Acid Base Titration

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Introduction:

Acids and Bases:

According to Brønsted-Lowry theory an acid is a substance that can transfer a proton to another compound, and a base is a substance that accepts a proton. For example, an acid HA, on dissociation would produce H^+ and a base AOH would give up OH^- ions.

When an acid/base dissociates completely into its ions it is said to be a strong acid/base, however, when it doesn't dissociate completely into its ions it is said to be a weak acid/base.

The concentration of an acid or base is directly proportional to the number of moles of the solute and inversely proportional to the volume of the solution in which it is dissolved.

Titrations of Acids and Bases:

Acids react with bases to neutralize the solution and form either neutral, acidic or basic salts. Every titration reaction reaches a point called, equivalence point at which the number of moles of the acid equal the number of moles of the base. And at this point the following formula can be used to determine an unknown concertation of the acid or the base:

$$C_{base} * V_{base} = C_{acid} * V_{acid}$$

Throughout this experiment we will be using the above-mentioned formula to first calcite the approximate concentration of the NaOH solution, then the exact concentration of the NaOH solution and then finally use the exact concentration of the base and titrate it with the given unknown acid to determine its concentration.

Procedure:

As described in the lab manual (Ref).

Data and Observations:

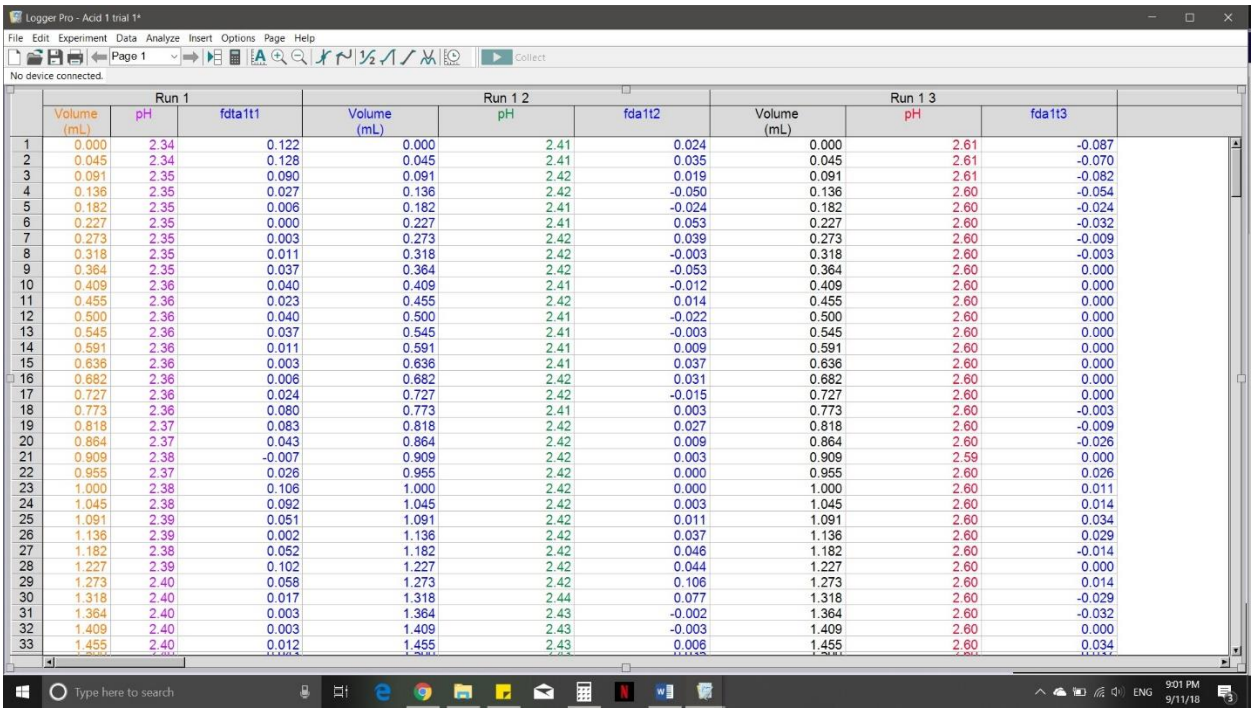
1. Observations for the titration of HCl acid:

During the titration experiment, 3 drops of phenolphthalein was poured into the beaker containing the Hydrochloric Acid. This was done so that when the solution reached the equivalence point, the mixture would change its color and turn from a clear solution to light pink in color. According to our observation, at the following volumes of the base the equivalence point was reached, and the color of the solution went from transparent to light pink.

Trial Number	Volume of NaOH at which the HCl solution changes color (in mL)
1.	9.227
2.	9.318

3.	9.409

A partial representation of the data collected in the titration of HCl acid with NaOH solution:



Logger Pro - Acid 1 trial 1*

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	Run 1			Run 1 2			Run 1 3		
	Volume (mL)	pH	fdta1t1	Volume (mL)	pH	fda1t2	Volume (mL)	pH	fda1t3
1	0.000	2.34	0.122	0.000	2.41	0.024	0.000	2.61	-0.087
2	0.045	2.34	0.128	0.045	2.41	0.035	0.045	2.61	-0.070
3	0.091	2.35	0.090	0.091	2.42	0.019	0.091	2.61	-0.082
4	0.136	2.35	0.027	0.136	2.42	-0.050	0.136	2.60	-0.054
5	0.182	2.35	0.006	0.182	2.41	-0.024	0.182	2.60	-0.024
6	0.227	2.35	0.000	0.227	2.41	0.053	0.227	2.60	-0.032
7	0.273	2.35	0.003	0.273	2.42	0.039	0.273	2.60	-0.009
8	0.318	2.35	0.011	0.318	2.42	-0.003	0.318	2.60	-0.003
9	0.364	2.35	0.037	0.364	2.42	-0.053	0.364	2.60	0.000
10	0.409	2.36	0.040	0.409	2.41	-0.012	0.409	2.60	0.000
11	0.455	2.36	0.023	0.455	2.42	0.014	0.455	2.60	0.000
12	0.500	2.36	0.040	0.500	2.41	-0.022	0.500	2.60	0.000
13	0.545	2.36	0.037	0.545	2.41	-0.003	0.545	2.60	0.000
14	0.591	2.36	0.011	0.591	2.41	0.009	0.591	2.60	0.000
15	0.636	2.36	0.003	0.636	2.41	0.037	0.636	2.60	0.000
16	0.682	2.36	0.006	0.682	2.42	0.031	0.682	2.60	0.000
17	0.727	2.36	0.024	0.727	2.42	-0.015	0.727	2.60	0.000
18	0.773	2.36	0.080	0.773	2.41	0.003	0.773	2.60	-0.003
19	0.818	2.37	0.083	0.818	2.42	0.027	0.818	2.60	-0.009
20	0.864	2.37	0.043	0.864	2.42	0.009	0.864	2.60	-0.026
21	0.909	2.38	-0.007	0.909	2.42	0.003	0.909	2.59	0.000
22	0.955	2.37	0.026	0.955	2.42	0.000	0.955	2.60	0.026
23	1.000	2.38	0.106	1.000	2.42	0.000	1.000	2.60	0.011
24	1.045	2.38	0.092	1.045	2.42	0.003	1.045	2.60	0.014
25	1.091	2.39	0.051	1.091	2.42	0.011	1.091	2.60	0.034
26	1.136	2.39	0.002	1.136	2.42	0.037	1.136	2.60	0.029
27	1.182	2.38	0.052	1.182	2.42	0.046	1.182	2.60	-0.014
28	1.227	2.39	0.102	1.227	2.42	0.044	1.227	2.60	0.000
29	1.273	2.40	0.058	1.273	2.42	0.106	1.273	2.60	0.014
30	1.318	2.40	0.017	1.318	2.44	0.077	1.318	2.60	-0.029
31	1.364	2.40	0.003	1.364	2.43	-0.002	1.364	2.60	-0.032
32	1.409	2.40	0.003	1.409	2.43	-0.003	1.409	2.60	0.000
33	1.455	2.40	0.012	1.455	2.43	0.006	1.455	2.60	0.034

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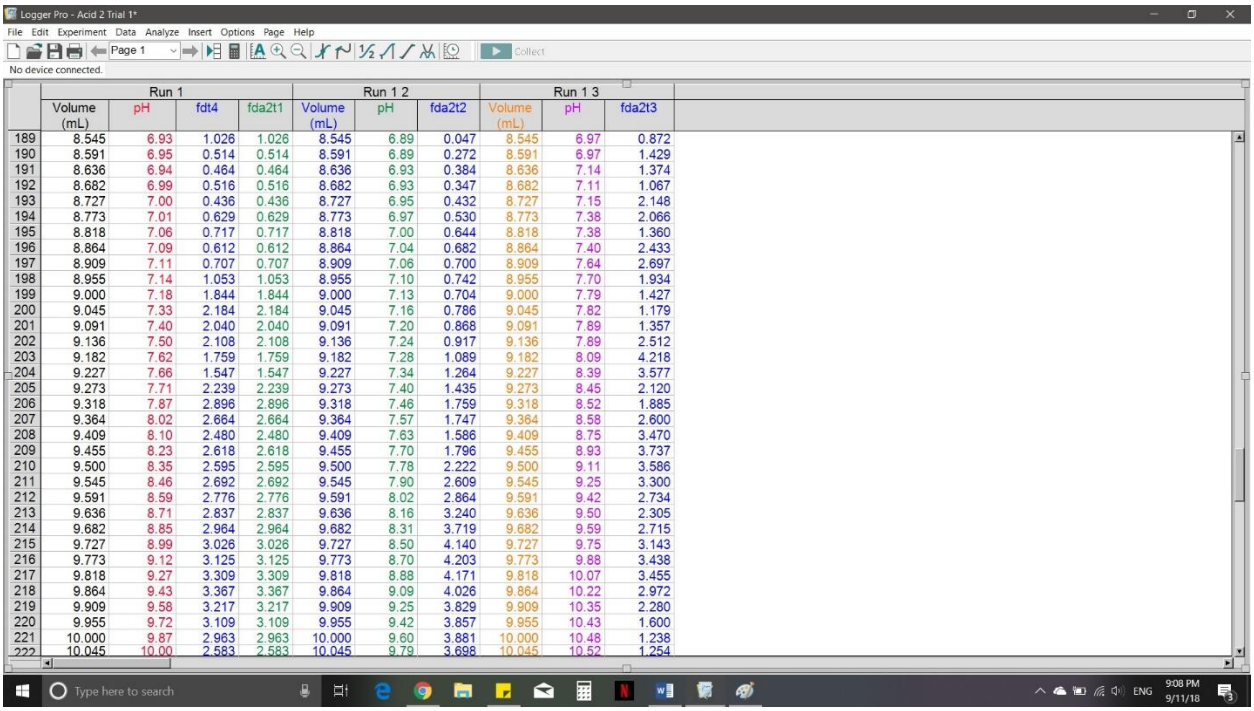
2. Observations for the titration of the provided unknown diprotic acid (Number 1):

During the next part of the titration experiment, 3 drops of phenolphthalein was poured into the beaker containing the unknown diprotic acid. This was done so that when the solution reached the equivalence point, the mixture would change its color and turn from a clear solution to light pink in color. According to our observation, at the following volumes of the base the equivalence point for the unknown acid was reached, and the color of the solution went from transparent to light pink.

Trial Number	Volume of NaOH at which the unknown diprotic acid solution changes its color (in mL)
1.	9.227
2.	9.409
3.	9.318

A partial representation of the data collected in the titration of the unknown diprotic acid with NaOH:


