

Experiment 3: Acid-Base Titration

By Emma Brown
8152045

Lab Partner: Melanie Chang
880357

CHM1311

Demonstrator: Alex Therien

October 21, 2016

University of Ottawa

Introduction:

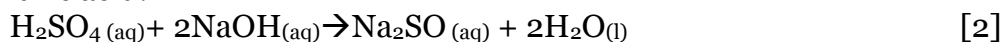
An acid is a substance that acts as a proton (or hydrogen ion) donor when dissolved in water and a base is a substance that acts as a hydroxide ion when dissolved in water. A strong acid or base dissociates almost completely when placed in water, whereas weak acids do not dissociate completely. This lab will be dealing with strong acid and strong base titrations.

The concentration of an acid or base depends on the amount of acid or base that is in a given amount of water. The more acid or base there is compared to the amount of water, the more concentrated the acid or base will be and the smaller the amount of acid or base in comparison to the amount of water, the weaker the acid will be. The amount of solute (i.e. acid or base) is typically measured in moles and the volume of the solution (containing both solute and solvent) is measured in litres. Concentration is measured in moles per litre and therefore can be calculated using the following equation:

$$\text{Concentration (mol/L)} = \frac{\text{amount of solute (mol)}}{\text{volume of solution (L)}} \quad [1]$$

The amount of solute in moles can be found by dividing the mass of the solute (in grams) by the molar mass of the solute (in grams per mole)

When acids and bases react, it forms a salt and water and is referred to as a neutralization reaction. The point of equivalence in a neutralization reaction is the point at which the amount of acid added is exactly the amount needed to titrate the base. The amount of acid required to titrate a base is determined by the stoichiometric coefficients of the acid and the base. For example, consider the neutralization reaction of sodium hydroxide and sulfuric acid:



From the stoichiometric coefficients, we can see the following relationship between amounts of acid and base (in moles) at the equivalency point:

$$n_{\text{NaOH}} = 2n_{\text{SO}_4} \quad [3]$$

However, this equation is only valid for the above stoichiometric ratio. The general equation can be described by:

$$n_{\text{base}} = \frac{b}{a} n_{\text{acid}} \quad [4]$$

Where b is the stoichiometric coefficient of the base and a is the stoichiometric coefficient of the acid. Also, recall from Equation [1] that the number of moles is also the product of the concentration of the solution and the volume of the solution. Therefore, we have that:

$$C_{\text{base}} V_{\text{base}} = \frac{b}{a} C_{\text{acid}} V_{\text{acid}} \quad [5]$$

If the number of moles of acid and molar mass of the acid of the solution the acid in are both known, the mass of the acid can be calculated by multiplying the amount of acid (in moles) by the molar mass. Given the density and volume of the solution, and that mass is equal to density multiplied by volume, the mass percentage of the acid can then be calculated according to the following equation:

$$\text{Mass \%} = \frac{\text{mass of acid (g)}}{\text{mass of solution (g)}} \times 100\% \quad [6]$$

This experiment deals with the preparation of a standardized solution of NaOH, titration involving an acid solution of known concentration (to determine the concentration of the standardized base), titration with an unknown acid, and titration of

a juice sample to determine the percent mass of acid in the juice. All parts of the experiment can be completed with a knowledge of the above relationships.

Reference: Jean-Louis Bergot, "Ionic Equilibria in Analytical Chemistry", Springer, Chapter 7, p.123-125, (2012)

Procedure:

As described in the lab manual (Dr. R. Venkateswaran, "What in the World ISN'T Chemistry?", General Chemistry Laboratory Manual, 2016, p.79).

Observations/Data/Results

Table 1. Formation of a stock solution of NaOH

Volume of concentrated NaOH solution (mL)	4.05
Concentration of concentrated NaOH solution (M)	6.00
Volume of stock solution after dilution (mL)	254.05
Approximate concentration of stock solution (M)	0.0957

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	-
Volume of Standard Acid solution (mL)	9.95	9.95	-
Volume of stock solution of NaOH (mL)	14.57	14.17	-
Concentration of stock solution of NaOH (M)	0.0683	0.0702	-

Average Concentration of stock solution of NaOH (M)	0.0693
--	--------

Table 3. Determination of the Concentration of an Unknown Acid

Data	Trial 1	Trial 2	Trial 3
Sample Number of Unknown Acid	1	1	-
Volume of Unknown Acid solution (mL)	9.90	10.00	-
Volume of stock solution of NaOH (mL)	12.99	13.78	-
Concentration of stock solution of NaOH (M)	0.0693	0.0693	-
Concentration of Unknown Acid Solution (M)	0.0455	0.0477	-
Average Concentration of Unknown Acid solution (M)	0.0466		

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

Data	Trial 1	Trial 2	Trial 3
Sample Number of Juice	2	2	-
Volume of Juice (mL)	9.98	9.88	-
Volume of stock solution of NaOH (mL)	12.99	13.78	-
Concentration of stock solution of NaOH (M)	0.0693	0.0693	-
Concentration of acid in Juice (M)	0.0334	0.0372	-

Average Concentration of Acid in Juice (M)	0.0353
Density of Juice (g/mL)	1.0001
Molar Mass of acid in Juice (g/mol)	192.14
Mass Percent of Acid in Juice (%)	0.678

