Experiment 3. Acid-Base Titration

CHM1311 Section E3

By: Emma Scruton
8616651

Partner: Eliza Isaac
8651773

Demonstrator: Yixin Zang

Tuesday October 11, 2016
6:30pm

Introduction:

In chemistry there have been a few attempts at describing acids and bases. The first theory that we started with was the Arrhenius theory of Acids and Bases which states that an acid was a species that dissociated into H+ ions in solution while a base was a species that dissociated into OH- ions in solution and that strong acids and bases will dissociate more completely than weak acids and weak bases. The second part of this theory stated that when an acid and base reacted with each other they would effectively neutralize each other producing water and a salt. While this theory made sense, it was limited because it could only explain acids and bases in aqueous solutions. So, another theory was introduced to better explain the broader scope of acids and bases, The Bronsted-Lowry Theory of Acids and Bases. This theory kept some of the ideas brought up in the earlier Arrhenius Theory but elaborated on the idea. The main point of this theory stated that interactions between acids and bases had to do with proton transfer between them. Acids were considered to be proton donators, while bases were considered to be proton acceptors. It also stated that in a reaction, when an acid donates a proton it will for a conjugate base and a conjugate acid is formed when a base accepts a proton. (https://www.khanacademy.org/science/chemistry/acids-and-bases-topic/acids-and-bases/a/bronsted-lowry-acid-base-theory, Saul Khan, Khan Academy) This new definition allowed chemists to describe acid-base interactions that occurred outside of aqueous solutions. One important way of determining the concentration of an acid or base in a solution is through a titration. This where a small amount of a dilute stock solution of base with a known molarity is slowly added into an unknown acid solution until it reaches the equivalence point when the acid is neutralized and where the number of moles of acid and base are equal. The titration is generally visibly represented through a pH or titration curve, a graph displaying the change in pH over the change in volume. We can tell when the titration is over once the pH on the graph begins to level off after the the number of moles of the stock solution outnumber the number of moles of the unknown acid. The only real difference in titrating a strong acid or base versus a weak acid or base comes from the earlier stated idea that stronger acids and bases will dissociate more fully than weaker acids and bases because it will be much harder to record the pH changes in the weaker solutions than the stronger ones making it much more difficult to clearly locate the equivalence point.

Procedure:

As described in the lab manual (What in the World ISN'T Chemistry, Dr. Rashmi Venkateswaran, 2016, Exp. 3, p. 73)

Observations/ Data:

Part 1: Standardizing the Diluted NaOH Solution

Trial 1
After the calibration of the diluted NaOH solution, the titration of the 0.1000M HCl solution with universal indicator was commenced, the clear colourless HCl solution began to change colour to a pale pink at approximately 10.650 mL.

Trial 2
During the second trial, the clear colourless solution began to change to a pale translucent pale pink at approximately 10.5 mL.

Table 1: Formation of A Stock Solution of NaOH

Volume of concentrated NaOH solution (mL)	4.5 mL
Concentration of concentrated NaOH solution (M)	6.0 M
Volume of stock solution after dilution (mL)	254.5 mL
Approximate concentration of stock solution (M)	0.106 M

Table 2: Standardization of Stock Solution of NaOH

Data	Trial 1	Trial 2	Trial 3
Concentration of Standard Acid solution (M)	0.100 M	0.100 M	N/A
Volume of Standard Acid solution (mL)	10.00 mL	10.05 mL	N/A
Volume of stock solution of NaOH (mL) Calculated from Titration Curve	11.72 mL	12.50 mL	N/A
Concentration of stock solution of NaOH (M) Calculated from Titration Curve	0.171M	0.166 M	N/A
Average Concentration of stock solution of NaOH (M) Calculated		0.169 M	

Table 3: Partial Representation of the Standardization of Stock Solution of NaOH Trial 1 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	2.2142	0.0000
0.0531	2.2142	0.0000
0.1061	2.2142	0.0000
0.1592	2.2142	0.0000
0.2122	2.2142	-0.0051
0.2653	2.2142	-0.0153
0.3183	2.2142	-0.0458
0.3714	2.2044	-0.0025
0.4244	2.2142	0.0360
0.4775	2.2142	-0.0144
0.5305	2.2095	-0.0171
0.5836	2.2095	0.0198
0.6366	2.2142	0.0222
0.6897	2.2142	-0.0148
0.7427	2.2095	-0.0100
0.7958	2.2142	-0.0204
0.8488	2.2095	-0.0588
0.9019	2.2044	-0.0415
0.9549	2.2044	-0.0103
1.0080	2.2044	0.0052
1.0610	2.2044	0.0262
1.1141	2.2095	0.0079
1.1671	2.2044	0.0000
1.2202	2.2095	-0.0079
1.2732	2.2044	-0.0236
1.3263	2.2044	0.0000
1.3793	2.2044	0.0210
1.4324	2.2095	0.0000
1.4854	2.2044	-0.0236
1.5385	2.2044	-0.0079

Figure 1: A graph of the Standardization of Stock Solution of NaOH Trial 1 with pH and pH Derivative as a Function of Volume