Logger Pro - Acid 2 Trial 1*

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	Run 1				Run 1 2			Run 1 3		
	Volume (mL)	pH	fdt4	fda2t1	Volume (mL)	pH	fda2t2	Volume (mL)	pH	fda2t3
189	8.545	6.93	1.026	1.026	8.545	6.89	0.047	8.545	6.97	0.872
190	8.591	6.95	0.514	0.514	8.591	6.89	0.272	8.591	6.97	1.429
191	8.636	6.94	0.464	0.464	8.636	6.93	0.384	8.636	7.14	1.374
192	8.682	6.99	0.516	0.516	8.682	6.93	0.347	8.682	7.11	1.067
193	8.727	7.00	0.436	0.436	8.727	6.95	0.432	8.727	7.15	2.148
194	8.773	7.01	0.629	0.629	8.773	6.97	0.530	8.773	7.38	2.066
195	8.818	7.06	0.717	0.717	8.818	7.00	0.644	8.818	7.38	1.360
196	8.864	7.09	0.612	0.612	8.864	7.04	0.682	8.864	7.40	2.433
197	8.909	7.11	0.707	0.707	8.909	7.06	0.700	8.909	7.64	2.697
198	8.955	7.14	1.053	1.053	8.955	7.10	0.742	8.955	7.70	1.934
199	9.000	7.18	1.844	1.844	9.000	7.13	0.704	9.000	7.79	1.427
200	9.045	7.33	2.184	2.184	9.045	7.16	0.786	9.045	7.82	1.179
201	9.091	7.40	2.040	2.040	9.091	7.20	0.868	9.091	7.89	1.357
202	9.136	7.50	2.108	2.108	9.136	7.24	0.917	9.136	7.89	2.512
203	9.182	7.62	1.759	1.759	9.182	7.28	1.089	9.182	8.09	4.218
204	9.227	7.66	1.547	1.547	9.227	7.34	1.264	9.227	8.39	3.577
205	9.273	7.71	2.239	2.239	9.273	7.40	1.435	9.273	8.45	2.120
206	9.318	7.87	2.896	2.896	9.318	7.46	1.759	9.318	8.52	1.885
207	9.364	8.02	2.664	2.664	9.364	7.57	1.747	9.364	8.58	2.600
208	9.409	8.10	2.480	2.480	9.409	7.63	1.586	9.409	8.75	3.470
209	9.455	8.23	2.618	2.618	9.455	7.70	1.796	9.455	8.93	3.737
210	9.500	8.35	2.595	2.595	9.500	7.78	2.222	9.500	9.11	3.586
211	9.545	8.46	2.692	2.692	9.545	7.90	2.609	9.545	9.25	3.300
212	9.591	8.59	2.776	2.776	9.591	8.02	2.864	9.591	9.42	2.734
213	9.636	8.71	2.837	2.837	9.636	8.16	3.240	9.636	9.50	2.305
214	9.682	8.85	2.964	2.964	9.682	8.31	3.719	9.682	9.59	2.715
215	9.727	8.99	3.026	3.026	9.727	8.50	4.140	9.727	9.75	3.143
216	9.773	9.12	3.125	3.125	9.773	8.70	4.203	9.773	9.88	3.438
217	9.818	9.27	3.309	3.309	9.818	8.88	4.171	9.818	10.07	3.455
218	9.864	9.43	3.367	3.367	9.864	9.09	4.026	9.864	10.22	2.972
219	9.909	9.58	3.217	3.217	9.909	9.25	3.829	9.909	10.35	2.280
220	9.955	9.72	3.109	3.109	9.955	9.42	3.857	9.955	10.43	1.600
221	10.000	9.87	2.963	2.963	10.000	9.60	3.881	10.000	10.48	1.238
222	10.045	10.00	2.583	2.583	10.045	9.79	3.698	10.045	10.52	1.254

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Calculations:

1. Approximate concentration of NaOH solution:

To determine the approximate concentration of the Sodium Hydroxide (NaOH) solution that was used throughout the experiment, we can use the following formula:

$$C_1V_1 = C_2V_2$$

Where, C_1 refers to the initial concentration of the NaOH solution, i.e., 6 mol/L,

V_1 is the initial volume of the NaOH solution, i.e., 5 mL,

C_2 is the approximate concentration of the new NaOH solution, and is yet to be found,