Table 5. Titration Results from LoggerPro

	Run 1			Run 2			Run 3			Run 4			Run 5			Run 6		
	Volume (mL)	pH	FD	Volume (mL)	pH	FD	Volume (mL)	pH	FD	Volume (mL)	pH	FD	Volume (mL)	pH	FD	Volume (mL)	pH	FD
1	0.000	2.09	0.000	0.000	2.10	-0.005	0.000	2.25	-0.067	0.000	2.21	0.046	0.000	2.96	-0.061	0.000	2.87	0.000
2	0.056	2.09	0.000	0.056	2.10	-0.010	0.056	2.24	-0.045	0.056	2.22	0.000	0.056	2.96	-0.023	0.056	2.87	0.004
3	0.112	2.09	0.000	0.112	2.10	-0.021	0.112	2.24	-0.036	0.112	2.21	-0.023	0.112	2.96	0.023	0.112	2.87	0.014
4	0.169	2.09	0.000	0.169	2.09	0.000	0.169	2.24	-0.013	0.169	2.21	-0.008	0.169	2.96	0.030	0.169	2.87	0.045
5	0.225	2.09	0.002	0.225	2.10	0.019	0.225	2.24	-0.010	0.225	2.21	-0.005	0.225	2.96	0.010	0.225	2.88	0.073
6	0.281	2.09	0.007	0.281	2.10	0.000	0.281	2.24	-0.025	0.281	2.21	-0.010	0.281	2.96	0.007	0.281	2.88	0.072
7	0.337	2.09	0.024	0.337	2.10	-0.019	0.337	2.24	-0.008	0.337	2.21	-0.031	0.337	2.96	0.017	0.337	2.89	0.048
8	0.394	2.10	0.010	0.394	2.09	0.000	0.394	2.24	-0.003	0.394	2.21	-0.031	0.394	2.96	0.057	0.394	2.89	0.032
9	0.450	2.09	0.010	0.450	2.10	0.021	0.450	2.24	0.000	0.450	2.21	-0.010	0.450	2.97	0.053	0.450	2.89	0.069
10	0.506	2.10	0.024	0.506	2.10	0.007	0.506	2.24	0.000	0.506	2.21	0.000	0.506	2.97	0.054	0.506	2.90	0.076
11	0.562	2.10	0.007	0.562	2.10	0.002	0.562	2.24	-0.002	0.562	2.21	0.005	0.562	2.98	0.100	0.562	2.90	0.063
12	0.619	2.10	0.002	0.619	2.10	0.000	0.619	2.24	-0.007	0.619	2.21	0.014	0.619	2.98	0.081	0.619	2.90	0.083
13	0.675	2.10	0.000	0.675	2.10	0.000	0.675	2.24	-0.024	0.675	2.21	-0.021	0.675	2.99	0.052	0.675	2.91	0.093
14	0.731	2.10	0.000	0.731	2.10	0.000	0.731	2.23	-0.007	0.731	2.20	-0.021	0.731	2.99	0.034	0.731	2.91	0.112
15	0.787	2.10	0.002	0.787	2.10	0.000	0.787	2.24	0.000	0.787	2.21	0.012	0.787	2.99	0.077	0.787	2.92	0.098
16	0.844	2.10	0.007	0.844	2.10	0.000	0.844	2.23	0.007	0.844	2.21	-0.002	0.844	3.00	0.109	0.844	2.92	0.100
17	0.900	2.10	0.026	0.900	2.10	0.000	0.900	2.24	0.024	0.900	2.21	-0.021	0.900	3.00	0.103	0.900	2.93	0.124
18	0.956	2.10	0.020	0.956	2.10	0.000	0.956	2.24	0.007	0.956	2.20	-0.007	0.956	3.01	0.112	0.956	2.94	0.139
19	1.012	2.10	0.042	1.012	2.10	0.000	1.012	2.24	0.005	1.012	2.21	-0.002	1.012	3.02	0.088	1.012	2.95	0.177
20	1.069	2.11	0.057	1.069	2.10	0.000	1.069	2.24	0.008	1.069	2.20	0.000	1.069	3.02	0.068	1.069	2.96	0.217
