“Oh How Bitter a Thing it is…” Acid Base Titrations
Experiment 3

CHM1311 SECTION

Demonstrators:

Department of Chemistry

University of Ottawa

Laboratory Report Form

Experiment 3.

Acid/Base Titrations

Checklist:

- **Raw Data Sheet written in pen, signed by TA AND Raw data from LabQuest attached**
- **Data tables and graphs (12 minimum!) made in Logger Pro attached**
- **Report Form attached**

Student's Initials

October 21, 2016

Experiment 3: "Oh How Bitter a thing is..." Acid-Base Titration

Introduction:

In a reaction between an acid and a base (neutralization reaction), a proton is transferred from the acid to the base. In other words, acids are proton donors whereas bases are hydroxide ion donors when they are placed in water. Arrhenius is a chemist who defined acids as substances that ionize in water to make H^+ ions and an alkali makes OH^- ions and the combination of these ions produces a neutralization reaction.[1] Some significant differences between an acid and a base is that acids taste sour, have a pH of less than 7.0, and are red on litmus paper whereas bases taste bitter, have a pH of greater than 7.0 and are blue on litmus paper.[2]

The Bronsted-Lowrey Theory is a theory that can be used for the explanation of how a neutralization reaction works. A bronsted-lowrey acid is an acid that donates a proton and a

[1] Bylikin, Sergey, Gary Horner, Brian Murphy, and David Tarcy. Ib Chemistry Online Course Book 2014. N.p.: Oxford Univ Pr, 2014. Print.
[2] Bylikin, Sergey, Gary Horner, Brian Murphy, and David Tarcy. Ib Chemistry Online Course Book 2014. N.p.: Oxford Univ Pr, 2014. Print.

bronsted-lowrey base is a base that accepts a proton.[3] A Lewis acid is an acid that accepts an electron pair and a Lewis base donates an electron pair.[4]

Acids and bases can either be strong or weak. A strong acid or base completely dissociates in water whereas a weak acid or base partially dissociates in water.[5] An example of that is:

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

In the above equation, HCl is a strong acid so the reaction goes to completion. In this case, the H_2O is a base.

However, if it was a weak acid, the reaction would go back and forth as it would not go to completion. In this experiment, a strong base, NaOH was used and a strong acid, HCl was used. Since an acid and a base result in a neutralization reaction, an equivalence point can be determined. The equivalence point is "the point at which the amount of acid added is exactly enough to titrate the base present." As mentioned above, both the acid species and the base species used were strong acids (HCl) and strong bases. This was done through titration. A titration is "a volumetric analysis technique that involves a reaction between a substance of unknown concentration with a standardized solution (the titrant). The titrant is delivered from a burette into the solution using small increments."[6] In this case, the small increments were in drops and this was converted to volume in mL.

In this lab, sodium hydroxide was diluted, standardized, and it was used to determine the concentration of hydrochloric acid (strong acid) and an unknown acid. It was also used to determine the concentration and weight percent of acid in a juice sample. The concentration can be determined using the equation:

$$C_1V_1 = C_2V_2$$

To determine the concentration of the species (acid or base), the volume of water and the species (acid or base) must be observed. If it is noted that there is not a lot of water but there is a lot of the species, then the solution is more concentrated, but if there is a lot of water and not a lot of the species, then the solution is less concentrated. The data is displayed on a pH curve, which is the first derivative of the equivalence point. A titration ends when the colour of the reaction changes, and this is determined with the help of the phenolphthalein (indicator). When the colour changes, the equivalence point is noticed.

Procedure:
As described in the lab manual (Ref).

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[3] Bylikin, Sergey, Gary Horner, Brian Murphy, and David Tarcy. Ib Chemistry Online Course Book 2014. N.p.: Oxford Univ Pr, 2014. Print.
[4] Bylikin, Sergey, Gary Horner, Brian Murphy, and David Tarcy. Ib Chemistry Online Course Book 2014. N.p.: Oxford Univ Pr, 2014. Print.
[5] Bylikin, Sergey, Gary Horner, Brian Murphy, and David Tarcy. Ib Chemistry Online Course Book 2014. N.p.: Oxford Univ Pr, 2014. Print.
[6] Bylikin, Sergey, Gary Horner, Brian Murphy, and David Tarcy. Ib Chemistry Online Course Book 2014. N.p.: Oxford Univ Pr, 2014. Print.