V_2 is the total volume of the new NaOH solution, i.e., 255mL (250 + 5),

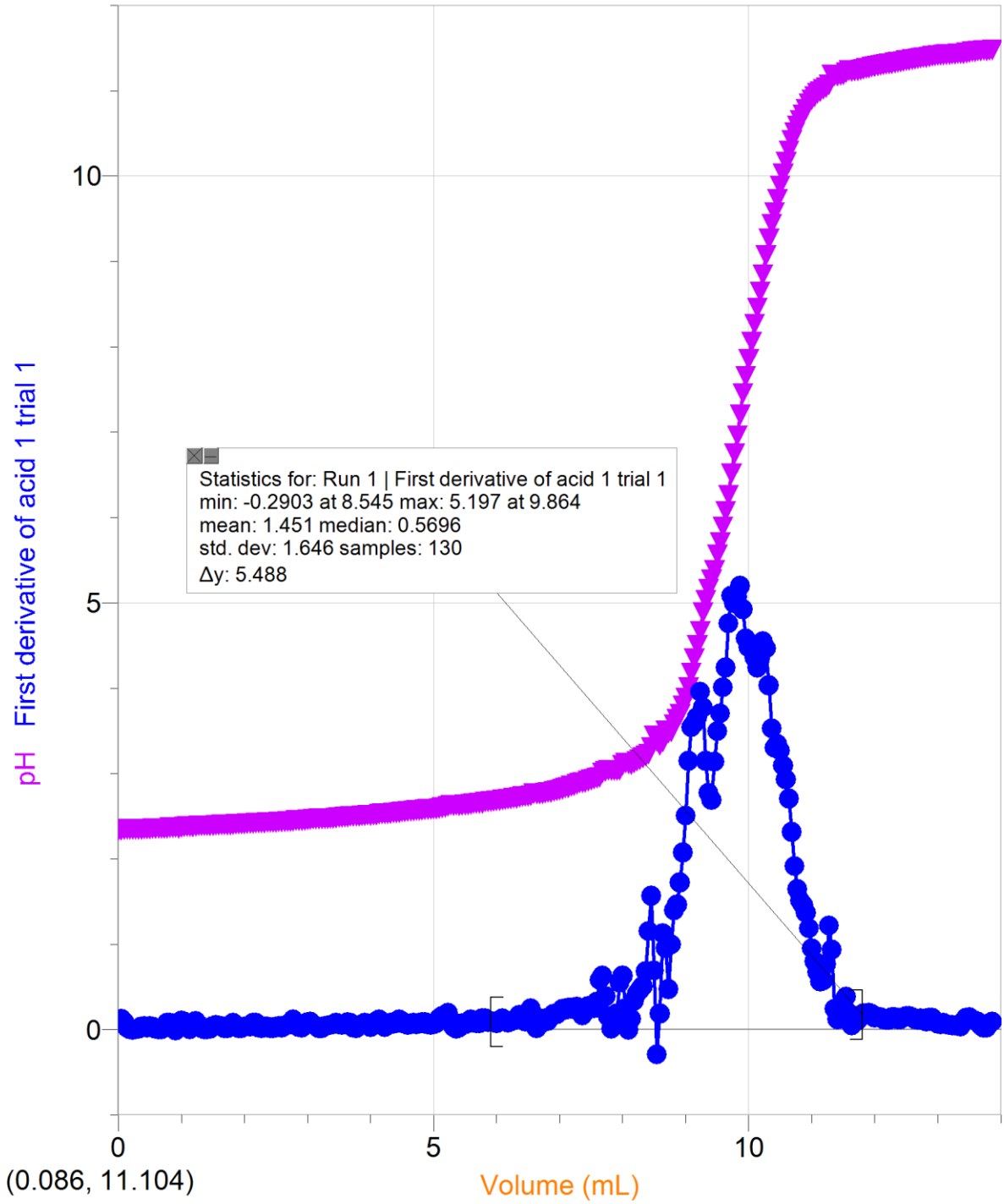
$$(6) * (5) = (C_2) * (255)$$

$$C_2 = 0.\underline{1}18 \text{ mol/L} \qquad \text{(1 sig digit)}$$

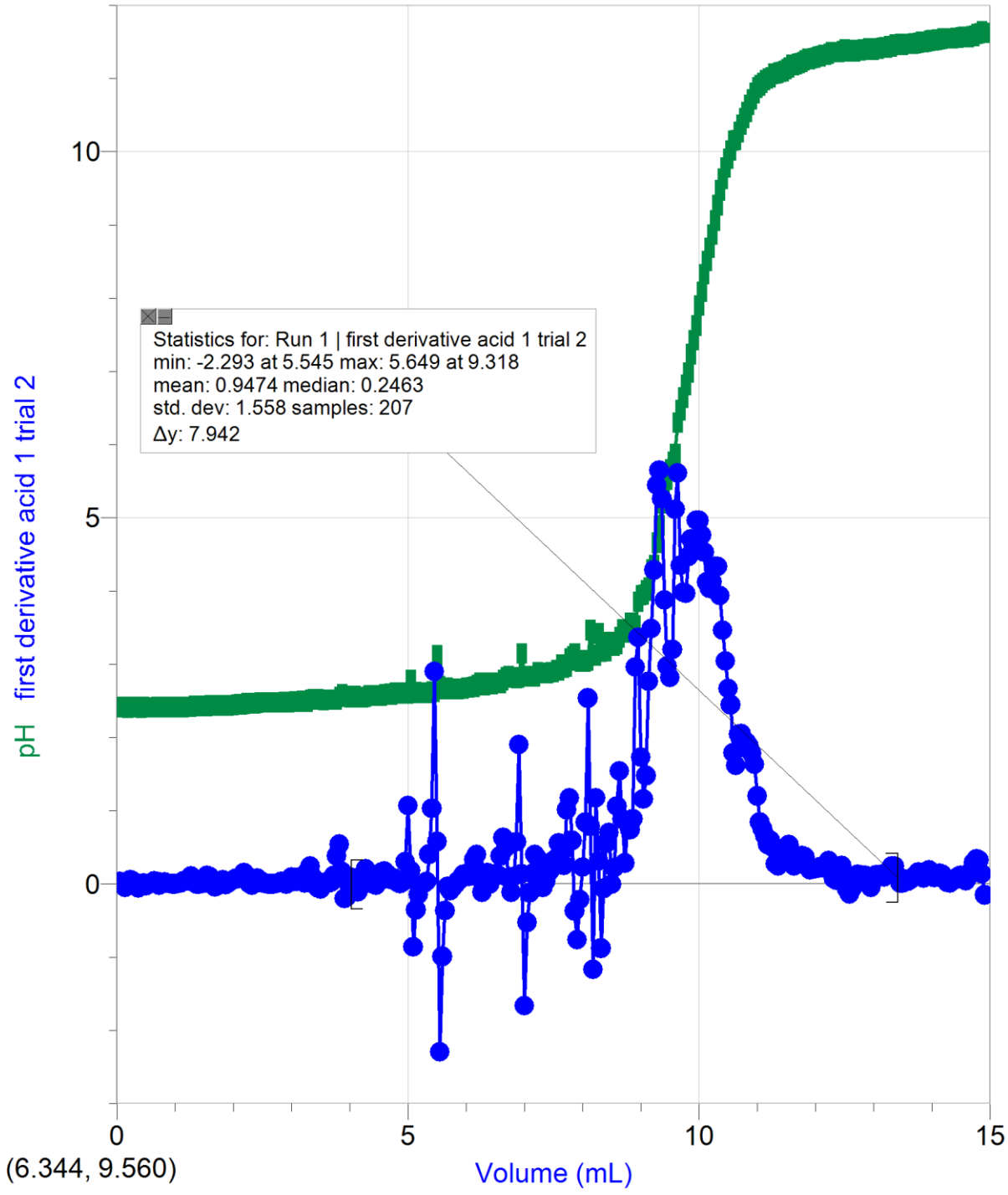
Therefore, the approximate concentration of the NaOH solution we are using in this experiment is 0.1 mol/L.