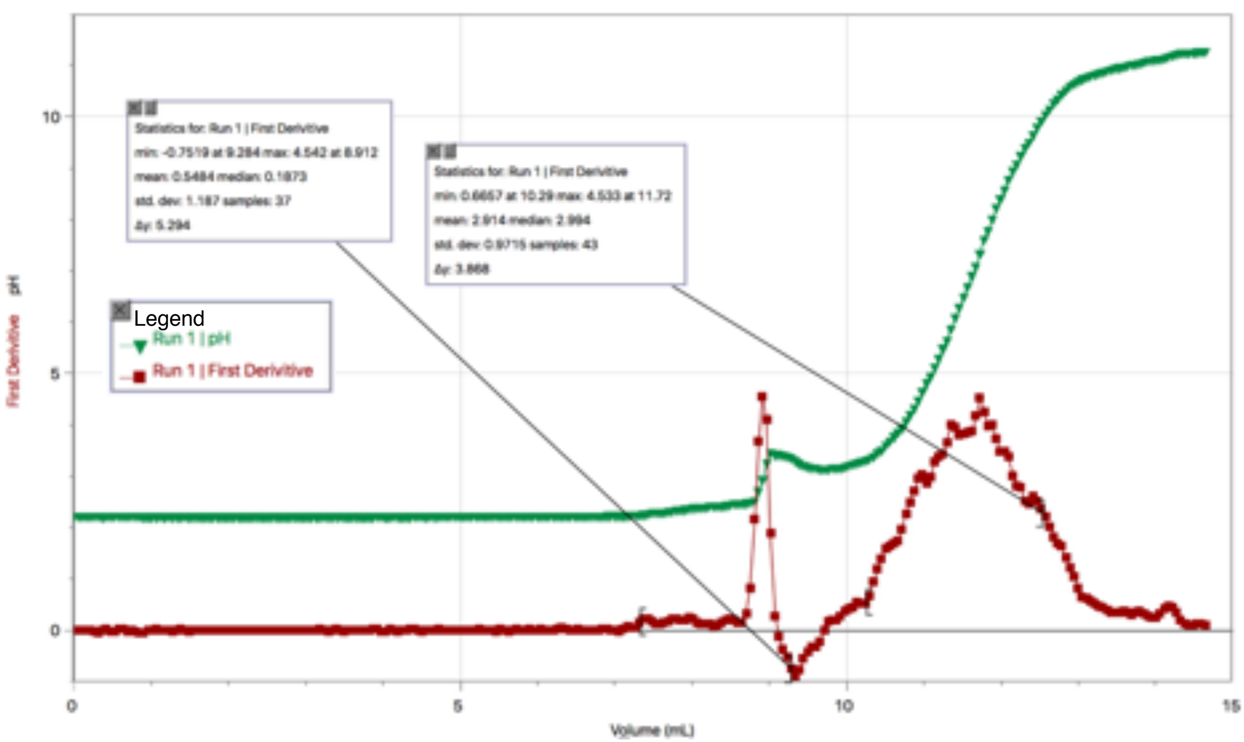
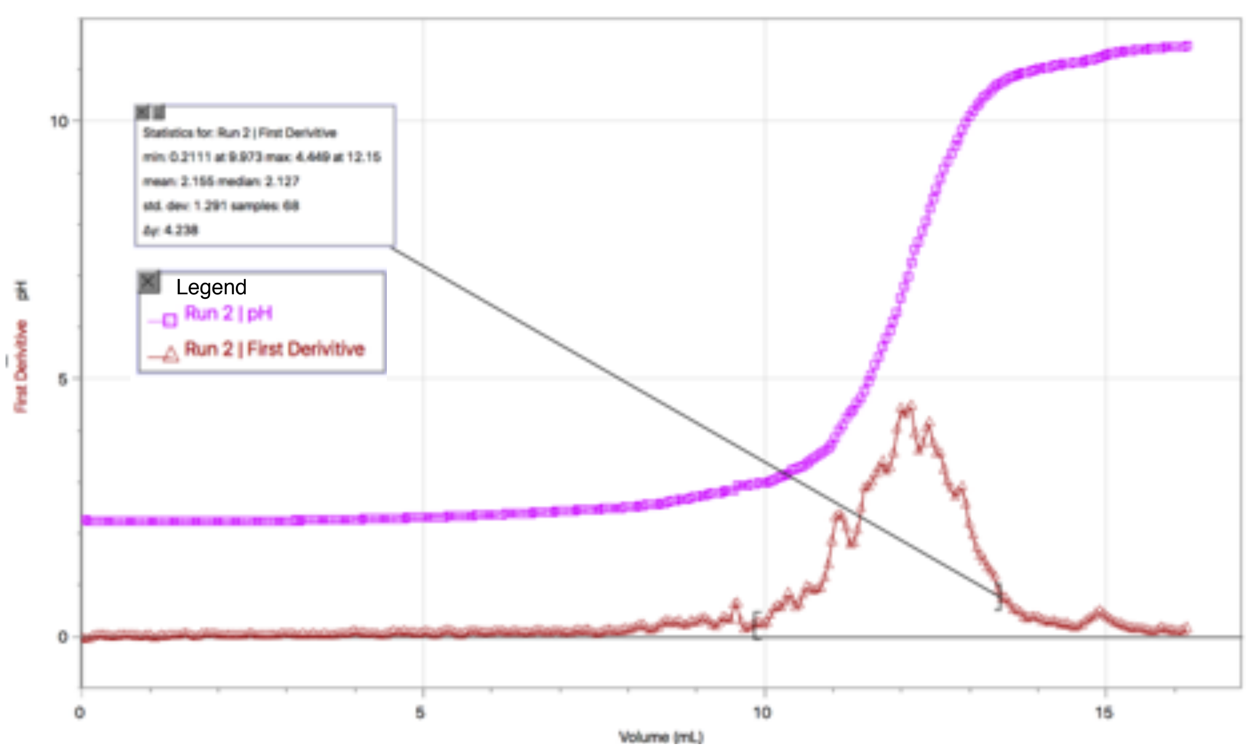


Table 4: Partial Representation of the Standardization of Stock Solution of NaOH Trial 2 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	2.2528	-0.0407
0.0531	2.2528	-0.0738
0.1061	2.2431	-0.0672
0.1592	2.2431	-0.0204
0.2122	2.2431	-0.0051
0.2653	2.2431	0.0000
0.3183	2.2431	-0.0025
0.3714	2.2431	-0.0099
0.4244	2.2431	-0.0321
0.4775	2.2383	-0.0321
0.5305	2.2383	-0.0099
0.5836	2.2383	-0.0025
0.6366	2.2383	0.0000
0.6897	2.2383	0.0000
0.7427	2.2383	-0.0026
0.7958	2.2383	-0.0105
0.8488	2.2383	-0.0315
0.9019	2.2333	-0.0262
0.9549	2.2333	0.0106
1.0080	2.2383	-0.0100
1.0610	2.2333	-0.0483
1.1141	2.2286	-0.0177
1.1671	2.2333	-0.0125
1.2202	2.2286	-0.0247
1.2732	2.2286	-0.0074
1.3263	2.2286	-0.0025
1.3793	2.2286	0.0025
1.4324	2.2286	0.0099
1.4854	2.2286	0.0321
1.5385	2.2333	0.0296

Figure 2: A Graph of the Standardization of the Stock Solution of NaOH Trial 2 with pH and pH Derivative as a Function of Volume



Part 2: Determining the Concentration of an Unknown Acid

Trial 1
During the titration, the clear colourless unknown acid solution began to change to a pale pink at approximately 11.2mL

Trial 2
During the second trial, the colour of the unknown acid solution began to change from clear and colourless to a pale pink at approximately 5.65mL

Trial 3
During the third trial, at approximately 5.8mL the clear and colourless unknown acid solution began to change to a pale pink.