21	1.125	2.11	0.017	1.125	2.10	0.002	1.125	2.24	0.025	1.125	2.21	0.002	1.125	3.02	0.089	1.125	2.97	0.311
22	1.181	2.11	0.007	1.181	2.10	0.010	1.181	2.24	0.010	1.181	2.20	0.005	1.181	3.03	0.119	1.181	3.00	0.247
23	1.237	2.11	0.010	1.237	2.10	0.034	1.237	2.24	0.008	1.237	2.21	0.019	1.237	3.04	0.130	1.237	3.00	0.076
24	1.294	2.11	0.029	1.294	2.10	0.041	1.294	2.24	0.018	1.294	2.21	-0.005	1.294	3.04	0.132	1.294	3.00	0.027
25	1.350	2.11	0.024	1.350	2.10	0.042	1.350	2.24	-0.015	1.350	2.20	0.031	1.350	3.05	0.132	1.350	3.00	0.033
26	1.406	2.11	-0.012	1.406	2.11	0.035	1.406	2.24	0.003	1.406	2.21	0.043	1.406	3.06	0.129	1.406	3.01	0.045
27	1.462	2.11	0.002	1.462	2.11	0.013	1.462	2.24	0.023	1.462	2.21	-0.014	1.462	3.06	0.127	1.462	3.01	0.072
28	1.519	2.11	0.024	1.519	2.11	0.007	1.519	2.24	0.010	1.519	2.21	-0.024	1.519	3.07	0.117	1.519	3.01	0.146
29	1.575	2.11	0.017	1.575	2.11	0.016	1.575	2.24	0.010	1.575	2.21	0.000	1.575	3.07	0.153	1.575	3.02	0.232
30	1.631	2.11	0.033	1.631	2.11	-0.013	1.631	2.24	0.024	1.631	2.21	0.029	1.631	3.09	0.152	1.631	3.05	0.186
31	1.687	2.12	0.031	1.687	2.10	0.010	1.687	2.25	0.012	1.687	2.21	0.031	1.687	3.09	0.115	1.687	3.05	0.073
32	1.744	2.12	0.010	1.744	2.11	0.047	1.744	2.24	0.017	1.744	2.21	0.010	1.744	3.10	0.121	1.744	3.05	0.081
33	1.800	2.12	0.005	1.800	2.11	0.017	1.800	2.25	0.048	1.800	2.21	0.002	1.800	3.10	0.188	1.800	3.06	0.086
34	1.856	2.12	0.010	1.856	2.11	0.014	1.856	2.25	0.017	1.856	2.21	0.000	1.856	3.12	0.205	1.856	3.06	0.097
35	1.912	2.12	0.033	1.912	2.11	0.031	1.912	2.25	0.012	1.912	2.21	0.000	1.912	3.13	0.192	1.912	3.06	0.122
36	1.969	2.12	0.033	1.969	2.12	0.031	1.969	2.25	0.024	1.969	2.21	0.000	1.969	3.14	0.203	1.969	3.07	0.130
37	2.025	2.12	0.010	2.025	2.12	0.010	2.025	2.25	0.010	2.025	2.21	0.003	2.025	3.15	0.183	2.025	3.08	0.142
38	2.081	2.12	0.005	2.081	2.12	0.002	2.081	2.25	0.013	2.081	2.21	0.010	2.081	3.16	0.180	2.081	3.08	0.170
39	2.137	2.12	0.012	2.137	2.12	0.000	2.137	2.25	0.033	2.137	2.21	0.033	2.137	3.17	0.185	2.137	3.09	0.253
40	2.193	2.12	0.041	2.193	2.12	0.003	2.193	2.26	0.035	2.193	2.22	0.035	2.193	3.18	0.207	2.193	3.12	0.238
41	2.250	2.13	0.064	2.250	2.12	0.008	2.250	2.26	0.020	2.250	2.22	0.017	2.250	3.20	0.208	2.250	3.13	0.111
42	2.306	2.13	0.049	2.306	2.13	0.005	2.306	2.26	0.004	2.306	2.22	0.006	2.306	3.21	0.186	2.306	3.13	0.090

