concentration of an Unknown Acid (Run 3)



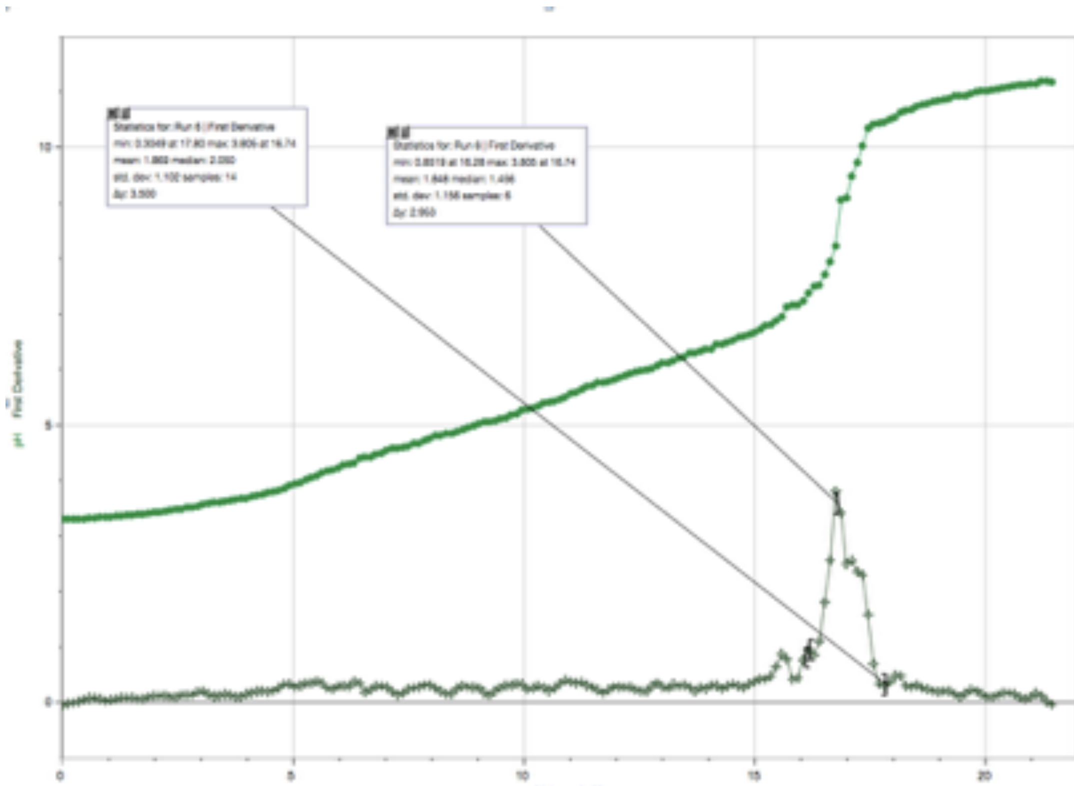
Graph 4. Concentration of an Unknown Acid (Run 4)



Graph 5. Acid Concentration in Juice Sample (Run 5)



Graph 6. Acid Concentration in Juice Sample (Run 6)



Sample Calculation: (Part 1)

1. Approximate concentration of stock solution

$C_1V_1 = C_2V_2$

$C_1 = 6.00$ M
$V_1 = 4.20$ mL (0.0042 L)
$C_2 = ?$
$V_2 = 246$ mL (0.25 L)

$$\frac{0.0042\ \text{L} \times 6.00}{0.246\text{L}}$$
= 0.102 M

Sample Calculation: (Part 2)

2. Exact concentration of stock solution (from visual endpoint and cV calculations AND by first derivative from titration curve using LabQuest 2 data):