Data Observations and Results:

Data Tables

Table 1. Formation of a stock solution of NaOH

Volume of concentrated NaOH solution (mL)	4.10
Concentration of concentrated NaOH solution (M)	6
Volume of stock solution after dilution (mL)	254.1
Approximate concentration of stock solution (M)	0.006

Table 2. Standardization of Stock Solution of NaOH

Data	**Trial 1**	**Trial 2**	**Trial 3**
Concentration of Standard Acid solution (M)	0.1000	0.1000	N/A
Volume of Standard Acid solution (mL)	10.00	10.00	N/A
Volume of stock solution of NaOH (mL)	14.406	14.905	N/A
Concentration of stock solution of NaOH (M)	0.06357	0.06447	N/A

Average Concentration of stock solution of NaOH (M)	0.06402

Table 3: Determination of the Concentration of an Unknown Acid

Data	Trial 1	Trial 2	Trial 3
Sample Number of Unknown Acid	#2	#2	N/A
Volume of Unknown Acid solution (mL)	10.00	9.95	N/A
Volume of stock solution of NaOH (mL)	7.071	7.652	N/A

Concentration of stock solution of NaOH (M)	0.06402	0.06402	N/A
Concentration of Unknown Acid Solution (M)	0.02635	0.02665	N/A
Average Concentration of Unknown Acid solution (M)	0.02650		

Observations (all parts of the experiment):

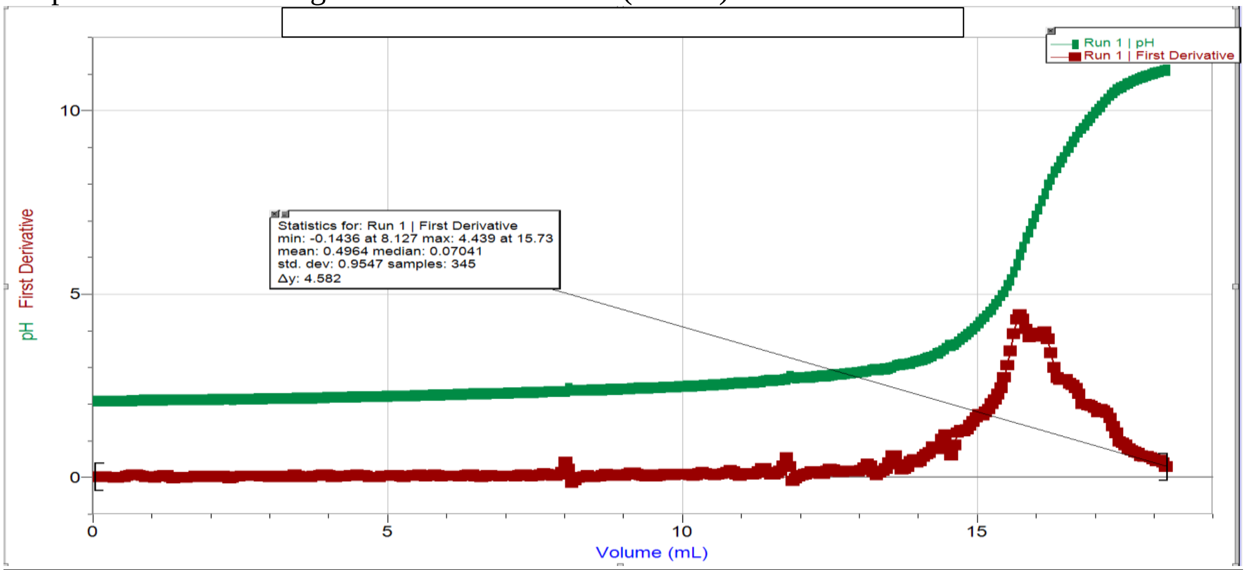
As mentioned above, in this experiment NaOH was dropped into a solution of HCl or the unknown acid or the citric juice. NaOH was colourless throughout the whole experiment as well as the HCl and unknown acid before the phenopthalein was added. The indicator was added in order to help visually see the endpoint.The colour of the juice sample was very light green. After a specific amount of drops of NaOH were added, the colour of the solution in the beaker changed which was what determined when the titration was finished. Specifically, when the solution in the beaker turned light pink for each titration determined when the titration was complete.