Fig. 1. Trial 1 of Standardization of NaOH Stock Solution

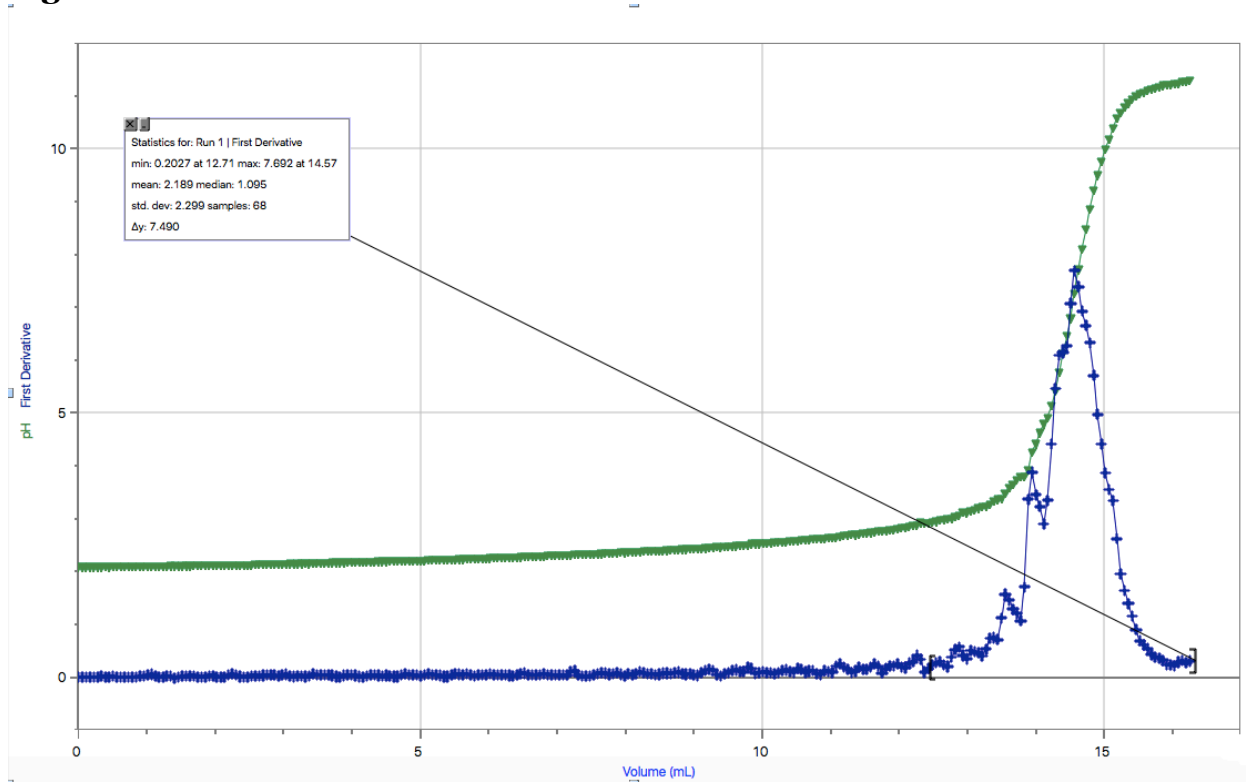


Fig. 2. Standardization of NaOH Stock Solution Trial 2

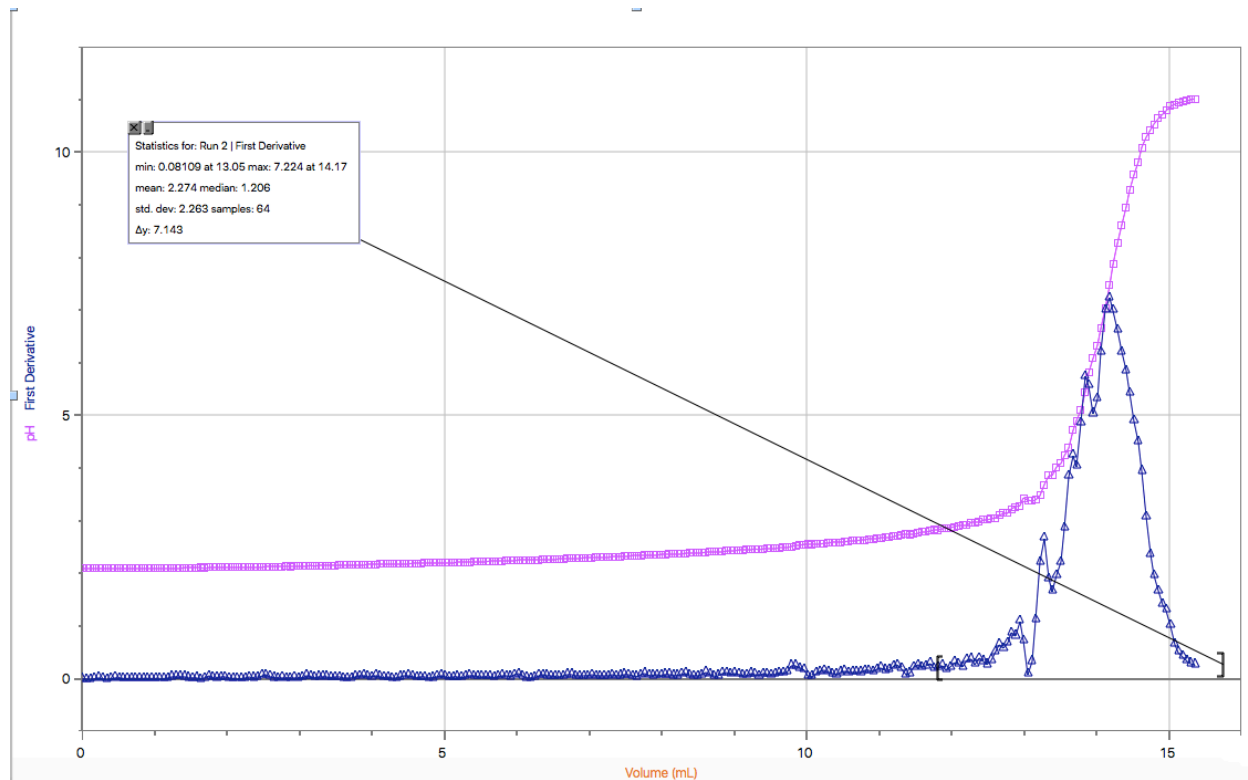