Table 5: Determination of the Concentration of an Unknown Acid

Data	**Trial 1**	**Trial 2**	**Trial 3**
Sample Number of Unknown Acid	#2	#2	#2
Volume of Unknown Acid solution (mL)	10.10 mL	10.10 mL	10.00 mL
Volume of stock solution of NaOH (mL) Calculated from Titration Curve	6.154 mL	5.040 mL	6.95 mL
Concentration of stock solution of NaOH (M)	0.171 M	0.166 M	0.169 M
Concentration of Unknown Acid Solution (M)	0.052 M	0.414 M	0.058 M
Average Concentration of Unknown Acid solution (M)		0.052 M	

Table 6: Partial Representation of the Titration of Unknown Acid 2, Trial 1 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	2.4841	0.0000
0.0531	2.4841	0.0000
0.1061	2.4841	-0.0031
0.1592	2.4841	-0.0130
0.2122	2.4841	-0.0440
0.2653	2.4791	-0.0687
0.3183	2.4744	-0.0525
0.3714	2.4744	-0.0446
0.4244	2.4697	-0.0346
0.4775	2.4697	-0.0099
0.5305	2.4697	-0.0025
0.5836	2.4697	0.0000
0.6366	2.4697	0.0000
0.6897	2.4697	0.0000
0.7427	2.4697	0.0025
0.7958	2.4697	0.0123
0.8488	2.4697	0.0471
0.9019	2.4744	0.0872
0.9549	2.4791	0.1262
1.0080	2.4888	0.1429
1.0610	2.4938	0.1526
1.1141	2.5083	0.1034
1.1671	2.5083	0.0014
1.2202	2.5033	-0.0136
1.2732	2.5033	0.0386
1.3263	2.5083	0.0864
1.3793	2.5130	0.1287
1.4324	2.5227	0.1509
1.4854	2.5274	0.1853
1.5385	2.5466	0.1480

Figure 3: A Graph of the Titration of Unknown Acid 2, Trial 1 with pH and pH derivative as a Function of Volume

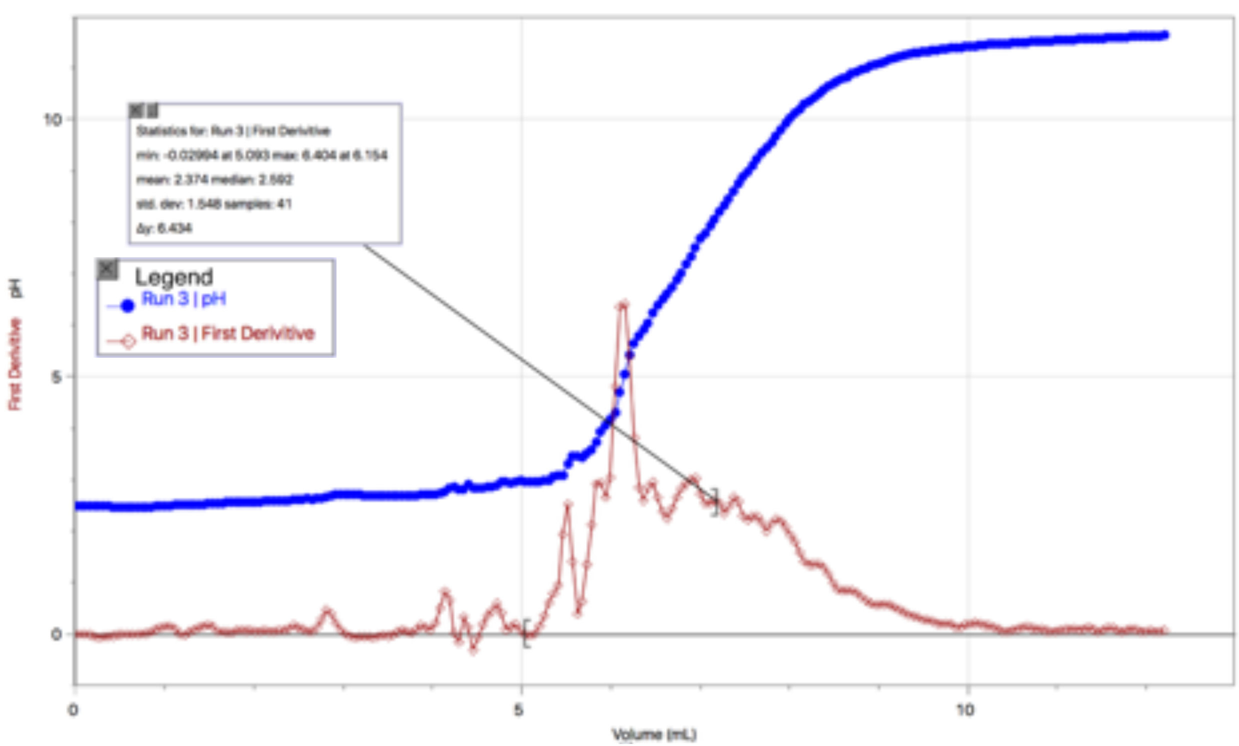


Table 7: Partial Representation of the Titration of Unknown Acid 2, Trial 2 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	2.4697	-0.0731
0.0531	2.4647	-0.0553
0.1061	2.4647	-0.0540
0.1592	2.4599	-0.0668
0.2122	2.4552	-0.0420
0.2653	2.4552	-0.0123
0.3183	2.4552	-0.0025
0.3714	2.4552	0.0000
0.4244	2.4552	0.0000
0.4775	2.4552	0.0000
0.5305	2.4552	0.0000
0.5836	2.4552	0.0025
0.6366	2.4552	0.0099
0.6897	2.4552	0.0346
0.7427	2.4599	0.0420
0.7958	2.4599	0.0395
0.8488	2.4647	0.0247
0.9019	2.4647	-0.0198
0.9549	2.4599	-0.0198
1.0080	2.4599	0.0248
1.0610	2.4647	0.0375
1.1141	2.4647	0.0361
1.1671	2.4697	0.0154
1.2202	2.4647	0.0179
1.2732	2.4697	0.0509
1.3263	2.4744	0.0202
1.3793	2.4697	0.0224
1.4324	2.4744	0.0619
1.4854	2.4791	0.0625
1.5385	2.4791	0.0864