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

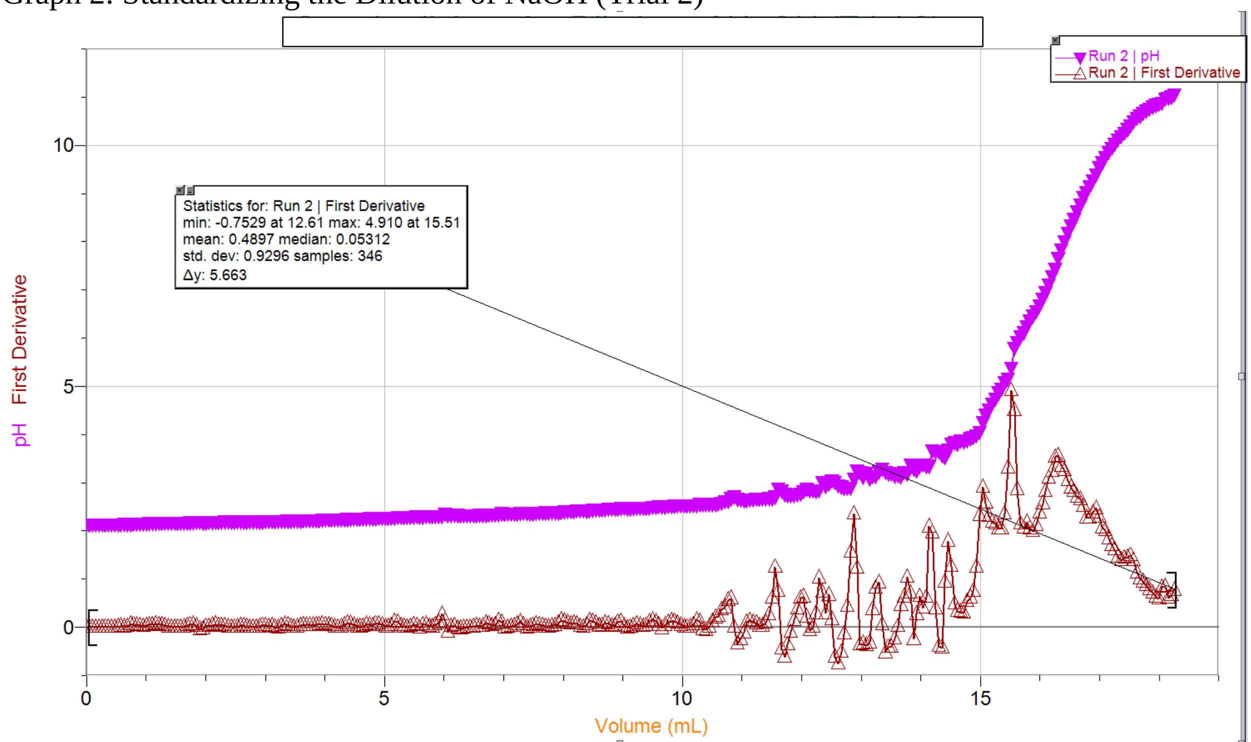
Data	Trial 1	Trial 2	Trial 3
Sample Number of Juice	1	1	1
Volume of Juice (mL)	9.95	9.95	9.90
Volume of stock solution of NaOH (mL)	11.451	11.082	11.926
Concentration of stock solution of NaOH (M)	0.6402	0.6402	0.6402
Concentration of acid in Juice (M)	0.02559	0.02466	0.02776
Average Concentration of Acid in Juice (M)	0.02600		
Density of Juice (g/mL)	1.0003		
Molar Mass of acid in Juice (g/mol)	192.12		
Mass Percent of Acid in Juice (%)	0.498		

GRAPHS: Attach Logger Pro data tables AND graphs (at least 12 [2 per trial]) to this form!!