Fig. 3. Titration with an Unknown Acid Trial 1

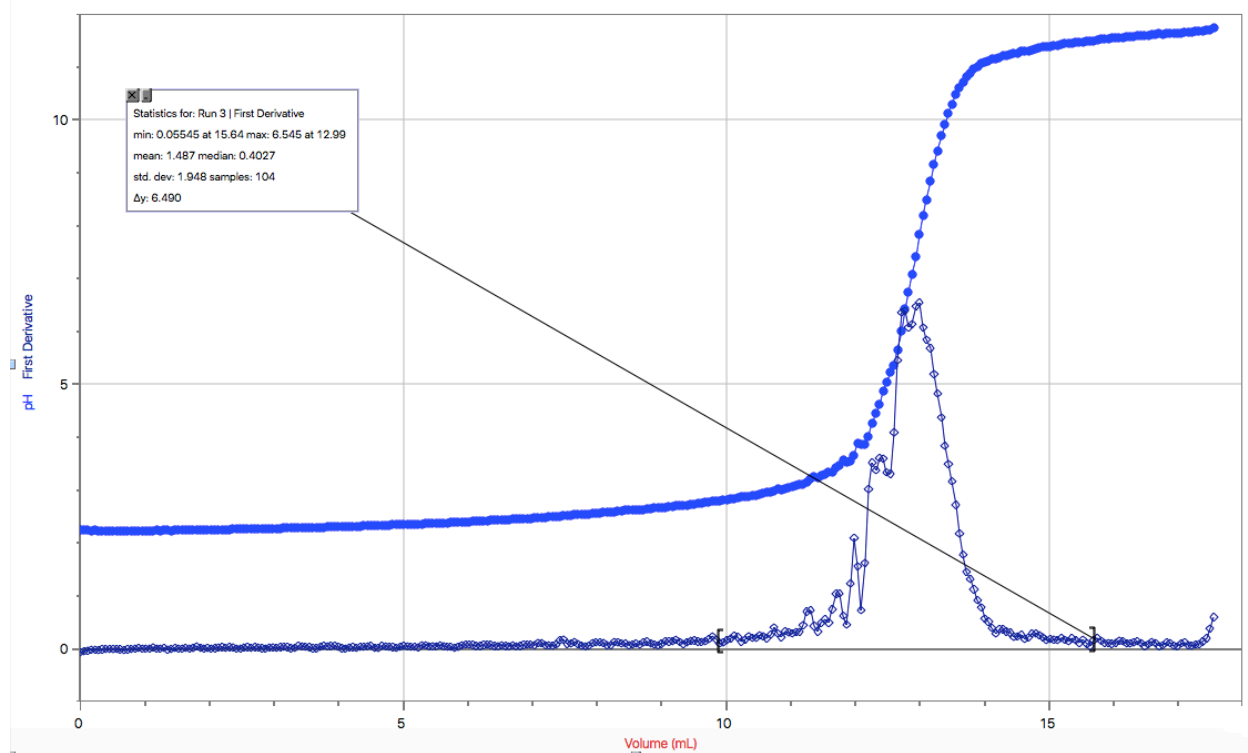


Fig. 4. Titration with an Unknown Acid Trial 2

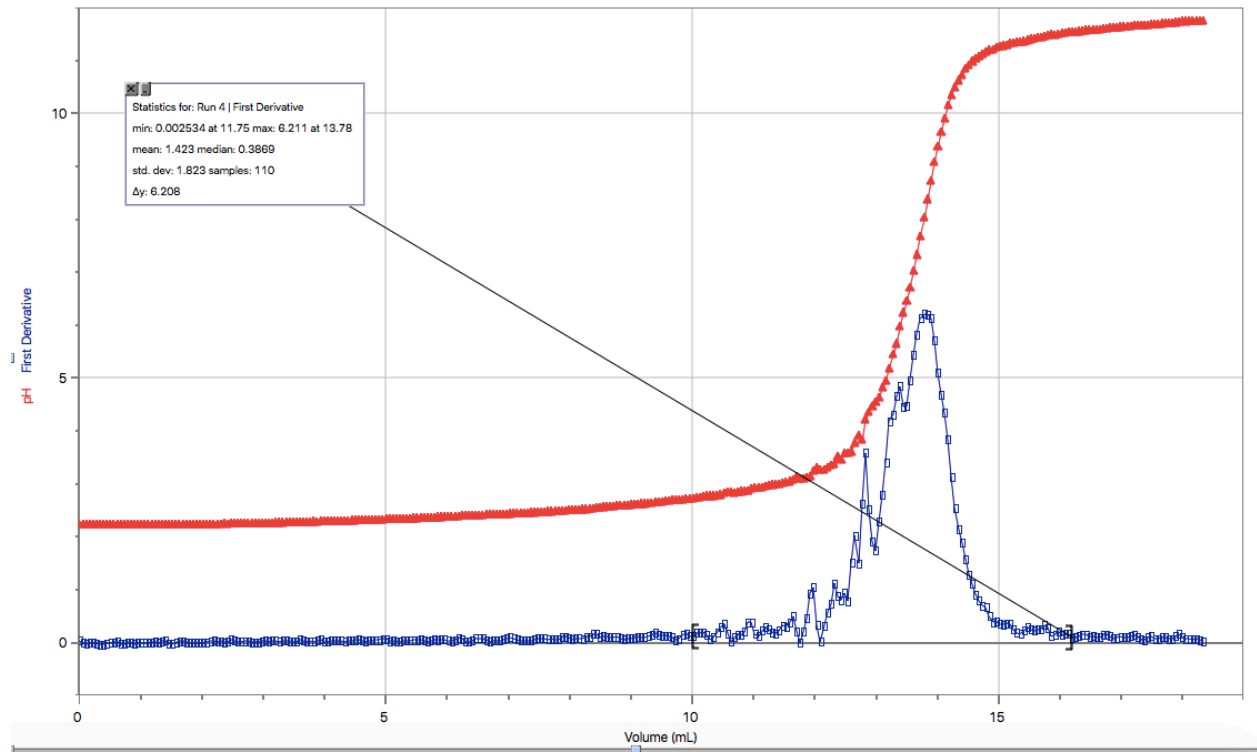


