SUBJECT: Principles of General Chemistry 2

FACULTY [redacted]

TITLE: Determination of Flavor Acids Concentration in Common Sodas

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ABSTRACT

All soft drinks in the markets contains some sort of acid as one of its essential component. This contributes to its taste and flavor. Through a common laboratory experiment like titration against a sodium hydroxide base of 0.15M, we can determine the concentration of acid that goes into the soft drink. A range of sodas have been grouped and titrated using a pH meter to determine the concentration of their respected acid. By the experiment it was observed that the tart sodas and sugar-free sodas tend to have a lower acid concentration than caramlized and regular versions. The composite results have been shown using data charts and summary tables.

INTRODUCTION

In chemistry, soft drinks can be classified by the acid that produces its flavor. Colas are caramelized drinks which primarily consists phosphoric acid as its flavor acid. From this group Coke and Dr. Pepper have been chosen as samples.

Lemon-lime flavored drinks have a sour or tart taste, which typically comes from the citric acid in these sodas. From the tart sodas Sprite and 7-up have been used for this experiment.

Keeping the health concerns in mind, market also launched a sugar-free, low calorie or predominantly known as “diet” version of most of the widely-consumed sodas. In order to sweeten these drinks some form of sugar substitutes are used in the sugar-free versions. These generally contains ingredients like aspartame, saccharin, sucaralose and sugar alcohol, which are not present in regular. Through titration a comparison of the acid concentration has been made between each sodas and their sugar-free alternatives.

The categories and the samples from each category has been displayed by the Punett square below;

Table : 1

	Dark (caramelized)	Light (tart)

Regular	Coke, Dr. Pepper	7-up, Sprite
Sugar-free	Coke Zero, Diet Dr. Pepper	Diet 7-up, Sprite

To determine the concentration of phosphoric acid and citric acid only, the elimination of carbonic acid was required. Techniques of degassing were utilized to remove the carbon dioxide from the drinks.

Since some of the samples were not colorless a pH meter can indicate the equivalence point at which the soda neutralizes the sodium hydroxide solution. Stock solutions of both the acids with equal molarity as their correspondent sodas have been titrated. Both phosphoric acid and citric acid are polyprotic acids meaning more than one proton undergoes a reaction with the base. Hence two to three acid dissociation constants were acquired from the titration curve for each soda.

MATERIALS

- Solid citric acid
- Solid sodium hydroxides pellet
- Phosphoric acid, 80%
- KHP (potassium hydrogen phthalate) solid
- Weigh boat
- Phenolphthalein indicator solution
- 1000mL volumetric flask
- 250mL Erlenmeyer flask
- 250mL beaker
- 100mL graduated cylinder
- Buret
- Ring stand and clamps
- Hotplate
- Magnetic Spin
- pH meter
- Standard buffer solution of pH 4
- Standard buffer solution of pH 7

METHODS

- Preparation of the base sodium hydroxide solution:

Pellets of sodium hydroxide was measured in a weight boat to 5.9g then added to a 1000mL volumetric flask to achieve 0.15M. One-third of the volumetric flask was filled with deionized water to evenly dissolve the full amount of sodium hydroxide. Once all the pellets have been dissolved in the deionized water the 1000mL volumetric flask has been filled to its shoulder.

- Standardization of sodium hydroxide:

  A buret has been washed with sodium hydroxide and set up for titration. In an Erlenmeyer flask, 0.345g of KHP has been mixed with 50mL of deionized water and 3 drops of phenolphthalein indicator solution. This has been titrated against sodium hydroxide to check for the molarity of sodium hydroxide. 11.39mL of sodium hydroxide was required to reach the equivalence point. The molarity of sodium hydroxide solution was 0.15M to two sig figs.