Volume of base from Labquest 2: 23.66 mL
Concentration of base: 0.102 mol/L

$n_{base} = c_{base} \times v_{base}$

$= 0.102 \text{ mol/L} \times (23.66 \text{ mL})$

$= 0.102 \text{ mol/L} \times (2.3 \times 10^{-2} \text{ L})$

$= 2.30 \times 10^{-3} \text{ mol}$

$n_{acid} = 0.5 n_{base}$

$= 0.5 (2.30 \times 10^{-3} \text{ mol})$

$= 1.15 \times 10^{-3} \text{ mol}$

$v_{acid} = n_{acid} / c_{acid}$

$= (1.15 \times 10^{-3}) \text{ mol} / (1.00 \times 10^{-1} \text{ mol/L})$

$= 1.15 \times 10^{-2} \text{ L}$

$= 11.5 \text{ mL}$

$c_{NaOH} \times v_{NaOH} = c_{HCl} \times v_{HCl}$

$c_{NaOH} = (c_{HCl} \times v_{HCl}) / v_{NaOH}$

$c_{NaOH} = (0.100 \text{ mol/L} \times 0.0115 \text{ L}) / (0.023\text{L})$

$= 5.00 \times 10^{-2} \text{ mol/L}$

3. Average concentration of stock solution:

(0.0500 + 0.0507) / 2
= 0.0503 mol/L

<u>Sample Calculation: (Part 3)</u>

4. Concentration of Unknown Acid (from visual endpoint and cV calculations AND by first derivative from titration curve using LabQuest data):

$n_{base} = c_{base} \times v_{base}$

= (5.03 x 10^-2 mol/L) x (9.83 mL)

= (5.03 x 10^-2 mol/L) x (9.83 x 10^-3 L)

= 4.94 x 10^-4 mol

$n_{acid} = 0.5n_{base}$

= 0.5(4.94 x 10^-4 mol)

= 2.47 x 10^-4 mol

$c_{acid} = n_{acid} / v_{acid}$

= (2.47 x 10^-4 mol) / (1.19 x 10^-2 L)

= 2.07 x 10^-2 mol/L

5. Average concentration of unknown acid:

(5.01 x 10^-2 M + 5.02 x 10^-2 M) / 2

= 1.25 x 10^-3 M

Sample Calculation: (Part 4)

6. Concentration of acid in juice (from visual endpoint and cV calculations AND by first derivative from titration curve using LabQuest data):

$n_{base} = c_{base} \times v_{base}$

= (5.03 x 10^-2 mol/L) x (17.33 mL)

= (5.03 x 10^-2 mol/L) x (1.73 x 10^-2 L)

= 8.71 x 10^-4 mol

$n_{acid} = 0.5n_{base}$

= 0.5(8.71 x 10^-4 mol)

$= 4.35 \times 10^{-4}$ mol

$c_{acid} = n_{acid} / v_{acid}$

$= (4.35 \times 10^{-4} \text{ mol}) / (5.00 \times 10^{-3} \text{ L})$

$= 8.70 \times 10^{-2}$ mol/L

7. Average concentration of acid in juice:

$(3.32 \times 10^{-2} + 3.81 \times 10^{-2} \text{ M}) / 2$

$= 3.56 \times 10^{-2}$ M

8. Mass percentage of acid in juice:

$$\text{Mass Percent of Acid in Juice} = \frac{(c_{acid}\text{, mol/L})(MM_{acid}\text{, g/mol})}{(\text{density}_{juice}\text{,g/mL}) \times 1000} \times 100\%$$

$$= \frac{(3.56 \times 10^{-2}) \times (192 \text{ g/mol})}{(1.0003 \text{ g/m}^3) \times 1000} \times 100\%$$

$$= \frac{6.83}{1000.3} \times 100\%$$

$$= 0.683\ \%$$

Discussion

The purpose of this lab is to use a sample of a stock solution of NaOH to conduct an acid-base titration to determine the unknown concentrations of a diprotic acid and a tripotic in a juice sample. In order to perform the titration experiments, 0.1% phenolphthalein indicator was used. When the amount of the hydronium ions became equivalent to the amount of hydroxide ions, the solution will turn a faint pink when the hydronium and hydroxide concentration reach the stoichiometric point of the indicator. Likewise, both the endpoints and equivalence points were shown on the logger pro graphs indicating that the increasing curve of the first derivative line from when the pH rises to the peak of the curve is the occurrence of each hydronium ion having reacted with every hydroxide ion, titrating the base solution. When the titration has reached its endpoint, the colour of the solution will turn pink. The values of the equivalence points and endpoints of the reaction were relatively very close in all 6 trials, indicating that the titration was successful. When balancing the chemical equation for the diprotic acid, it is determined that the stoichiometric coefficient ratio for the base and the acid is 2, determining that the acid is diprotic. If the stoichiometric coefficient ratio is 3, this indicates that the acid is triprotic. The graphs made on logger pro demonstrate that trials for the monoprotic acid and the standardization of stock solution, there was one point of inflection in the reaction, which shows on the increasing curve of the first derivative. The graphs that measured pH vs. volume of NaOH base solution for the diprotic acid had 2 points of inflection in the reaction, which can be seen clearly on the graph, to show that there are 2 points of inflection in a diprotic reaction. For the trials that measured the pH of the acid inside the unknown juice sample, due to an experimental error while conducting the lab, the first derivative value curve doesn't meet the pH curve of the acid, showing that the reaction never reached the equivalence point or endpoint of the titration, although the solution did turn pink during the conduction of the lab, therefore an error occurred while the data was transferred onto Labquest, and perhaps the drop counter was not aligned properly, not taking account the accurate count of the drops to reach the equivalence and end points of the titration, therefore, the graphs and results for for this trial are deemed to be inaccurate. Moreover, the volume of NaOH that is used in the beginning of the experiment does not matter, as the NaOH will continue to be added to the acid solution, until the equivalence points and end points are reached. The ions in the base solution will react with the ions in the acid solution until the amounts of each are equivalent, therefore the volume does not matter. Also, the concentration of NaOH is determined before it is used due to the fact that it is a value that will be needed in further calculations to calculate the unknown concentrations of the acids in the juice sample. The volumes at equivalence point determined by Logger Pro are relatively the same as the volumes at which the colour changed was observed, since the Labquest was able to measure the volume using the drop counter.