Figure 4: A Graph of the Titration of Unknown Acid 2, Trial 2 with pH and pH Derivative as a Function of Volume

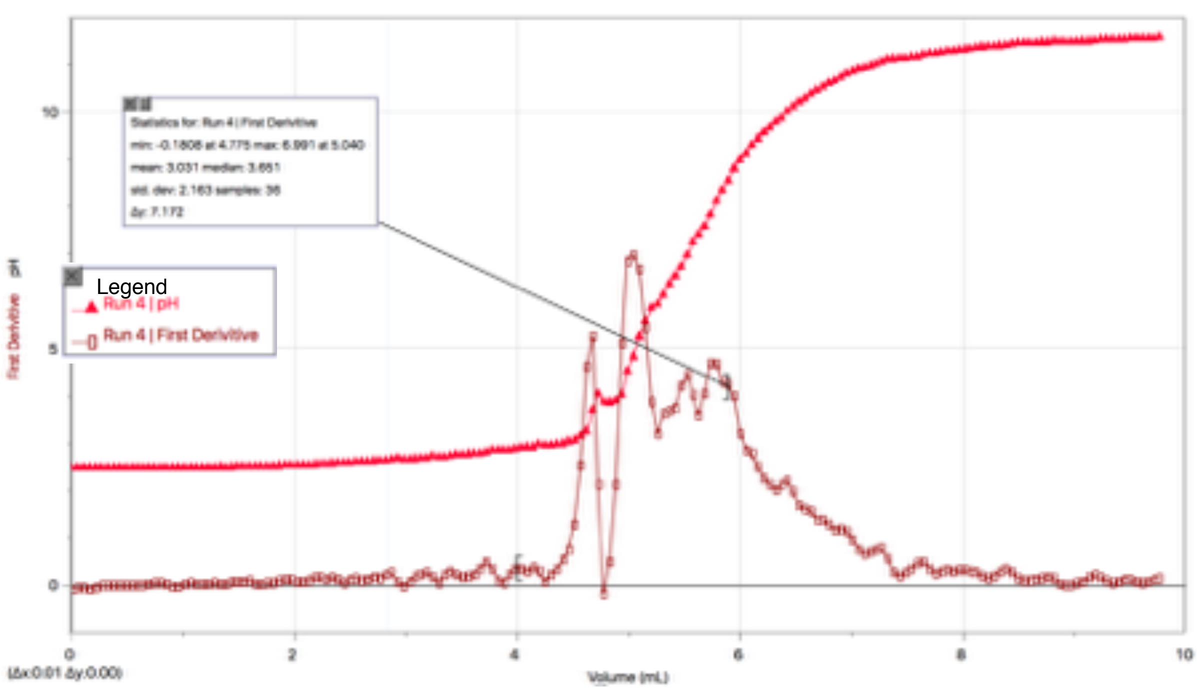
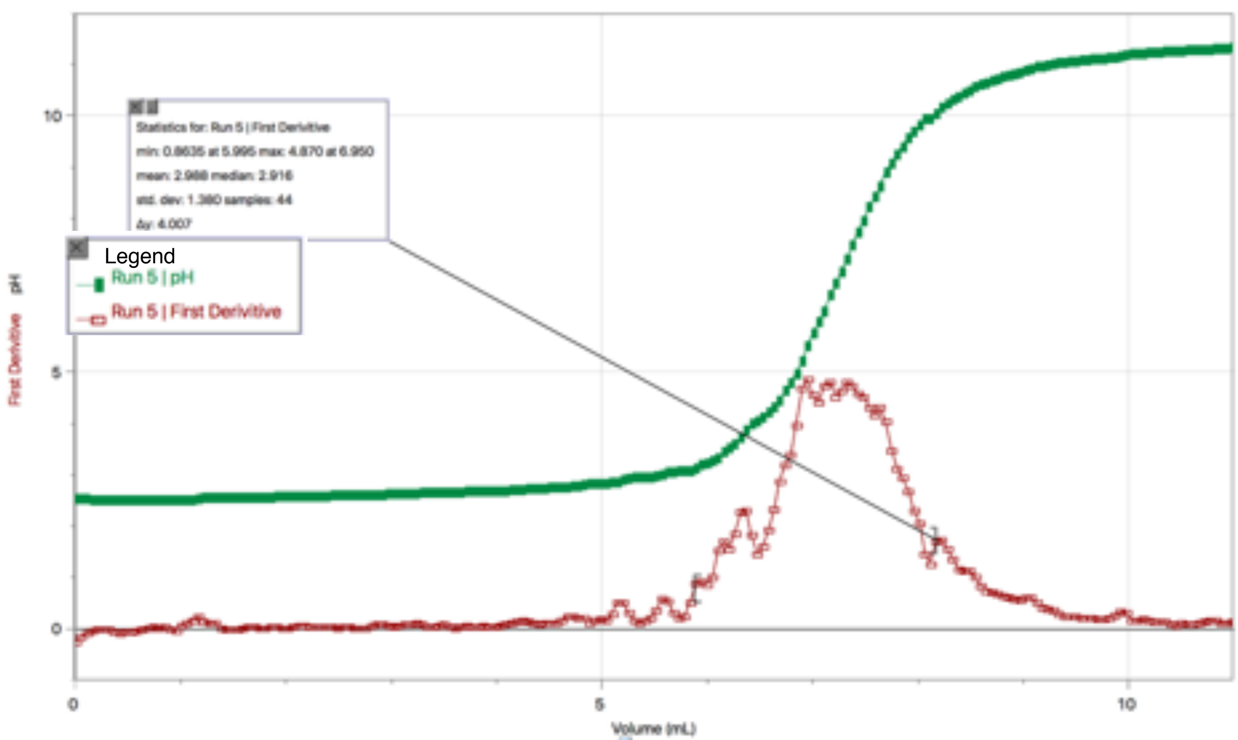


Table 8: Partial Representation of the Titration of Unknown Acid 2, Trial 3 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	2.5466	-0.2657
0.0531	2.5274	-0.1590
0.1061	2.5274	-0.0747
0.1592	2.5227	-0.0421
0.2122	2.5227	-0.0099
0.2653	2.5227	-0.0051
0.3183	2.5227	-0.0130
0.3714	2.5227	-0.0440
0.4244	2.5177	-0.0687
0.4775	2.5130	-0.0525
0.5305	2.5130	-0.0446
0.5836	2.5083	-0.0321
0.6366	2.5083	0.0000
0.6897	2.5083	0.0296
0.7427	2.5130	0.0372
0.7958	2.5130	0.0252
0.8488	2.5130	0.0483
0.9019	2.5227	0.0051
0.9549	2.5130	-0.0255
1.0080	2.5130	0.0610
1.0610	2.5227	0.1088
1.1141	2.5227	0.1785
1.1671	2.5419	0.2315
1.2202	2.5563	0.1390
1.2732	2.5516	0.1139
1.3263	2.5660	0.1182
1.3793	2.5708	0.0278
1.4324	2.5660	-0.0147
1.4854	2.5660	-0.0074
1.5385	2.5660	0.0000

Figure 5: A Graph of the Titration of Unknown Acid 2, Trial 3 with pH and pH Derivative as a Function of Volume



Part 3: Determing the Mass Percent of Acid in a Juice

Trial 1
During the first test, the juice solution began to change to a pale pink at approximately 9.2 mL.