- Titration of stock solutions of citric acid and phosphoric acid against standardized sodium hydroxide solution:

  A buret was set up with sodium hydroxide, the someway it was done for standardization of sodium hydroxide with KHP. The pH meter was calibrated using a buffer solution of pH 4 and pH 7. 50mL of the stock solution was obtained using a 100mL graduated cylinder, which was then carefully transferred to an Erlenmeyer flask. In addition, a magnetic spin stirrer was used to make sure the solution is mixing well. Phenolphthalein indicator solution was also added to determine equivalence point via color change. The pH electrode was immersed in the flask, and the initial pH of the sample without any addition of base was recorded. The pH was recorded approximately at every 0.5mL increment to figure out volume of base required to reach the equivalence point.

  Once the pH of 9 was reached, the pH was reached, and the pH change occurred at a much slower rate, hence the pH was recorded at 1mL increment, and 6-7mL more data points were collected. For light sodas, phenolphthalein was also added.

- Degas:

  Since the objective of the experiment was to determine the concentration of citric and phosphoric acid present in the samples to make sure no carbonic acid was interfering, all sodas were degassed in two steps, one was leaving them open overnight.

  Then they were degassed in a hot water bath. To do this samples were poured into a 250mL Erlenmeyer flask (to a volume adequate to conduct three trials). Attached to a ring stand using a clamp a 500mL beaker was filled with tap water and placed on a hot plate. The Erlenmeyer flask was then immersed in the beaker, and a thermometer was dipped in the water to make sure the temperature was not exceeding 90°C.

- Titration of sample sodas against standardized sodium hydroxide solution:

  A buret was set up with sodium hydroxide, the someway it was done for standardization of sodium hydroxide with KHP. The pH meter was calibrated using a buffer solution of pH 4 and pH 7. 75mL of the degased soda was obtained using a 100mL graduated cylinder, which was then carefully transferred to an Erlenmeyer flask. In addition, a magnetic spin stirrer was used to make sure the solution is mixing well with the base. The pH electrode was immersed in the flask, and the initial pH of the sample without any addition of base was recorded. The pH was recorded approximately at every 0.5mL increment to figure out how much base was required to reach the equivalence point.

  Once the pH of 9 was reached, the pH was reached, and the pH change occurred at a much slower rate, hence the pH was recorded at 1mL increment, and 6-7mL more data points were collected.

  The procedures and volume of analyte was same for all the sample sodas. Only an additional indicator of phenolpthalein solution was also used for the colorless sample sodas to ensure the effectiveness of titration.

RESULTS AND DISCUSSION

Standarization of NaOH against KHP:

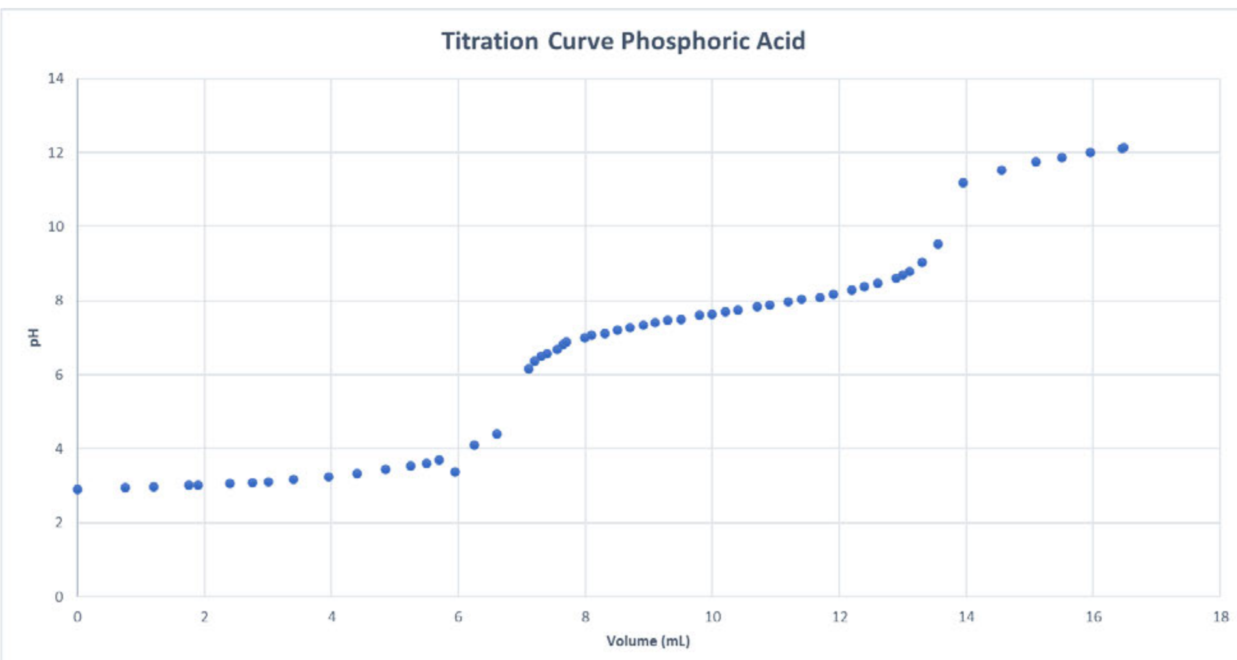
Table: 2

	Trial: 1	Trial: 2	Trial:3
Mass of KHP	0.345 g	0.345 g KHP	0.378 g
Moles of KHP	0.001689 mol	0.001690 mol	0.001850 mol
NaOH added	6.20 mL	6.70 mL	7.17 mL
Molarity of NaOH	0.272 M	0.2522 M	0.2579 M

Citric Acid

Table: 3

Experimental pKa1	Accepted pKa1	Experimental pKa2	Accepted pKa2
3.9	3.128	5.35	4.761
Experimental Ka1	Accepted Ka1	Experimental Ka2	Accepted pKa2
1.26×10^{-4}	7.45×10^{-4}	4.47×10^{-6}	1.73×10^{-5}