2. Concentration of NaOH solution determined from the experiment with HCl acid:

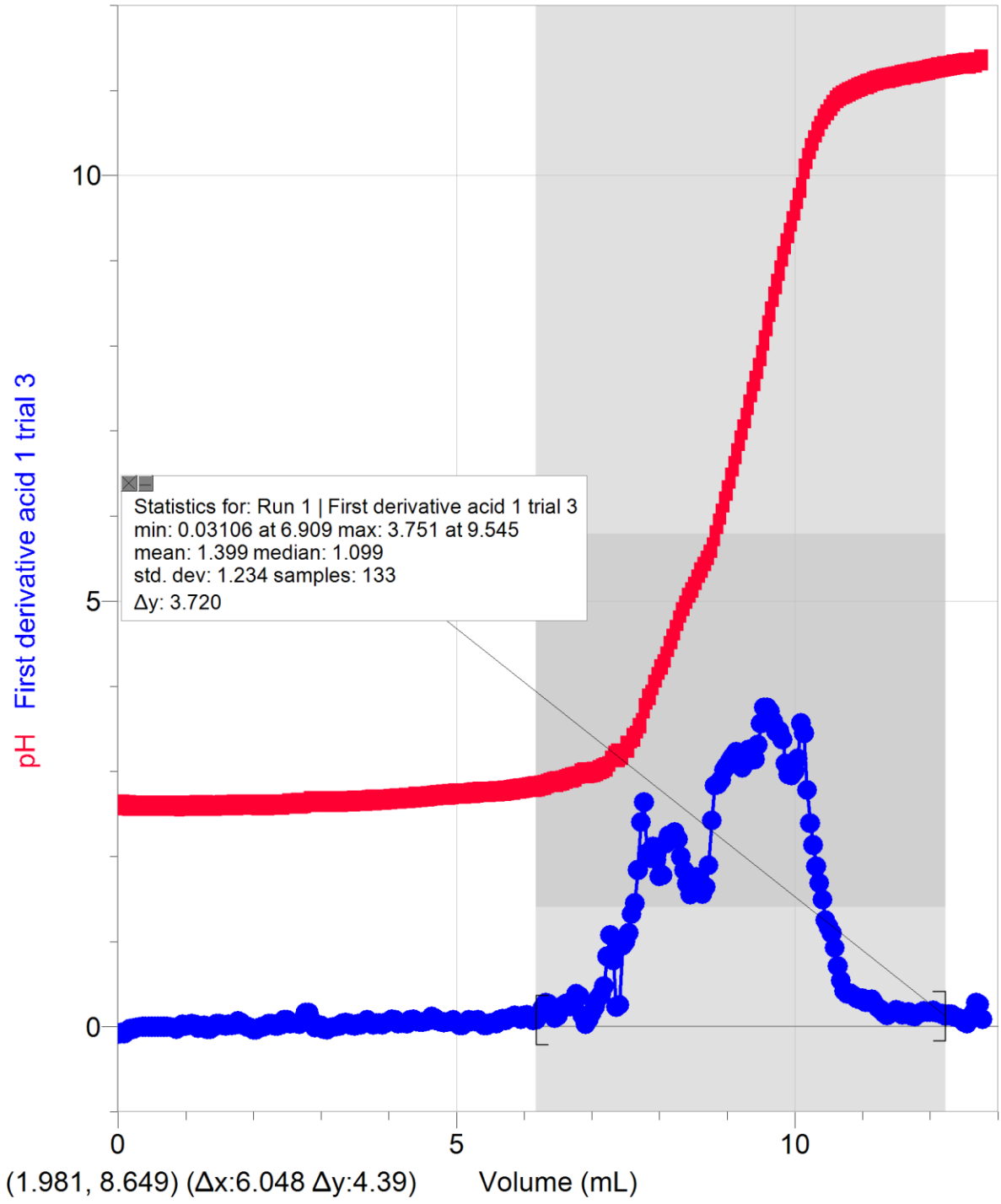
Trial 1 for HCl acid:



Trial 2 for HCl acid:



Trial 3 for HCl acid:



For our sample calculation we can see from the graph of the first trial with HCl acid attached above, that the equivalence point, i.e., the volume of the base where the first derivative is the highest, is 9.864 mL, to determine the concentration of NaOH solution we can again use the same formula $C_1V_1 = C_2V_2$. In this case,

C_1 is the concentration of the HCl acid, which is 0.1 mol/L,

V_1 is the volume of the HCl acid, which is 10.0 mL,

C_2 is the concentration of the base NaOH, which we are trying to find out,

And V_2 is the volume of the equivalence point, which is 9.864 mL

$$(0.1) * (10.0) = (C_2) * (9.864)$$

$$C_2 = 0.1014 \text{ mol/L}$$

From this sample calculation we see that the concentration of the NaOH solution is 0.1014 mol/L.

Similarly, we can calculate the concentration from the other trials and determine the average concentration of the NaOH solution.

Trial Number	C_1 (in mol/L)	V_1 (in mL)	V_2 (in mL)	C_2 (in mol/L)
1	0.1	10	9.864	0.101379
2	0.1	10.2	9.318	0.109466
3	0.1	10	9.545	0.104767