Trial 2
For the second trial, a change in the colour of the juice solution to a pale pink was observed at approximately 8.5mL.

Table 9: Determing the Mass Percentage of Acid in a Juice

Data	**Trial 1**	**Trial 2**	**Trial 3**
Sample Number of Juice	#5	#5	N/A
Volume of Juice (mL)	10.05 mL	10.00 mL	N/A
Volume of stock solution of NaOH (mL)	10.29 mL	8.97 mL	N/A
Concentration of stock solution of NaOH (M)	0.171 M	0.166 M	N/A
Concentration of acid in Juice (M)	0.109 M	0.078 M	N/A
Average Concentration of Acid in Juice (M)	0.093 M		
Density of Juice (g/mL)	1.0002 g/mL		
Molar Mass of acid in Juice (g/mol)	192.124 g/mol		
Mass Percent of Acid in Juice (%)	2.09%		

Table 10: Partial Representation of the Titration of Unknown Juice 5, Trial 1 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	3.0865	-0.0198
0.0531	3.0865	-0.0358
0.1061	3.0818	-0.0357
0.1592	3.0818	-0.0253
0.2122	3.0818	-0.0639
0.2653	3.0767	-0.1312
0.3183	3.0673	-0.1935
0.3714	3.0529	-0.2024
0.4244	3.0479	-0.2325
0.4775	3.0287	-0.2648
0.5305	3.0143	-0.2078
0.5836	3.0093	-0.1801
0.6366	2.9948	-0.1386
0.6897	2.9901	-0.0329
0.7427	2.9948	0.0173
0.7958	2.9948	0.0204
0.8488	2.9948	0.0540
0.9019	2.9998	0.1091
0.9549	3.0045	0.1966
1.0080	3.0190	0.2956
1.0610	3.0431	0.2659
1.1141	3.0529	0.1367
1.1671	3.0529	0.0776
1.2202	3.0576	0.0822
1.2732	3.0623	0.0859
1.3263	3.0673	0.0810
1.3793	3.0720	0.0600
1.4324	3.0720	0.0701
1.4854	3.0767	0.1236
1.5385	3.0865	0.1648

Figure 6: A Graph of the Titration of Unknown Juice 5, Trial 1 with pH and pH Derivative as a Function of Volume

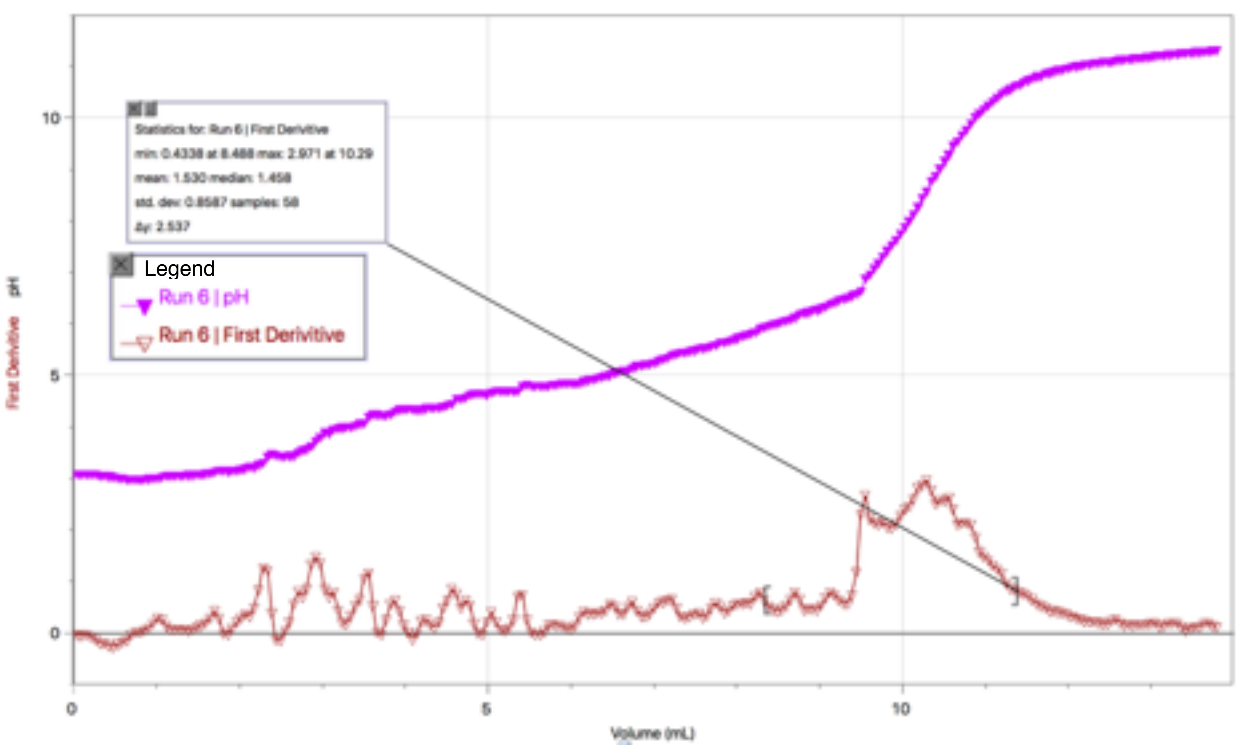
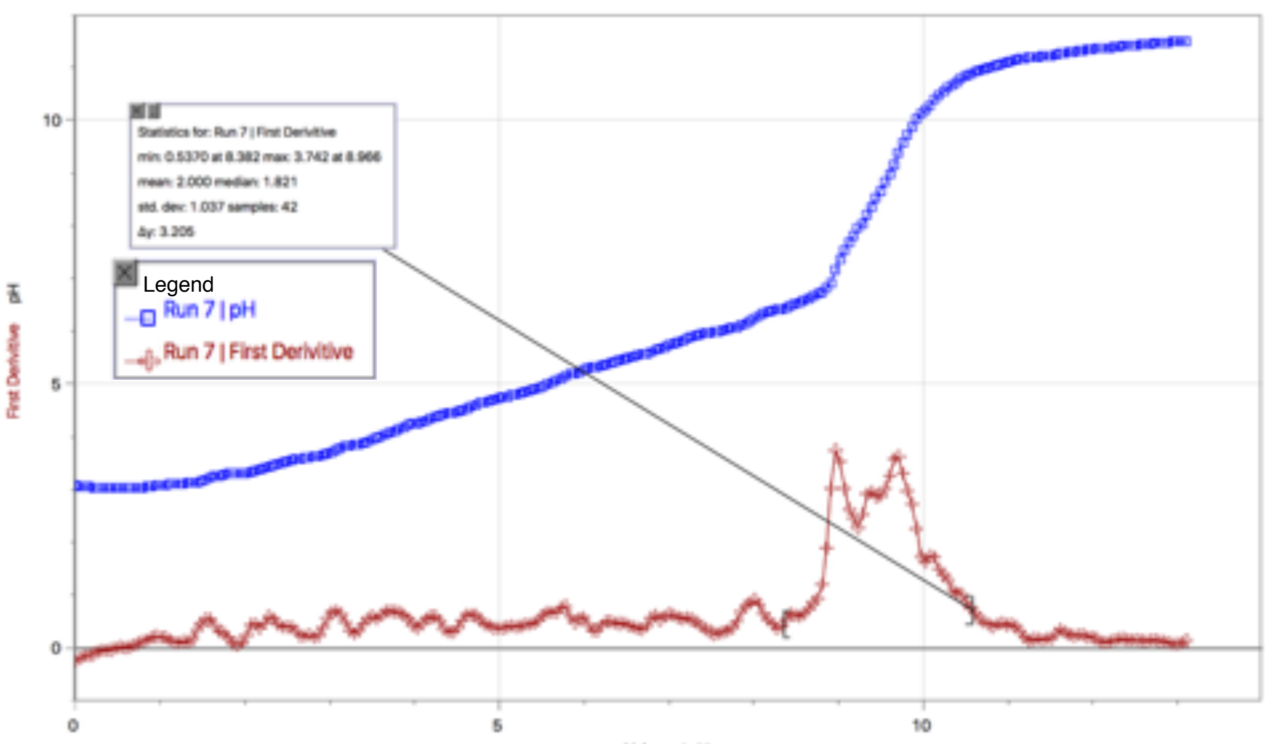