Phosphoric Acid

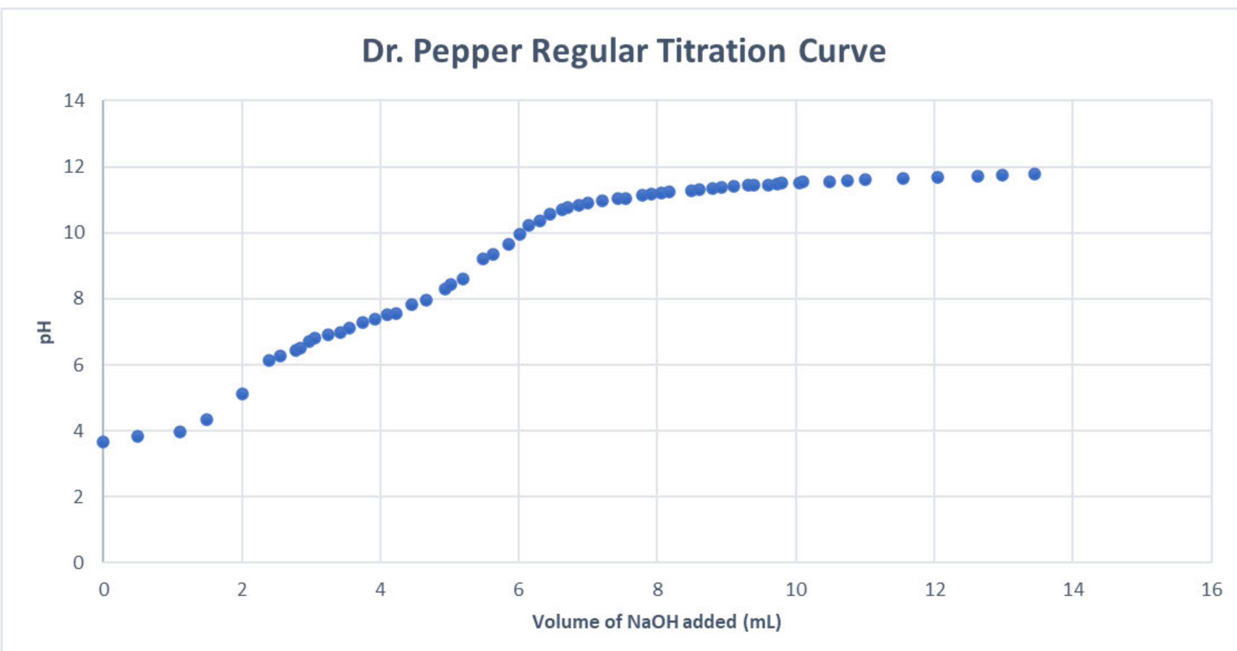
Table: 4

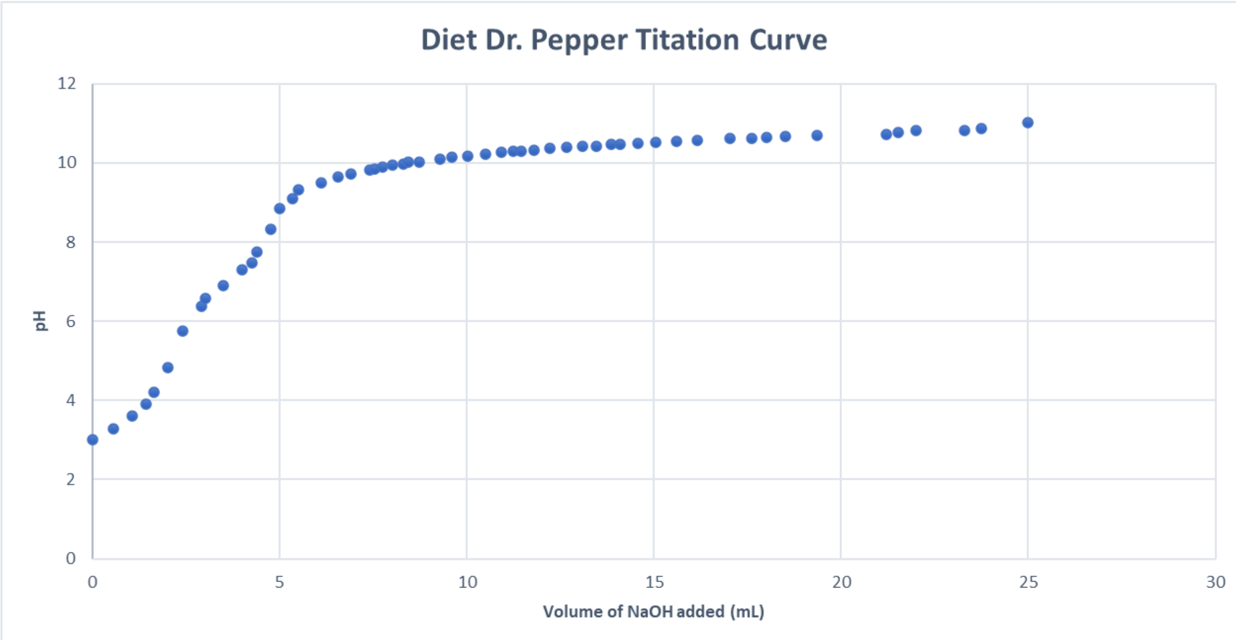
Experimental pKa2	Accepted pKa2	Experimental pKa3	Accepted pKa3