Fig. 5. Titration With Juice 2 Trial 1

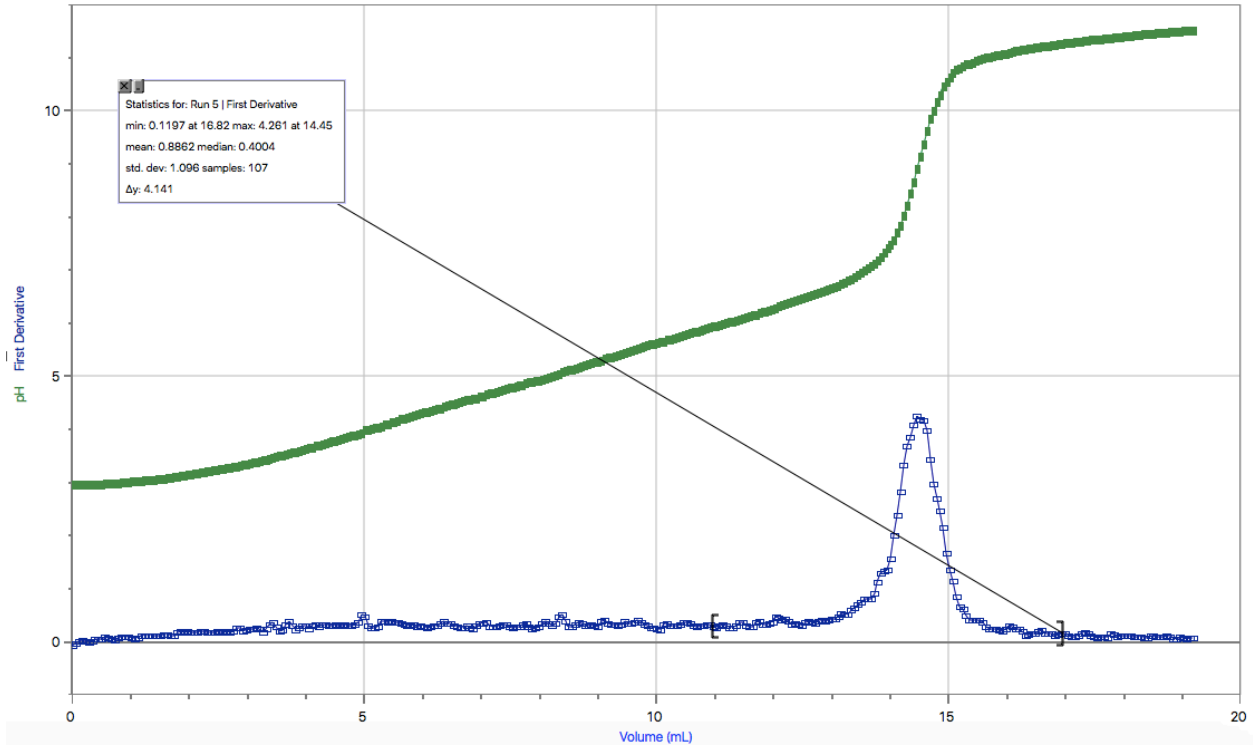
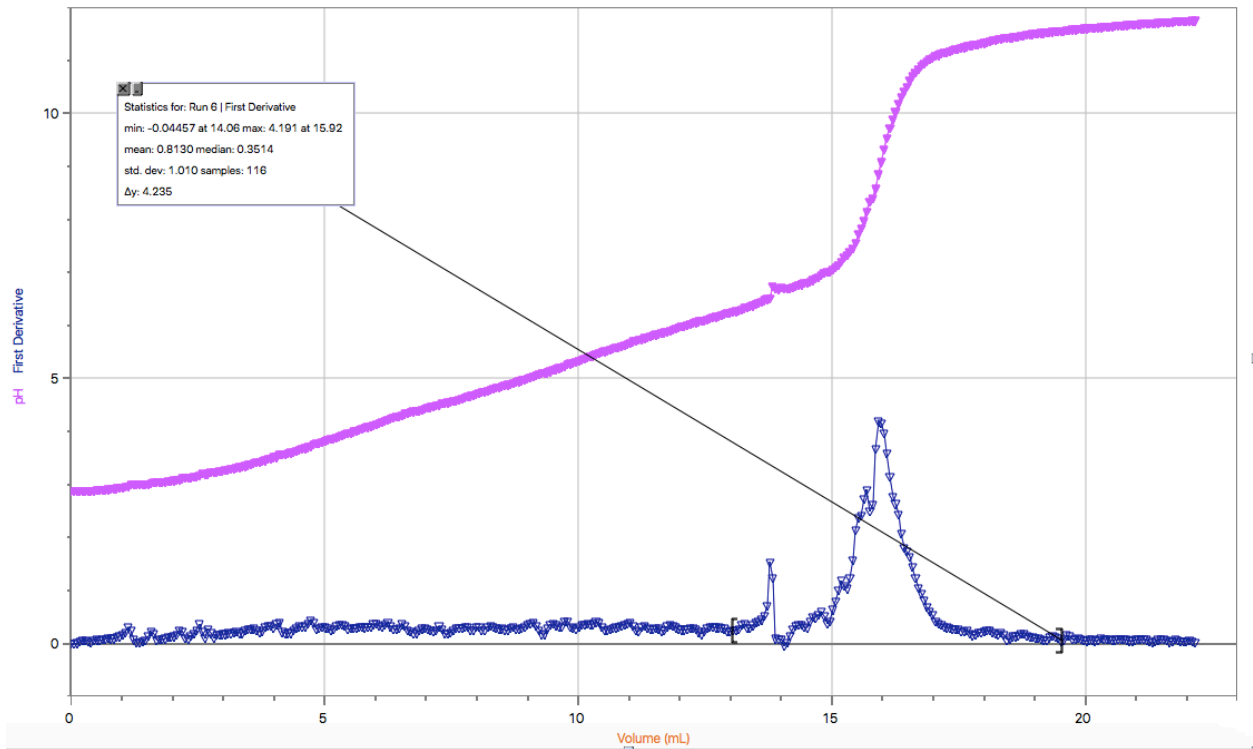


Fig.6. Titration with Juice 2 Trial 2



Raw Data:

Table 6: Logger Pro Table

	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	2.09	0.000	2.10	0.000	2.25	0.000	2.21	0.000	2.96	0.000	2.87
2	0.056	2.09	0.056	2.10	0.056	2.24	0.056	2.22	0.056	2.96	0.056	2.87
3	0.112	2.09	0.112	2.10	0.112	2.24	0.112	2.21	0.112	2.96	0.112	2.87
4	0.169	2.09	0.169	2.09	0.169	2.24	0.169	2.21	0.169	2.96	0.169	2.87
5	0.225	2.09	0.225	2.10	0.225	2.24	0.225	2.21	0.225	2.96	0.225	2.88
6	0.281	2.09	0.281	2.10	0.281	2.24	0.281	2.21	0.281	2.96	0.281	2.88
7	0.337	2.09	0.337	2.10	0.337	2.24	0.337	2.21	0.337	2.96	0.337	2.89
8	0.394	2.10	0.394	2.09	0.394	2.24	0.394	2.21	0.394	2.96	0.394	2.89
9	0.450	2.09	0.450	2.10	0.450	2.24	0.450	2.21	0.450	2.97	0.450	2.89
10	0.506	2.10	0.506	2.10	0.506	2.24	0.506	2.21	0.506	2.97	0.506	2.90
11	0.562	2.10	0.562	2.10	0.562	2.24	0.562	2.21	0.562	2.98	0.562	2.90
12	0.619	2.10	0.619	2.10	0.619	2.24	0.619	2.21	0.619	2.98	0.619	2.90
13	0.675	2.10	0.675	2.10	0.675	2.24	0.675	2.21	0.675	2.99	0.675	2.91
14	0.731	2.10	0.731	2.10	0.731	2.23	0.731	2.20	0.731	2.99	0.731	2.91
15	0.787	2.10	0.787	2.10	0.787	2.24	0.787	2.21	0.787	2.99	0.787	2.92
16	0.844	2.10	0.844	2.10	0.844	2.23	0.844	2.21	0.844	3.00	0.844	2.92
17	0.900	2.10	0.900	2.10	0.900	2.24	0.900	2.21	0.900	3.00	0.900	2.93
18	0.956	2.10	0.956	2.10	0.956	2.24	0.956	2.20	0.956	3.01	0.956	2.94
19	1.012	2.10	1.012	2.10	1.012	2.24	1.012	2.21	1.012	3.02	1.012	2.95
20	1.069	2.11	1.069	2.10	1.069	2.24	1.069	2.20	1.069	3.02	1.069	2.96
21	1.125	2.11	1.125	2.10	1.125	2.24	1.125	2.21	1.125	3.02	1.125	2.97
22	1.181	2.11	1.181	2.10	1.181	2.24	1.181	2.20	1.181	3.03	1.181	3.00
23	1.237	2.11	1.237	2.10	1.237	2.24	1.237	2.21	1.237	3.04	1.237	3.00
24	1.294	2.11	1.294	2.10	1.294	2.24	1.294	2.21	1.294	3.04	1.294	3.00
25	1.350	2.11	1.350	2.10	1.350	2.24	1.350	2.20	1.350	3.05	1.350	3.00
26	1.406	2.11	1.406	2.11	1.406	2.24	1.406	2.21	1.406	3.06	1.406	3.01
27	1.462	2.11	1.462	2.11	1.462	2.24	1.462	2.21	1.462	3.06	1.462	3.01
28	1.519	2.11	1.519	2.11	1.519	2.24	1.519	2.21	1.519	3.07	1.519	3.01
29	1.575	2.11	1.575	2.11	1.575	2.24	1.575	2.21	1.575	3.07	1.575	3.02
30	1.631	2.11	1.631	2.11	1.631	2.24	1.631	2.21	1.631	3.09	1.631	3.05
31	1.687	2.12	1.687	2.10	1.687	2.25	1.687	2.21	1.687	3.09	1.687	3.05
32	1.744	2.12	1.744	2.11	1.744	2.24	1.744	2.21	1.744	3.10	1.744	3.05
33	1.800	2.12	1.800	2.11	1.800	2.25	1.800	2.21	1.800	3.10	1.800	3.06
34	1.856	2.12	1.856	2.11	1.856	2.25	1.856	2.21	1.856	3.12	1.856	3.06
35	1.912	2.12	1.912	2.11	1.912	2.25	1.912	2.21	1.912	3.13	1.912	3.06

Data Tables:

Data Tables

Table 1. Formation of a stock solution of NaOH

Volume of concentrated NaOH solution (mL)	4.05
Concentration of concentrated NaOH solution (M)	0.44
Volume of stock solution after dilution (mL)	254.05 mL
Approximate concentration of stock solution (M)	

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	0.1000
Volume of Standard Acid solution (mL)	9.95 mL	9.95	
Volume of stock solution of NaOH (mL)	14.57 14.67	14.17	
Concentration of stock solution of NaOH (M)			
Average Concentration of stock solution of NaOH (M)			

Report Form...Page 2

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

Data	Trial 1	Trial 2	Trial 3
Sample Number of Juice	2	2	
Volume of Juice (mL)	9.98	9.88	
Volume of stock solution of NaOH (mL)			
Concentration of stock solution of NaOH (M)			
Concentration of acid in Juice (M)			
Average Concentration of Acid in Juice (M)			
Density of Juice (g/mL)	1.001	g/cm ³	
Molar Mass of acid in Juice (g/mol)			
Mass Percent of Acid in Juice (%)			

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

Report Form...Page 4

Data Tables

Table 1. Formation of a stock solution of NaOH

Volume of concentrated NaOH solution (mL)	4.05
Concentration of concentrated NaOH solution (M)	0.44
Volume of stock solution after dilution (mL)	254.05 mL
Approximate concentration of stock solution (M)	

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	0.1000
Volume of Standard Acid solution (mL)	9.95 mL	9.95	
Volume of stock solution of NaOH (mL)	14.57 14.67	14.17	
Concentration of stock solution of NaOH (M)			
Average Concentration of stock solution of NaOH (M)			

Report Form...Page 2

Sample Calculation: (Part 1)