Table 11: Partial Representation of the Titration of Unknown Juice 5, Trial 2 with pH and pH Derivative as a Function of Volume

Volume (mL)	pH	First Derivative
0.0000	3.0767	-0.2413
0.0531	3.0623	-0.2033
0.1061	3.0529	-0.1559
0.1592	3.0479	-0.1375
0.2122	3.0381	-0.1162
0.2653	3.0334	-0.0650
0.3183	3.0334	-0.0497
0.3714	3.0287	-0.0424
0.4244	3.0287	-0.0335
0.4775	3.0237	-0.0025
0.5305	3.0287	0.0236
0.5836	3.0287	0.0103
0.6366	3.0287	0.0150
0.6897	3.0287	0.0471
0.7427	3.0334	0.0872
0.7958	3.0381	0.1287
0.8488	3.0479	0.1552
0.9019	3.0529	0.2048
0.9549	3.0720	0.2134
1.0080	3.0767	0.1960
1.0610	3.0912	0.1969
1.1141	3.1009	0.1440
1.1671	3.1056	0.1091
1.2202	3.1106	0.1015
1.2732	3.1153	0.1163
1.3263	3.1251	0.1142
1.3793	3.1251	0.1620
1.4324	3.1348	0.3356
1.4854	3.1637	0.4680
1.5385	3.1875	0.5342

Figure 7: A Graph of Titration of Unknown Juice 5, Trial 2 with pH and pH Derivative as a Function of Volume



Sample Calculations:

1. Approximate concentration of stock solution:

$$\text{Concentration} = \frac{\text{amount of solute (mol)}}{\text{volume of solution (L)}}$$

$$\text{Vol. of NaOH} = \frac{4.5 \text{ mL} \times 1\text{L}}{1000\text{mL}} = 0.0045 \text{ L}$$

Concentration of NaOH= 6.0 M = 6.0 mol/L

$$\text{Vol. of Stock Solution} = \frac{254.5 \text{ mL} \times 1\text{L}}{1000\text{mL}} = 0.2545\text{L}$$

Mol NaOH= 6.0 mol/L x 0.0045 L
Mol NaOH= 0.0270 mol

$$\text{Concentration} = \frac{0.0270 \text{ mol}}{0.2545\text{L}}$$

Concentration= 0.106 M

Therefore, the concentration of the stock solution is 0.106 M

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

$H_2A_{(aq)} + 2\ NaoH_{(aq)} \longrightarrow Na_2A + 2\ H_2O_2$

$nH_2A = nNaOH$

Using Data from Trial #1:

Visual Endpoint:
$2\ (C_aV_a) = C_bV_b$

$C_a = 0.100$ M $\qquad$ $C_b = ?$ $\qquad$ $V_a = 10.00$ mL

V_b(observed)= 10.65 mL

$C_b = [2(C_aV_a)/V_b]$
$C_b = [2(0.100M)(0.010L)/0.01065L)$
$C_b = 0.188$ M

Therefore, the concentration of the stock solution based on its visual endpoint is 0.188 M.

First Derivative from Titration Curve:
$2(C_aV_a)=C_bV_b$

C_a= 0.100 M C_b=? V_a= 10.00 mL

V_b(from curve)= 11.72 mL

$C_b = [2(C_aV_a)/V_b]$
C_b= [2(0.100M)(0.010L)/0.01172L)
C_b = 0.171M

Therefore, the concentration of the stock solution based on the first derivative of the titration curve is 0.171 M

3. Average concentration of stock solution:

Average concentration: $\frac{C_{b1} + C_{b2}}{2}$

Average concentration from Visual Endpoint= $\frac{0.188M + 0.160M}{2}$
Therefore the average concentration from Visual Endpoint= 0.174 M

Average concentration from First Derivative of Titration Curve
= $\frac{0.171M + 0.166M}{2}$
= 0.169 M

Therefore the average concentration from First Derivative of the Titration Curve is 0.169 M.