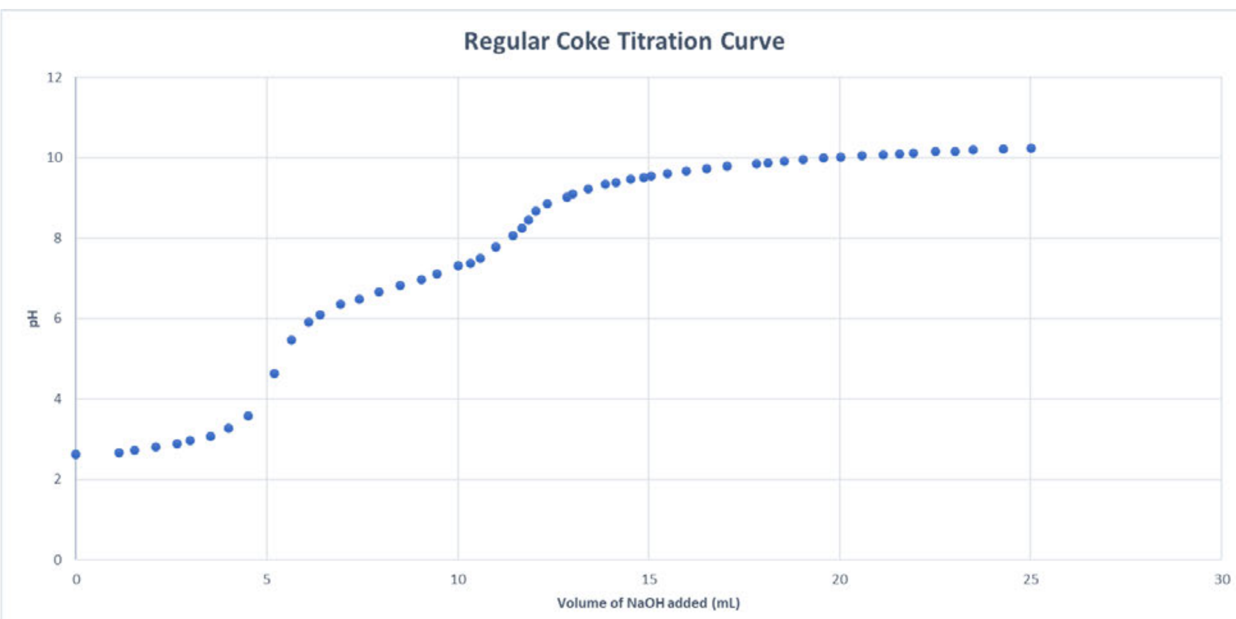
6.10	7.199	10.35	12.35
Experimental Ka2	Accepted Ka2	Experimental Ka3	Accepted pKa3
7.94×10^{-7}	6.32×10^{-8}	4.47×10^{-11}	4.50×10^{-13}