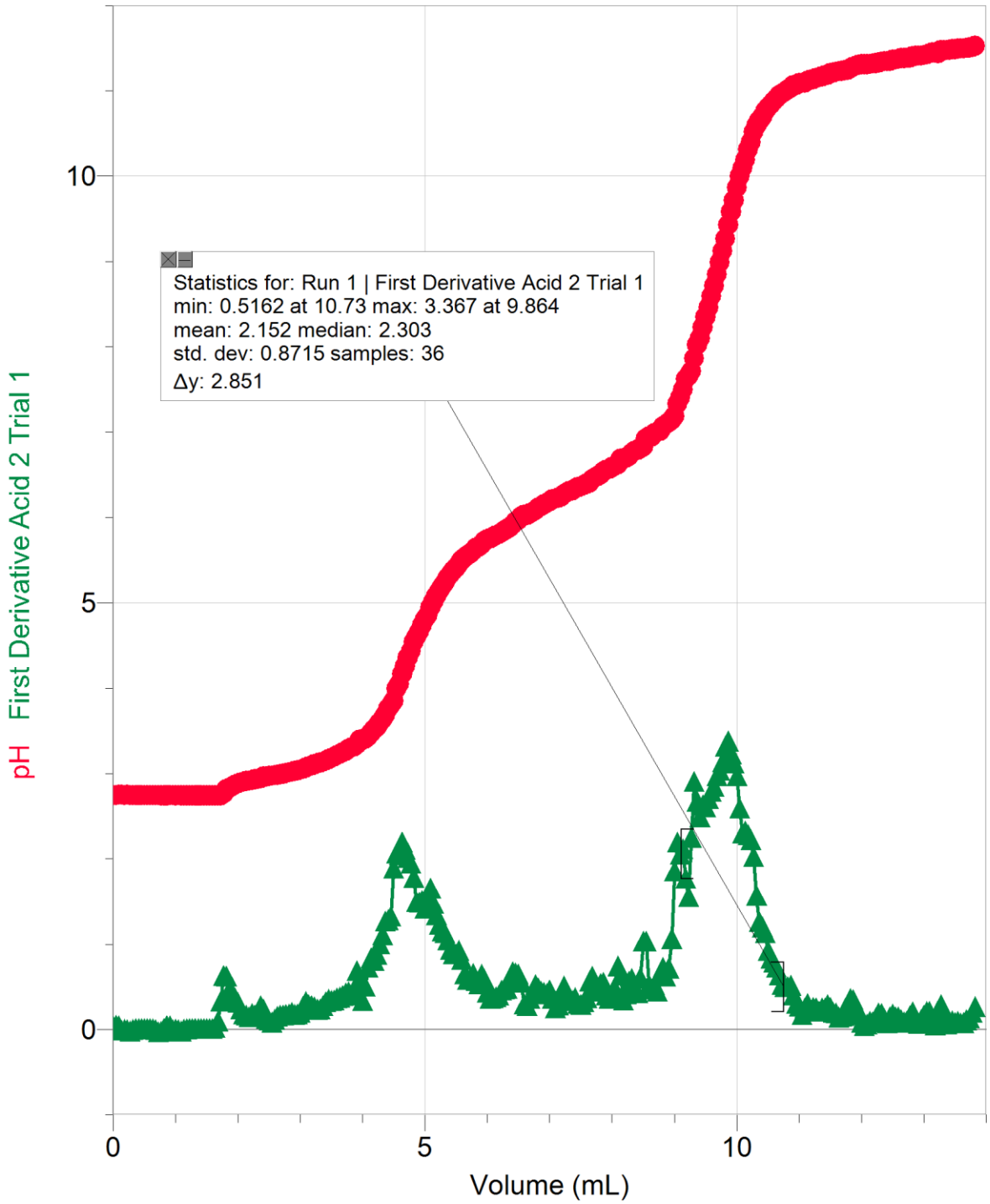
Hence, the average concentration of the NaOH solution we were using can be calculated as:

$C_{avg.} = (0.101379 + 0.109466 + 0.104767)/3 = 0.1052$ mol/L.

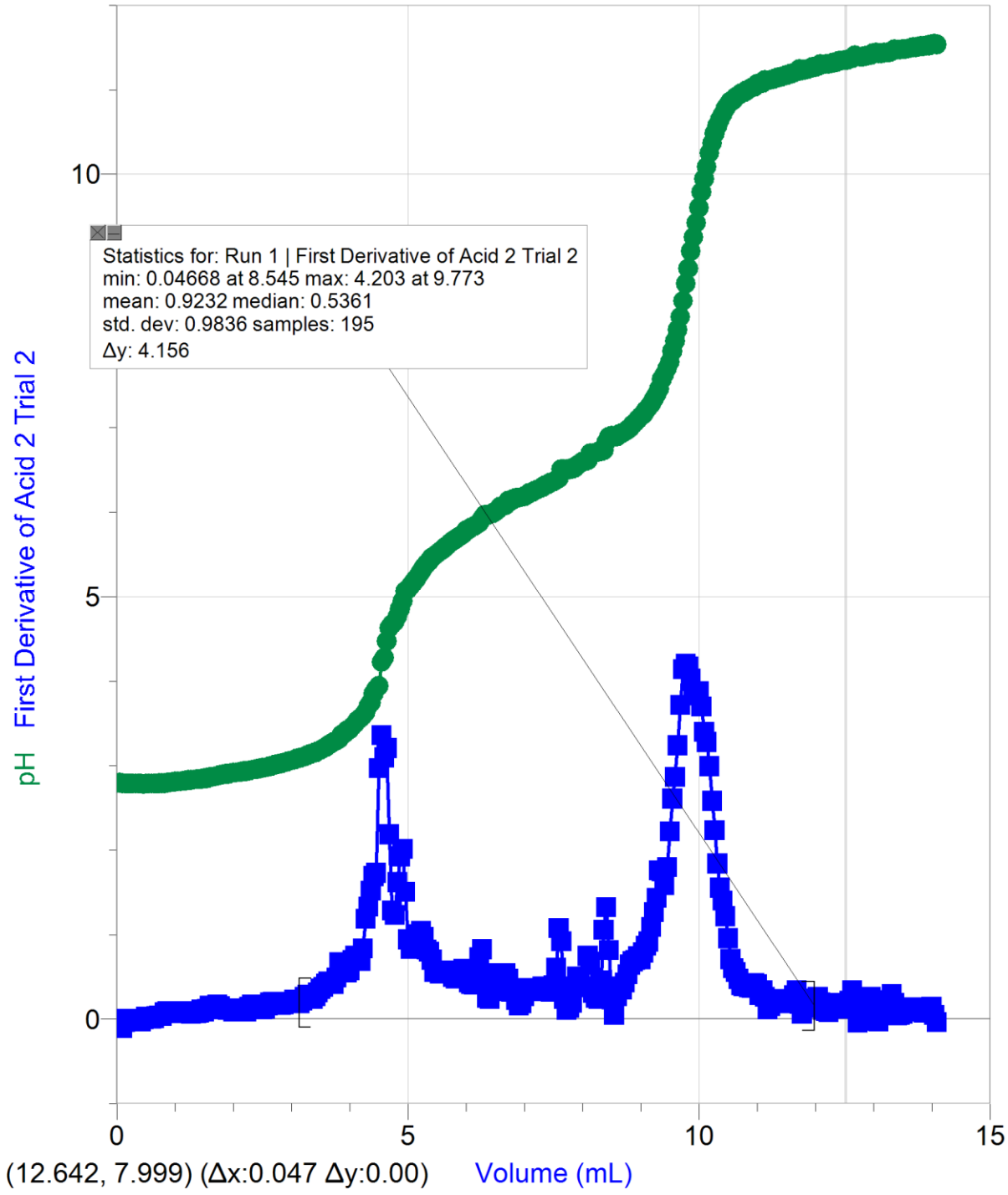
Therefore, the concentration of the NaOH solution is found to be 0.1052 mol/L.