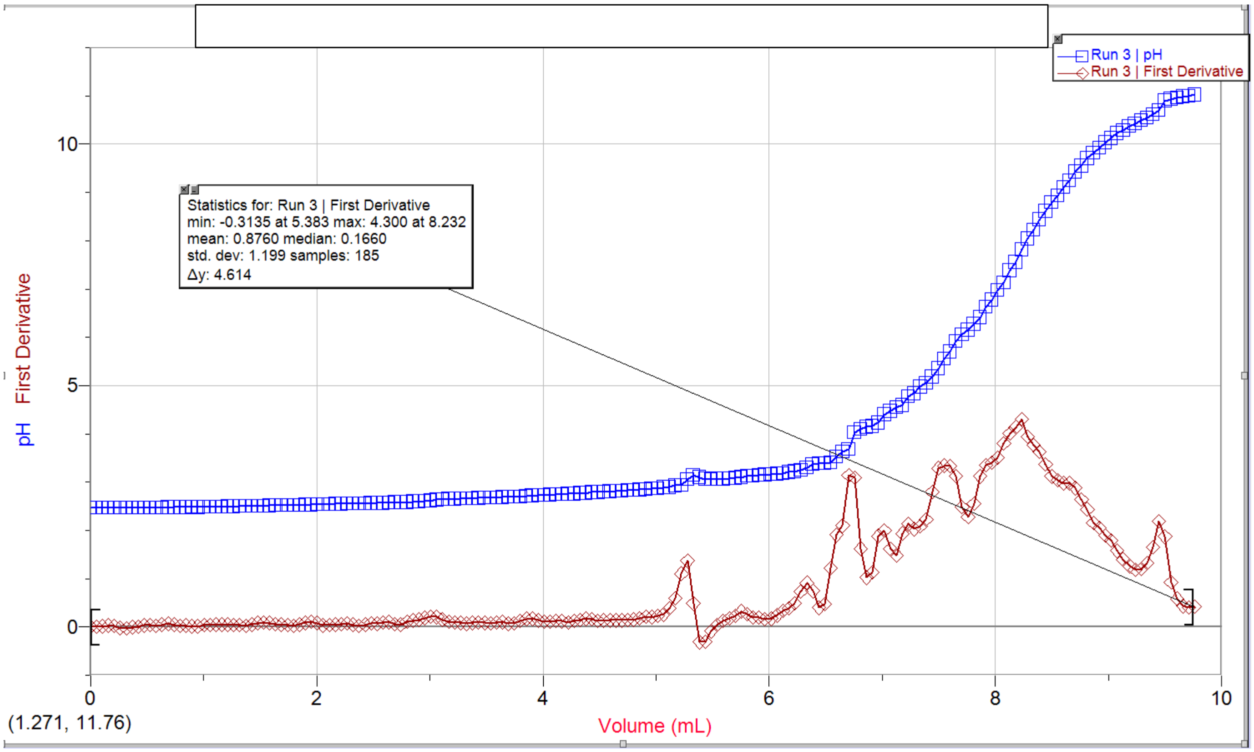
Graph 1.0: Standardizing the Dilution of NaOH (Trial 1)



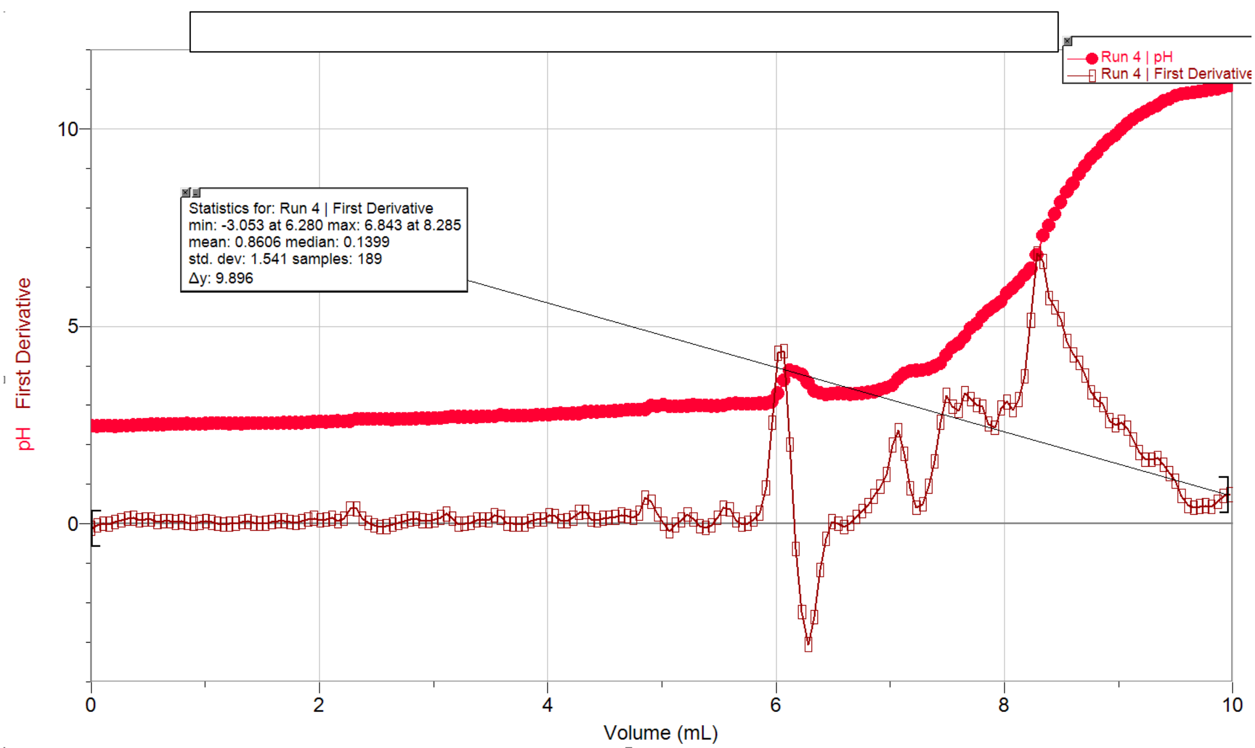
Graph 2: Standardizing the Dilution of NaOH (Trial 2)