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

Data from Trial #3

$2(C_aV_a)=C_bV_b$

Visual Endpoint:
C_a= ? mol/L C_b= 0.171 M V_a= 10.10 mL or 0.0101L
V_b= 5.80 mL or 0.00580L

$C_a = (C_bV_b)/(2V_a)$
C_a= [(0.171 M)(0.00580 L)]/2(0.0101L)
C_a=0.049 M

Therefore the unknown acid has a concentration of 0.049 M based on the Visual Endpoint.

First Derivative from Titration Curve:
C_a= ? mol/L C_b= 0.171 M V_a= 10mL or 0.010L
V_b= 6.154 mL or 0.006154L

$C_a = (C_bV_b)/(2V_a)$
$C_a = [(0.171\ M)(0.006154\ L)]/2(0.010\ L)$
$C_a = 0.052\ M$

Therefore the unknown acid has a concentration of 0.052 M based on the First Derivative from the titration curve.

5. Average concentration of unknown acid:

Average concentration from visual endpoint= $\frac{Ca_1 + Ca_2 + Ca_3}{3}$

Average concentration from visual endpoint= $\frac{0.049\ M + 0.046\ M + 0.094\ M}{3}$
= 0.063 M

Therefore the unknown acid has an an average concentration of 0.063 M from its visual endpoint.

Average concentration from First Derivative of Titration Curve
$= \frac{Ca_1 + Ca_2 + Ca_3}{3}$
$= \frac{0.052\ M + 0.0414\ M + 0.058\ M}{3}$
= 0.052 M

Therefore the unknown acid has an average concentration of 0.052 M from its first derivative of the titration curve.

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

Data from Trial #1

$2 (C_aV_a)=C_bV_b$

Visual Endpoint:
C_a= ? mol/L C_b= 0.171 M V_a= 10.10 mL or 0.01005L
V_b= 9.20 mL or 0.00920 L

C_a= $(C_bV_b)/(2V_a)$
C_a= [(0.171 M)(0.00920L)]/2(0.01005 L)
C_a= 0.078 M

Therefore the concentration of acid in the juice would be 0.109 M based on the visual endpoint results.

First Derivative from Titration Curve:
C_a= ? mol/L C_b= 0.171 M V_a= 10mL or 0.010L
V_b= 10. 29 mL or 0.0129 L
C_a= $(C_bV_b)/(2V_a)$
C_a= [(0.171 M)(0.0129 L)]/2(0.010 L)
C_a= 0.109 M

Therefore the unknown acid has a concentration of 0.078 M based on the First Derivative from the titration curve.

7. Average concentration of acid in juice:

Average concentration from visual endpoint= $\frac{Ca_1 + Ca_2}{2}$

Average concentration from visual endpoint= $\frac{0.078\text{ M} + 0.071\text{M}}{2}$

= 0.075 M

Therefore the unknown acid has an an average concentration of 0.075 M from its visual endpoint.

Average concentration from First Derivative of Titration Curve

= $\frac{Ca_1 + Ca_2}{2}$

= $\frac{0.109\text{M} + 0.078\text{M}}{2}$

= 0.093 M

Therefore the unknown acid has an average concentration of 0.093 M from its first derivative of the titration curve.

8. Mass percentage of acid in juice:

Data from Trial #1:

Mass % of acid in the juice= $[(C_a)(MM_{\text{acid in juice}})]/(Density_{\text{juice}})$(1000 conversion factor g/mL —> kg/L) x100%

Molar Mass of $H_3C_6H_5O_7$= 192.14 g/mol C_a= 0.109 M

$Density_{juice}$= 1.0002 g/cm^3 which is equivalent to 1.0002 g/mL

Mass % of Acid in Juice= [(0.109 M)(192.14 g/mol)]/(1.0002 g/mL)(1000) x 100%
Mass % of Acid in Juice= 2.09%

Therefore, the mass percentage of acid in the juice is 2.09 %.

Discussion:

At the beginning of the lab it was super important to find the volume of the NaOH used to create the stock solution because this value would be need to calculate the concentration of the solution that would be used throughout the remainder of the lab. It was important to get this concentration right because it would be important for many further calculations. During our first trial we noted that the graph of our derivative of the pH showed not one but two major peaks. This was initially confusing because there should have only been one major peak occurring at the equivalence point but we think this was likely due to the fact that the magnetic stirring device was not fully functioning during our first trial and that this could have caused an uneven mixture of the stock solution and acid and that it resulted in weird numbers on our graph. This error thankfully did not affect the overall results as the second trial appeared to have both similar equivalent points visually, and graphically. The two endpoints were fairly close together but the disparity was logical because even focusing on the data screen showing the increase in volume as the titration progressed it was highly unlikely to get a perfectly accurate visual endpoint because the volume was increasing so quickly.
During the second part of the lab we were testing to find the concentration of the unknown acid by using the data we had obtained in the previous part as a reference. We were able to use the data to find the mathematical answer as well as observing the pH curves to compare. We noted that the graphs appeared to be similar noting that there must be a similar concentration although the more gradual slope would appear to indicate that the concentration might be lower. We decided to preform three trials of this test because there was one trial where the indicator was added later than it should have and as a result the visual endpoint was affected. One of the major sources of error for this lab had to do with the sensitivity of the equipment used. If things weren't measured or recorded exactly right, it would cause significant issues in the resulting data. For example if the materials weren't properly cleaned well enough in between tests it would cause problems from the left over residue such as perceiving the results between two tests to be more similar because of slight crossover of the solutions. During the third test we were testing to find the mass percent of acid in a juice and right away we noticed that the graphs were quite different which right away clued in that the composition of this solution would be very different than the standard solution. It was quite obvious that the equivalent point was very different when the visually retrieved point appeared to occur much quicker than in previous tests. The curves between the two trials were however similar enough that it made sense.