3. Concentration of the unknown diprotic acid (Number 1):

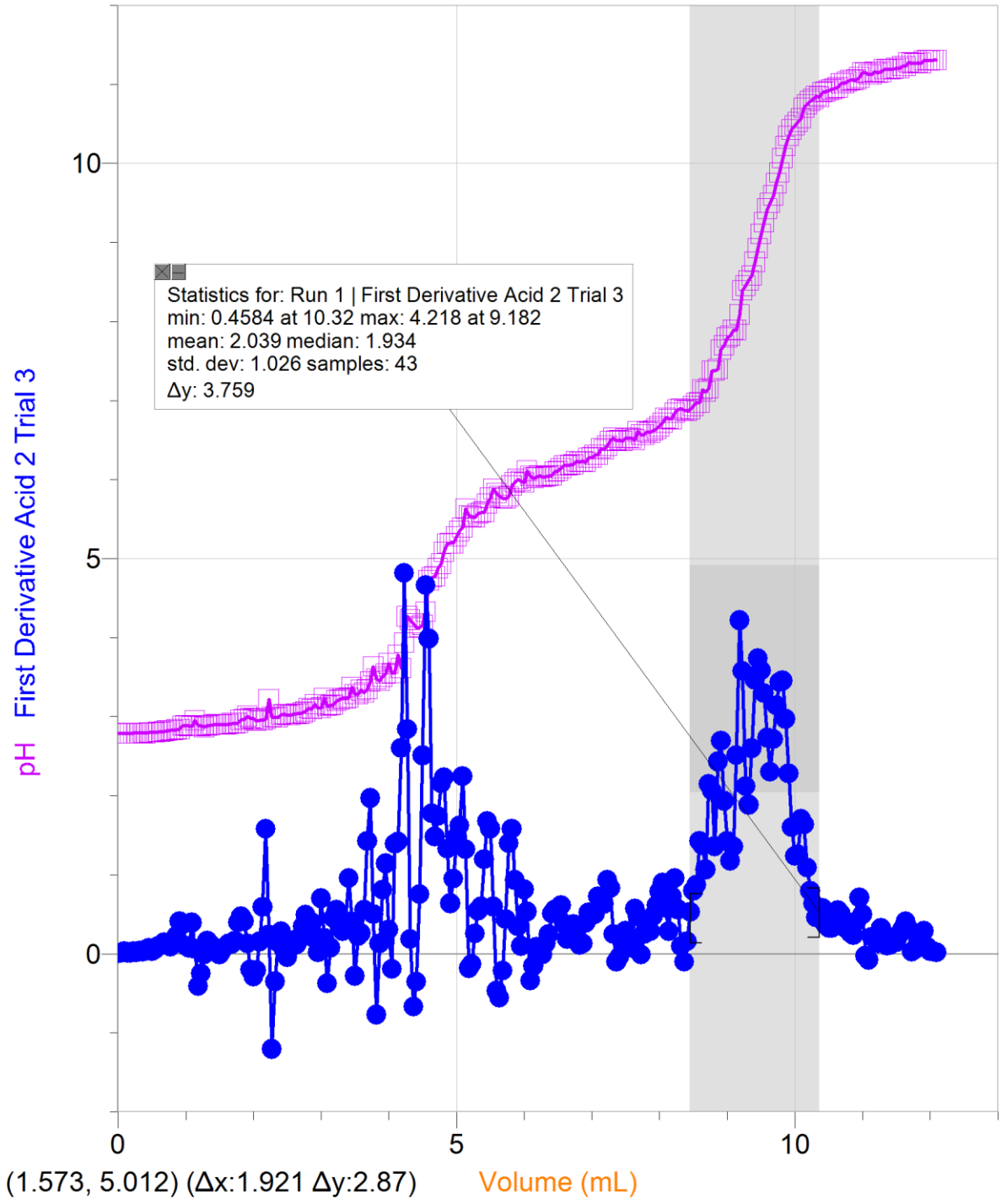
Trial 1 for the unknown diprotic acid:



Trial 2 for the unknown diprotic acid:



Trial 3 for the unknown diprotic acid:



From the previous calculation we know that the concentration of the NaOH solution is 0.1052 mol/L. We are now going to use this concentration to find the concentration of the unknown diprotic acid (number 1) that was given to us in the lab.

The reaction of the NaOH base with the unknown diprotic acid (H_2A) would be as follows:

$$H_2A\ (aq) + 2NaOH\ (aq) \rightarrow Na_2A\ (aq) + 2H_2O\ (l)$$

From the above-mentioned reaction, we can come up with the following equation, that would help us find out the concentration of the unknown diprotic acid:

$$C_{base} * V_{base} = 2\ C_{acid} * V_{acid}$$

For our sample calculation we can see from the graph of the first trial of the unknown diprotic acid attached above, that the equivalence point, i.e., the volume of the base where the first derivative is the highest, is 9.864 mL, to determine the concentration of the unknown acid we can again use the formula $C_{base} * V_{base} = 2\ C_{acid} * V_{acid}$. In this case,

C_{base} is the concentration of the NaOH solution, which was found to be 0.1052 mol/L,

V_{base} is the volume of the NaOH, which is 9.864 mL,

C_{acid} is the concentration of the unknown acid, which we are trying to find out,

And V_{acid} is the volume of the acid in the beaker, which is 10.0 mL

$$(0.1052) * (9.864) = 2\ (C_{acid}) * (10.0)$$

$$C_{acid} = 0.051885\ mol/L$$

From this sample calculation we see that the concentration of the given unknown acid is 0.051885 mol/L.

Similarly, we can calculate the concentration of the unknown acid form the other trials as well,

Trial Number	C_{base} (in mol/L)	V_{base} (in mL)	V_{acid} (in mL)	C_{acid} (in mol/L)
1	0.1052	9.864	10	0.051885
2	0.1052	9.773	10	0.051406
3	0.1052	9.182	10	0.048297

Hence, the average concentration of the unknown diprotic acid we were given can be calculated as:

$$C_{avg.} = (0.0.051885 + 0.051406 + 0.048297)/3 = 0.0505\ mol/L.$$

Therefore, the concentration of the unknown diprotic acid (number 1) is found to be 0.0505 mol/L

Discussion:

The main objective of this lab was to determine the concentration of the acid that was provided to us in the lab, using the Sodium Hydroxide base solution we made. However, in order to achieve that we must go through three different steps: firstly to calculate approximate concentration of the base, second was to find the actual concentration of the base and then finally we would be able to calculate the concentration of unknown diprotic acid.