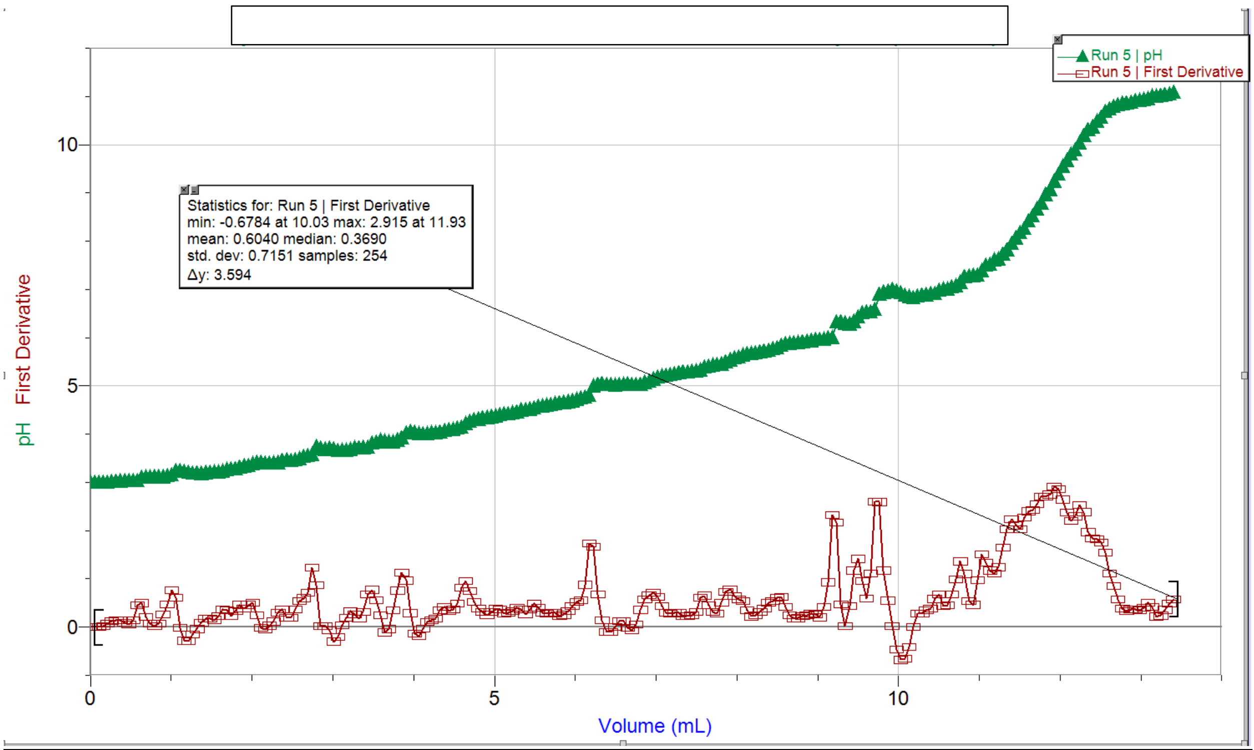
Graph 3: pH and First Derivative of the Unknown Acid (Trial 1)