Conclusion:

The standardization of the NaOH allowed us to set a baseline example for which to compare the resulting pH curves and equivalent points of an acid with an unknown concentration and a juice with an unknown composition of acid. This comparison allowed us to determine to concentration and mass percentage of the respective solutions

Reference:

https://www.khanacademy.org/science/chemistry/acids-and-bases-topic/acids-and-bases/a/bronsted-lowry-acid-base-theory, Saul Khan, Khan Academy

Table 12: Partial Representation of the Raw Data of All Seven Titration Trials

	Run 1		Run 2		Run 3		Run 4		Run 5		Run 6		Run 7	
	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH	Volume (mL)	pH
1	0.000	2.21	0.000	2.25	0.000	2.48	0.000	2.47	0.000	2.55	0.000	3.09	0.000	3.08
2	0.053	2.21	0.053	2.25	0.053	2.48	0.053	2.46	0.053	2.53	0.053	3.09	0.053	3.06
3	0.106	2.21	0.106	2.24	0.106	2.48	0.106	2.46	0.106	2.53	0.106	3.08	0.106	3.05
4	0.159	2.21	0.159	2.24	0.159	2.48	0.159	2.46	0.159	2.52	0.159	3.08	0.159	3.05
5	0.212	2.21	0.212	2.24	0.212	2.48	0.212	2.46	0.212	2.52	0.212	3.08	0.212	3.04
6	0.265	2.21	0.265	2.24	0.265	2.48	0.265	2.46	0.265	2.52	0.265	3.08	0.265	3.03
7	0.318	2.21	0.318	2.24	0.318	2.47	0.318	2.46	0.318	2.52	0.318	3.07	0.318	3.03
8	0.371	2.20	0.371	2.24	0.371	2.47	0.371	2.46	0.371	2.52	0.371	3.05	0.371	3.03
9	0.424	2.21	0.424	2.24	0.424	2.47	0.424	2.46	0.424	2.52	0.424	3.05	0.424	3.03
10	0.477	2.21	0.477	2.24	0.477	2.47	0.477	2.46	0.477	2.51	0.477	3.03	0.477	3.02
11	0.531	2.21	0.531	2.24	0.531	2.47	0.531	2.46	0.531	2.51	0.531	3.01	0.531	3.03
12	0.584	2.21	0.584	2.24	0.584	2.47	0.584	2.46	0.584	2.51	0.584	3.01	0.584	3.03
13	0.637	2.21	0.637	2.24	0.637	2.47	0.637	2.46	0.637	2.51	0.637	2.99	0.637	3.03
14	0.690	2.21	0.690	2.24	0.690	2.47	0.690	2.46	0.690	2.51	0.690	2.99	0.690	3.03
15	0.743	2.21	0.743	2.24	0.743	2.47	0.743	2.46	0.743	2.51	0.743	2.99	0.743	3.03
16	0.796	2.21	0.796	2.24	0.796	2.47	0.796	2.46	0.796	2.51	0.796	2.99	0.796	3.04
17	0.849	2.21	0.849	2.24	0.849	2.47	0.849	2.46	0.849	2.51	0.849	2.99	0.849	3.05
18	0.902	2.20	0.902	2.23	0.902	2.47	0.902	2.46	0.902	2.52	0.902	3.00	0.902	3.05
19	0.955	2.20	0.955	2.23	0.955	2.48	0.955	2.46	0.955	2.51	0.955	3.00	0.955	3.07
20	1.008	2.20	1.008	2.24	1.008	2.49	1.008	2.46	1.008	2.51	1.008	3.02	1.008	3.08
21	1.061	2.20	1.061	2.23	1.061	2.49	1.061	2.46	1.061	2.52	1.061	3.04	1.061	3.09
22	1.114	2.21	1.114	2.23	1.114	2.51	1.114	2.46	1.114	2.52	1.114	3.05	1.114	3.10
23	1.167	2.20	1.167	2.23	1.167	2.51	1.167	2.47	1.167	2.54	1.167	3.05	1.167	3.11
24	1.220	2.21	1.220	2.23	1.220	2.50	1.220	2.46	1.220	2.56	1.220	3.06	1.220	3.11
25	1.273	2.20	1.273	2.23	1.273	2.50	1.273	2.47	1.273	2.55	1.273	3.06	1.273	3.12
26	1.326	2.20	1.326	2.23	1.326	2.51	1.326	2.47	1.326	2.57	1.326	3.07	1.326	3.13
27	1.379	2.20	1.379	2.23	1.379	2.51	1.379	2.47	1.379	2.57	1.379	3.07	1.379	3.13
28	1.432	2.21	1.432	2.23	1.432	2.52	1.432	2.47	1.432	2.57	1.432	3.07	1.432	3.13
29	1.485	2.20	1.485	2.23	1.485	2.53	1.485	2.48	1.485	2.57	1.485	3.08	1.485	3.16
30	1.538	2.20	1.538	2.23	1.538	2.55	1.538	2.48	1.538	2.57	1.538	3.09	1.538	3.19

ρ=1.0002 g/cm³ → Juice #5
unknown acid #2

Trial 1

NaOH → clear colourless sol'n (4.5 mL)
distilled water → clear colourless sol'n (250 mL)

7.8 mL NaOH sol'n (147 drops)

25 mL 0.1000 HCl (clear + colourless

HCl in buret came to 2.4 mL on the buret
after flowing some HCl it came to 4.15 mL

14.15 mL Final buret reading + 3 drops 0.1 M phenophthalein
↳ 10.00 mL in beaker
pH 2.22

10.650 mL - colour turned pale pink
Final pH 11.31

Trial 2

Final burette reading 24.20 mL (10.05 mL)

10.5 mL - colour turned pale pink
Final pH 11.45

Acid #2:
Trial #1 UA #2
first buret reading 2.05 mL
after flow reading 4.00 mL
Final buret reading 14.00 mL (10.00 mL in beaker)

colour changed at 11.2 mL 11.65 pH

Trial 2 UA#2
initial buret reading 14.00mL
Final reading 24.10 mL

5.65 mL colour change (light pink) 11.60 pH

Trial #3 Acid 3
Unknown

Initial 2.1 mL
+flow 3.45 mL
final 13.55 mL (1.10mL)

colour changed at 5.8 mL light pink
pH 11.33

Trial #1 Juice 5

Initial reading 1.75 mL
+flow 3.15 mL
Final 13.2 mL (10.05 mL sample.

colour changed at 9.2 mL pale pink pH 11.2

Trial 2 Juice 5
Initial 13.2 mL
Final 23.2 mL (10.00 mL sample) pH 11.45

~~colour changed at 8.5 mL light pink~~