Conclusion

Based on the calculations made from the results conducted in this lab, the average concentration of the stock solution of the NaOH base was 5.03 x 10^-2 mol/L. For part 2, the concentration of the unknown acid #2 was 5.01 x 10^-2 mol/L. For part 3, the concentration of the acid inside the citric acid juice #1 was 3.32 x 10^-2 mol/L. The average percent of acid in juice was calculated to be 0.683%.

Works Cited

Ahmad, A. B., Muhammad, N. A., Idris, M. B., & Da'u Khalid, K. (2016). “Phytochemicals screening and acid-base indicator property of ethanolic extract of althea rosea flower”, Journal Of Advanced Scientific Research, 7(2), 30-32.

Dr. R. Venkateswaran, “What In The World ISN’T Chemistry?”, General Chemistry Laboratory Manual, 2016, Experiment 3. p(74-76)

Raw Data - Lab #3

2.2 mL distilled H_2O.

Volume of NaOH : 4.2 mL.

19. 7.6 mL after callibration (exact volume)

63 drops

25 mL standard acid

→ 0.1000 M HCl (monoprotic)

glass buret { initial buret reading : 19.5 (25 - 5.5)

exact final reading : (25 - 15.5 = 9.5 mL)

Phenolphthalein 0.1% solution : 3 drops.

Volume of added base at which the colour of the acid solution changes : 23.8 mL

pH : ~~9.85~~ ~~[illegible]~~.

9.85 → 11.25.

Trial 2

Volume of NaOH : ~~4.6~~ 4.2 mL (6 mol/L).

246 ~~250~~ mL of distilled H_2O.

#19. ~~5.0~~ 4.8 mL after callibration (41 drops).

25 mL standard acid

↳ 0.1000 M HCl

initial buret reading (25 - 5.8) = 19.2 mL

exact final reading (25 - 15.8) = 9.2 mL

pH : 11.04.

Volume of added base / colour change

: 24.356 mL

Determining the concentration of unknown acid.

unknown # = #2.

initial buret reading (25 - 2.8 = 22.2) mL
final buret reading. (25 - 11.9 = 13.1) mL.

3 drops phenolphthalein.

pH: 11.02
volume of added base / colour change. 9.836mL
volume → pH go to 11.02 : 13.232 mL.

Trial # 2

initial buret reading (25 - 5 = 20) mL.
final buret reading (25 - 10 = 15) mL.

3 drops phenolphthalin.

pH: 11.02
colour change (turns pink) at : 7.963 mL
volume of pH change: 11.710 mL.

Determing the Mass Percentage of Acid in Juice.
Density of juice : 1.0003 g/m³
initial buret reading (25 − 5) = ~~21.8~~ 20.0 mL
final buret reading : (25 − 13.1) mL = 11.9 mL.

3 drops phenolphthalein.
volume colour change : 17.681 mL
pH : 11.00
volume / pH change : ~~11.00~~ 20.023

Trial #2

Density of juice : 1.0003 g/m³
initial reading (25 − 4) = 21 mL
final reading (25 − 11) = 14 mL.

3 drops
volume colour change : 16.745 mL.
pH : 11.19
volume / pH change : 21.429 mL