While making the NaOH solution we were given its initial concentration in only 1 significant digit (6 mol/L), and hence we were left with just an approximate concentration of the NaOH solution, which was 0.1 mol/L. In order to continue with the experiment of finding the concentration of the unknown diprotic acid we would first have to know the exact concentration of the base.

In order to find the exact concentration of the base we titrated Hydrochloric Acid (mol/L), after titrating HCl acid for three times we came up with the average concentration of NaOH to be 0.1052 mol/L.

Now, with this known concentration of the base we titrated the given unknown diprotic acid for three times and using the formula $C_{base} * V_{base} = 2\ C_{acid} * V_{acid}$, we found the concentration of the unknown acid to be 0.0505 mol/L.

The errors in manually finding out the equivalence point of the acid-base titration, by noting the volume at which the solution in the beaker changes color, could possibly be due to the fast changing value of volume on the lab quest, however when the actual values from the graph are compared to the values that were noted down manually there was not much great difference, and almost all noted values were very close to the actual values.

Even when the trials are compared to each other the volume at which the equivalence point is reached appears to be virtually the same. Thus, it can be said that the errors made in this experiment are insignificant and hence negligible.

Conclusion:

In conclusion, there were three major parts to this experiment:

Firstly, it was the approximate concentration of the NaOH solution which was found out to be 0.1 mol/L.

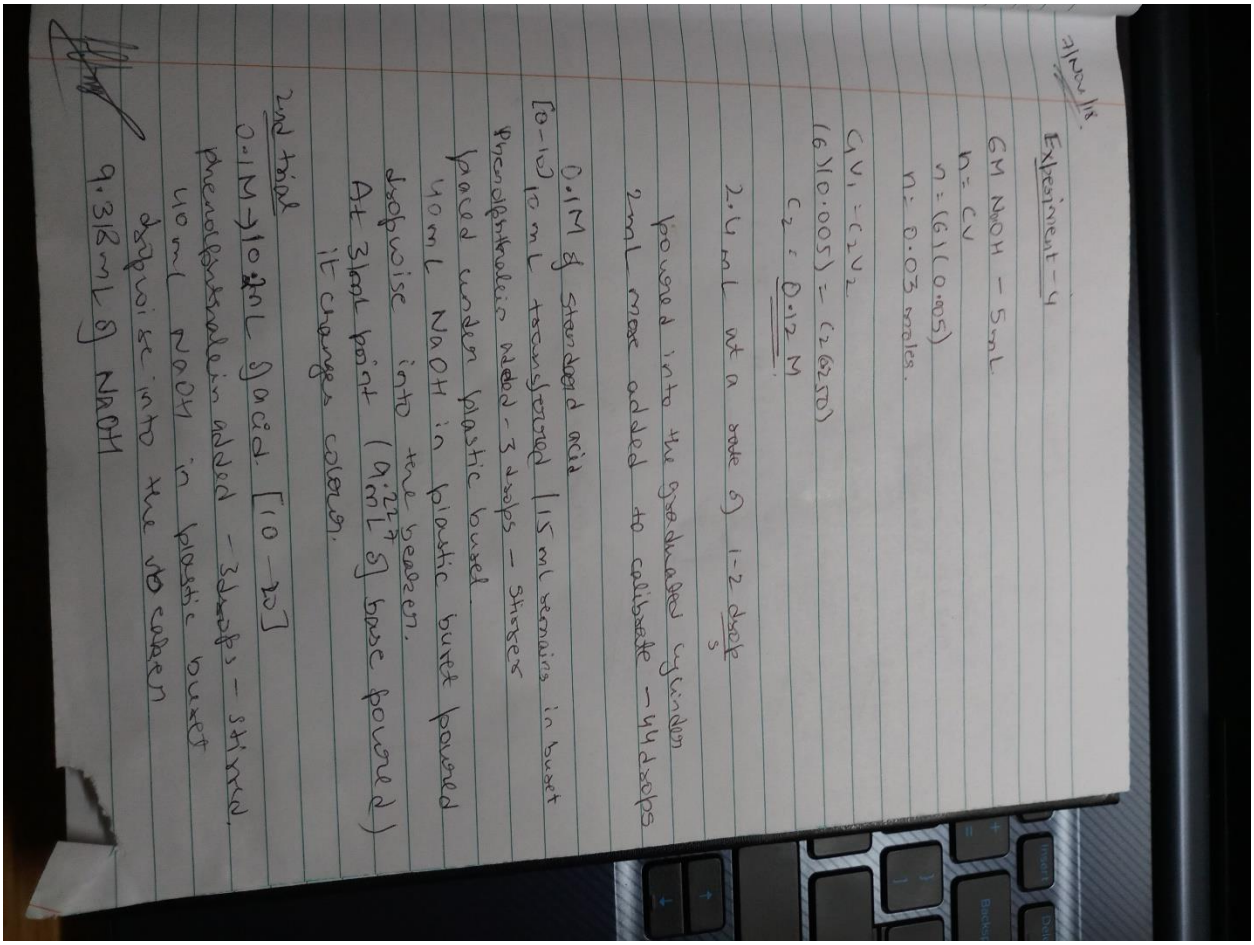
Second, was to use the monoprotic acid HCl (0.1 mol/L) and find the exact concentration of the NaOH solution we were using, and that turned out to have a concentration of 0.1052 mol/L.

The final part of this lab was to find the concentration of the unknown diprotic acid (Number 1) that was given to us, this turned out to have a concentration of 0.0505 mol/L.

References:

"OH, HOW BITTER A THING IT IS..." ACID BASE TITRATIONS, Exp. 4

Raw Data:



Dibasic: (Number 1 acid)

Trial 1:
10.0 ml of acid in the beaker [0 – 10]
3 drops of indicator.
9.227 ml changes color
g NaOH

Trial 2
10.0 ml of acid [10 – 20]
3 drops → 9.409 ml of NaOH change color

Trial 3
10.0 mL of acid [11.7 – 21.7]
9.318 → changes color.

1st acid:
3rd trial:
10.0 ml (0 – 10)
9.409 ml → change color