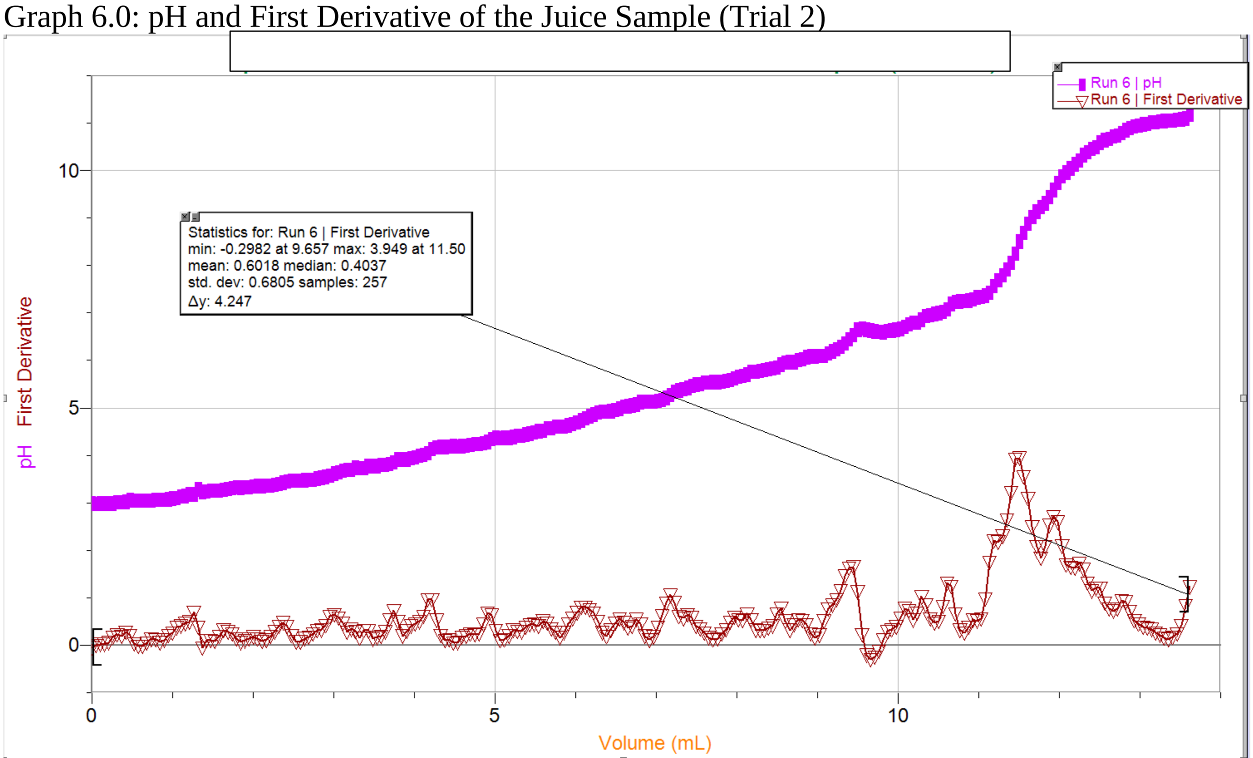
Graph 4.0: pH and First Derivative of the Unknown Acid (Trial 2)



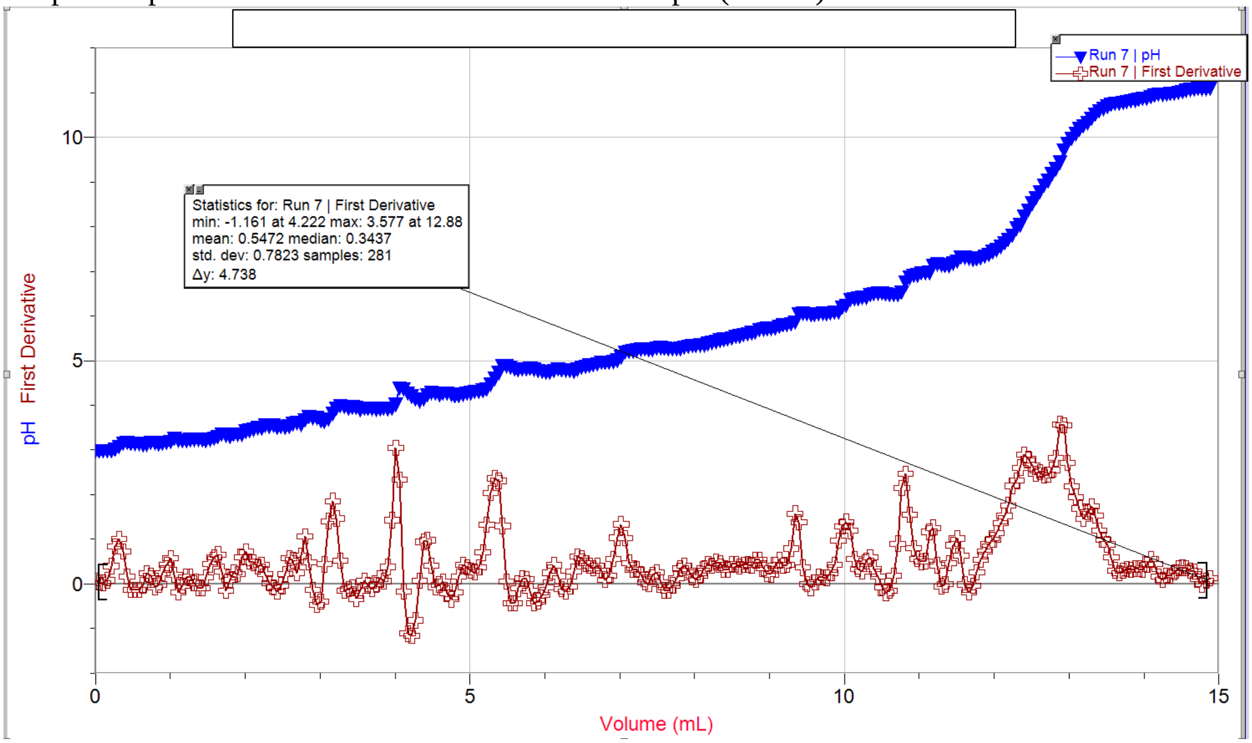
Graph 5.0: pH and First Derivative of the Juice Sample (Trial 1)