1. Approximate concentration of stock solution

$$\begin{aligned}C_i V_i &= C_f V_f \\ C_f &= C_i V_i / V_f \\ &= (6.00\text{M})(4.05\text{ mL}) / (254.05\text{ mL}) \\ &= 0.0957\text{ M}\end{aligned}$$

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):

Trial 1: $[\text{HCl}] = 0.1000\text{M}$, $V_{\text{HCl}} = 9.95\text{mL}$, $V_{\text{NaOH}} = 14.57\text{mL}$

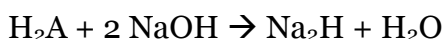
$$\begin{aligned}[\text{NaOH}] V_{\text{NaOH}} &= [\text{HCl}] V_{\text{HCl}} \\ [\text{NaOH}] &= [\text{HCl}] V_{\text{HCl}} / V_{\text{NaOH}} \\ &= (0.100\text{ M})(9.95\text{mL}) / (14.57\text{mL}) \\ &= 0.0683\text{ M}\end{aligned}$$

3. Average concentration of stock solution:

$$\begin{aligned}[\text{NaOH}]_{\text{avg}} &= (0.0683\text{M} + 0.0702\text{M}) / 2 \\ &= 0.0693\text{M}\end{aligned}$$

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):



$$\begin{aligned}n_{\text{NaOH}} &= 2n_{\text{H}_2\text{A}} \\ C_{\text{NaOH}} V_{\text{NaOH}} &= 2C_{\text{H}_2\text{A}} V_{\text{H}_2\text{A}} \\ C_{\text{H}_2\text{A}} &= C_{\text{NaOH}} V_{\text{NaOH}} / 2V_{\text{H}_2\text{A}}\end{aligned}$$

Using the data from Trial 1,

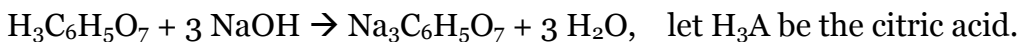
$$\begin{aligned}C_{\text{H}_2\text{A}} &= (0.0693\text{M})(12.99\text{mL}) / (2)(9.90\text{mL}) \\ &= 0.0455\text{M}\end{aligned}$$

5. Average concentration of unknown acid:

$$\begin{aligned}[\text{H}_2\text{A}]_{\text{avg}} &= (0.0455\text{M} + 0.0477\text{M}) / 2 \\ &= 0.0466\text{ M}\end{aligned}$$

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):



$$n_{\text{NaOH}} = 3n_{\text{H}_3\text{A}}$$

$$C_{\text{H}_3\text{A}} = C_{\text{NaOH}}V_{\text{NaOH}}/3V_{\text{H}_3\text{A}}$$

For trial 1, $C_{\text{NaOH}} = 0.0693\text{M}$, $V_{\text{NaOH}} = 14.45\text{mL}$, $V_{\text{H}_3\text{A}} = 9.98\text{ mL}$

$$\begin{aligned} C_{\text{H}_3\text{A}} &= (0.0693\text{M})(14.45\text{mL})/3(9.98\text{mL}) \\ &= 0.0334\text{M} \end{aligned}$$

7. Average concentration of acid in juice:

$$\begin{aligned} [\text{H}_3\text{C}_6\text{H}_5\text{O}_7]_{\text{avg}} &= (0.0334\text{M} + 0.0372\text{M})/2 \\ &= 0.0353\text{M} \end{aligned}$$

8. Mass percentage of acid in juice:

$[\text{H}_3\text{C}_6\text{H}_5\text{O}_7] = 0.0353\text{M}$, $MM_{\text{H}_3\text{C}_6\text{H}_5\text{O}_7} = 192.14\text{ g/mol}$, density = 1.0001 g/mL , let $V = 1\text{L}$ for convenience.

$$\begin{aligned} m_{\text{acid}} &= [\text{H}_3\text{C}_6\text{H}_5\text{O}_7](V)(MM) \\ &= (0.0353\text{M})(1\text{L})(192.14\text{g/mol}) \\ &= 6.78\text{ g} \end{aligned}$$

$$\begin{aligned} \text{mass}\% &= (m_{\text{acid}}/m_{\text{total}}) \times 100\% \\ &= (6.78\text{g})/(1.0001\text{g/mL})(1000\text{mL}/1\text{L}) \times 100\% \\ &= 0.678\% \end{aligned}$$

Discussion

The concentration of the NaOH solution must be known in order to calculate the concentration of the unknown acid solution and of the acid in the juice. The initial approximate calculation of the concentration is much higher than the concentration determined experimentally through the titration with HCl. This is due to the fact that the added volume of water was a rough estimation. Therefore, there could have been much more water in the beaker than the amount that we estimated to be in there, resulting in a lower concentration than initially calculated.

Although a useful tool for visualizing the equivalence point of a titration, the use of an indicator is not necessarily accurate in determining the equivalence point of a titration. This is because phenolphthalein changes colour once the pH is higher than 7, meaning that even the slightest colour change won't occur until the solution is already basic and a noticeable colour change won't occur until the pH is significantly higher than 7. Whereas, by using LoggerPro, you can measure the exact point of equivalence with much less room for error.

Additional sources of error include that extra water may have gotten into the burette used to measure out the amount of acid being titrated. Any dilution of the acid inside the burette would result in a smaller amount of the acid (in moles) present in the acid solution being titrated, meaning that the calculated concentration of the acid would be lower than the actual concentration of the acid.

Conclusion

The concentration of the standardized NaOH solution was determined to be 0.0693M. The concentration of unknown acid #1 was determined to be 0.0466M. The mass percentage of citric acid in juice #2 was determined to be 0.678%.