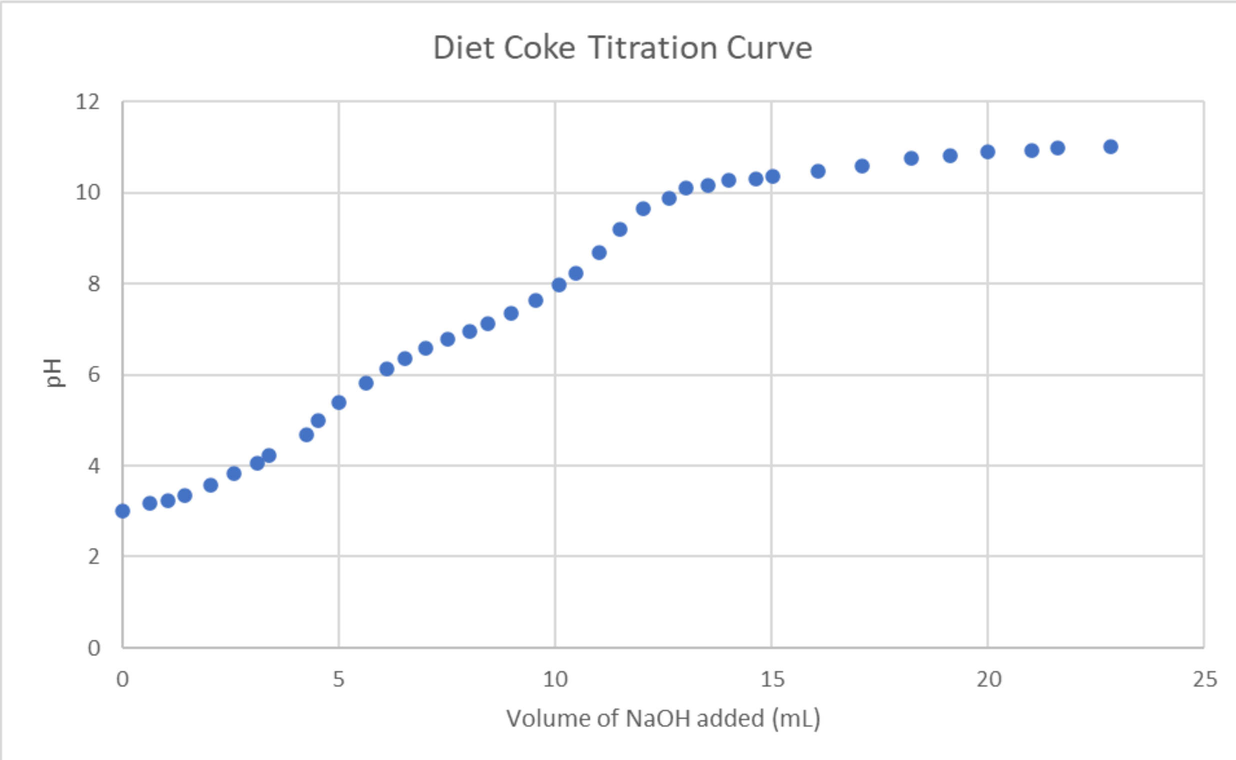
Table: 5

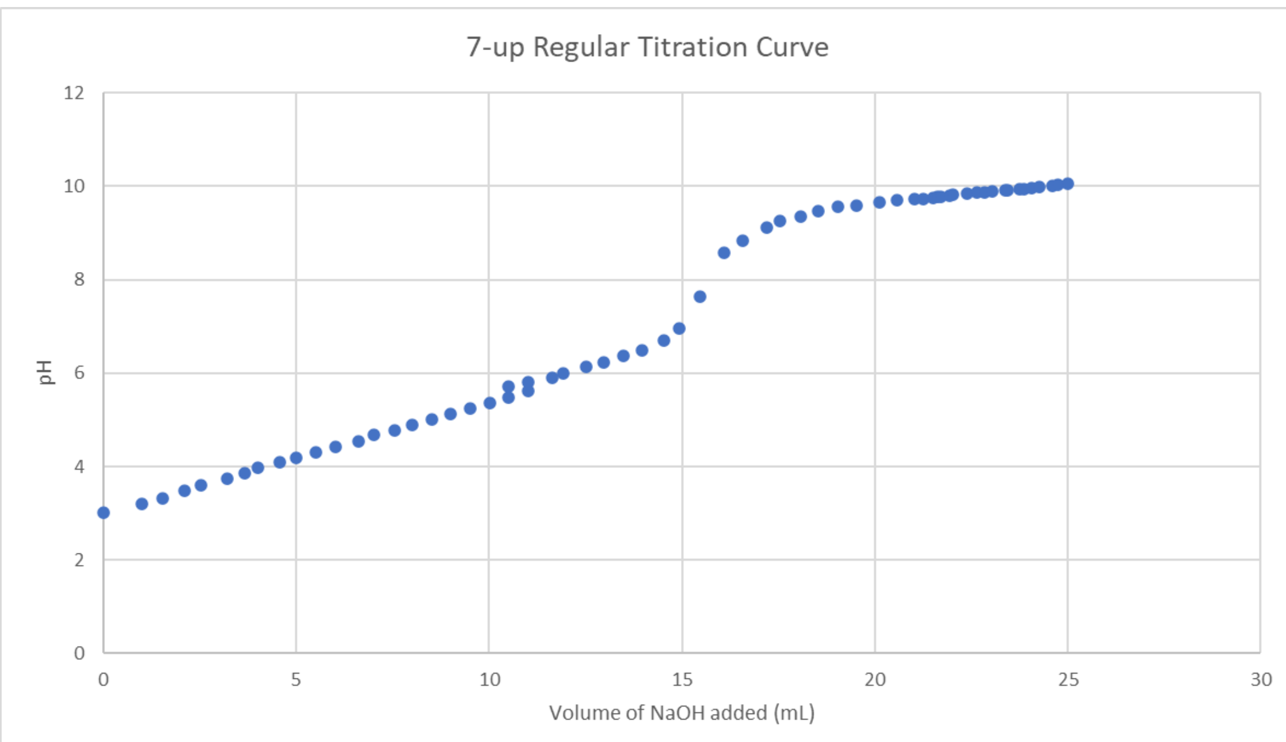
Acid	Volume of NaOH added (mL)	Concentration found using Titration (M)	Concentration in the stock solution (M)
Citric	15.70	3.14×10^{-2}	1.3×10^{-2}
Phosphoric	6.40	1.28×10^{-2}	4.00×10^{-2}