Graph 6.0: pH and First Derivative of the Juice Sample (Trial 2)



Graph 7.0: pH and First Derivative of the Juice Sample (Trial 3)



Calculations:

Sample Calculation: (Part 1)

1. Approximate concentration of stock solution

$C_1V_1 = C_2V_2$
*C_2 is the C of stock, and V_2 is the V of stock

(6 mol/L)(0.0041 L) = C_2(0.2541 L)
C_2 = 0.006 mol/L

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):

Visual
Trial 1:
Equivalence point is when $n_{HCl} = n_{NaOH}$
$C_1V_1 = C_2V_2$
*C_1 and V_1 is for NaOH and C_2 andV_2 is for HCl
C_1(0.014406 L) = (0.1000 mol/L)($1.000*10^{-2}$ L)
Concentration of NaOH = 0.06942 mol/L

Trial 2:
Same calculations as above except for:
volume of NaOH =0.014905 L
volume of HCl =$1.00*10^{-2}$ L
Concentration of NaOH = 0.06709 mol/L

LabQuest
Trial 1:
Volume of NaOH = 15.73 mL = 0.01573 L (this is obtained from Graph 1.0)
$C_1V_1 = C_2V_2$
*C_1 and V_1 is for NaOH and C_2 andV_2 is for HCl
C_1(0.01573 L) = (0.1000 mol/L)($1.000*10^{-2}$ L)
Concentration of NaOH = 0.06357 mol/L

Trial 2:
Same calculations as above except for:
volume of NaOH =0.014905 L (this is obtained from Graph 2.0)
volume of HCl =$1.00*10^{-2}$ L
Concentration of NaOH = 0.06447 mol/L

3. Average concentration of stock solution:

$$\text{Average concentration} = \frac{Concentration_{NaOH\ trial\ 1} + Concentration_{NaOH\ trial\ 2}}{2}$$

$$= \frac{0.06357+0.06447}{2}$$

$$= 0.06402\ mol/L$$

Sample Calculation: (Part 3)

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

Visual

Trial 1:

Equivalence point is when $2n_{H2A} = n_{NaOH}$ because…

$H_2A + 2NaOH \rightarrow Na_2A + 2H_2O$

$C_1V_1 = 2C_2V_2$

*C1 and V1 is for NaOH and C2 and V2 is for H_2A

$(0.06402\ mol/L)(0.007071\ L) = 2C_2\ (1.000*10^{-2}\ L)$

Concentration of NaOH = 0.02263 mol/L

Trial 2:

Same calculations as above except for:

volume of NaOH =0.07652 L

volume of H_2A =0.009950 L

Concentration of NaOH = 0.02462 mol/L

LabQuest

Trial 1:

Volume of NaOH = 8.232 mL = 0.008232 L (this is obtained from Graph 3.0)

$C_1V_1 = 2C_2V_2$

*C_1 and V_1 is for NaOH and C_2 andV_2 is for H_2A

$(0.06402\ mol/L)(0.008232\ L) = 2C_2(1.000*10^{-2}\ L)$

Concentration of NaOH = 0.02635 mol/L

Trial 2:

Same calculations as above except for:

volume of NaOH =0.008285 L

volume of H_2A =0.009950 L

Concentration of NaOH = 0.02665 mol/L

5. Average concentration of unknown acid:

$$\text{Average concentration} = \frac{Concentration_{Unknown\ acid\ trial\ 1} + Concentration_{Unknown\ acid\ trial\ 2}}{2}$$

$$= \frac{0.02635+0.02665}{2}$$

= 0.02650 mol/L

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):

Visual

Trial 1:

Equivalence point is when $3n_{H2A} = n_{NaOH}$ because…

$H_2A + 3NaOH \rightarrow Na_2A + 2H_2O$

$C_1V_1 = 3C_2V_2$

*C1 and V1 is for NaOH and C2 and V2 is for H_2A

(0.06402 mol/L)(0.011451 L) = $3C_2$ (0.009950 L)

Concentration of NaOH = 0.02456 mol/L

Trial 2:

Same calculations as above except for:

volume of NaOH =0.011082 L

volume of H_2A =0.009950 L

Concentration of NaOH = 0.02377 mol/L

Trial 3:

Same calculations as above except for:

volume of NaOH =0.011926 L

volume of H_2A =0.009900 L

Concentration of NaOH = 0.02389 mol/L

LabQuest

Trial 1:

Volume of NaOH = 11.93 mL = 0.01193 L (this is obtained from Graph 5.0)

$C_1V_1 = 3C_2V_2$

*C_1 and V_1 is for NaOH and C_2 andV_2 is for H_2A

(0.06402 mol/L)(0.01193 L) = $3C_2$(0.009950 L)

Concentration of NaOH = 0.02559 mol/L

Trial 2:

Same calculations as above except for:

volume of NaOH =0.01150 L (this is obtained from Graph 6.0)

volume of H_2A =0.009950 L

Concentration of NaOH = 0.02466 mol/L

Trial 2:

Same calculations as above except for:

volume of NaOH =0.01288 L (this is obtained from Graph 7.0)

volume of H_2A =0.009900 L
Concentration of NaOH = 0.02776 mol/L

7. Average concentration of acid in juice:

$$\text{Average concentration} = \frac{Concentration_{juice\ trial\ 1} + Concentration_{\ juice\ trial\ 2} + Concentration_{juice\ trial\ 3}}{3}$$

$$= \frac{0.02559+0.02466+0.02776}{3}$$

$$= 0.02600\ mol/L$$

8. Mass percentage of acid in juice:

$$\text{Mass percent of acid in juice} = \frac{0.02600\frac{mol}{L}*192.12\frac{g}{mol}}{1.0003\frac{g}{mL}*1000} * 100\%$$

Mass percent of acid in juice = 0.4980 %

Discussion:

The main objective is to use the standardized NaOH solution in order to determine the concentration of an unknown acid and to determine the concentration and weight percent of acid in a juice sample. Once the equivalence point was obtained, equal amounts of the base and the acid were located in the beaker. Since the acid solution has a concentration that is given, determining the concentration of the base can be done.
The average concentration of the NaOH stock solution was determined (in the calculations above) to be *0.06402 mol/L*. This value was also used to calculate both the concentration of the acid in the juice as well as the concentration of the unknown acid. The concentration of the acid in the juice is *0.02600 mol/L.* The concentration of the unknown acid is *0.02650 mol/L.*

In the calculation of mass percentage of acid in the juice above, mass percent was determined by multiplying the average concentration of acid in the juice by the molar mass of $H_3C_6H_5O_7$ and then dividing it by the density and multiplying this value by 100%.
The data above reveals that most of the concentrations were fairly close. Specifically, the exact concentration of the stock solution in the HCl trials differed by about 0.0009 mol/L. The concentration of the stock solution in the unknown acid trials differed by about 0.0003 mol/L. The concentration of the stock solution in the juice trials differed by about 0.003 mol/L.

Although all results were similar, the third trial results for the juice was slightly different. Specifically, if Graph 6.0 and Graph 7.0 were compared, many more peaks were are seen in Graph 7.0. Furthermore, there are many peaks in Graph 5.0. This could suggest that the pH probe being used was not clean and contaminated with leftover acid because the same one was used for all of the trials. This is why the equivalence point could have differed for those specific trials in Graph 6.0, Graph 7.0 and Graph 5.0.

Conclusion:
The concentration of the stock solution of NaOH and water was *0.06402 mol/L.*The concentration of the unknown acid #2 is *0.02650 mol/L.* The mass percentage of the juice sample #1 is *0.4980 %.*

Raw Data:
Insert pics of data here