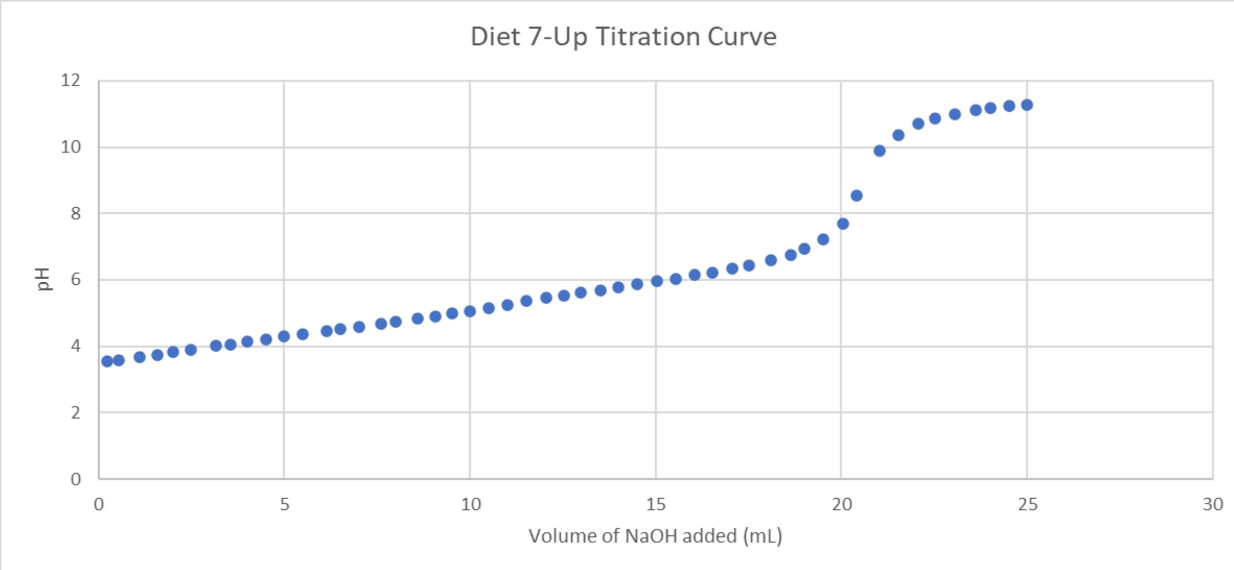



Diet Dr. Pepper Titation Curve
pH
0
2
4
6
8
10
12
0
5
10
15
20
25
30
Volume of NaOH added (mL)

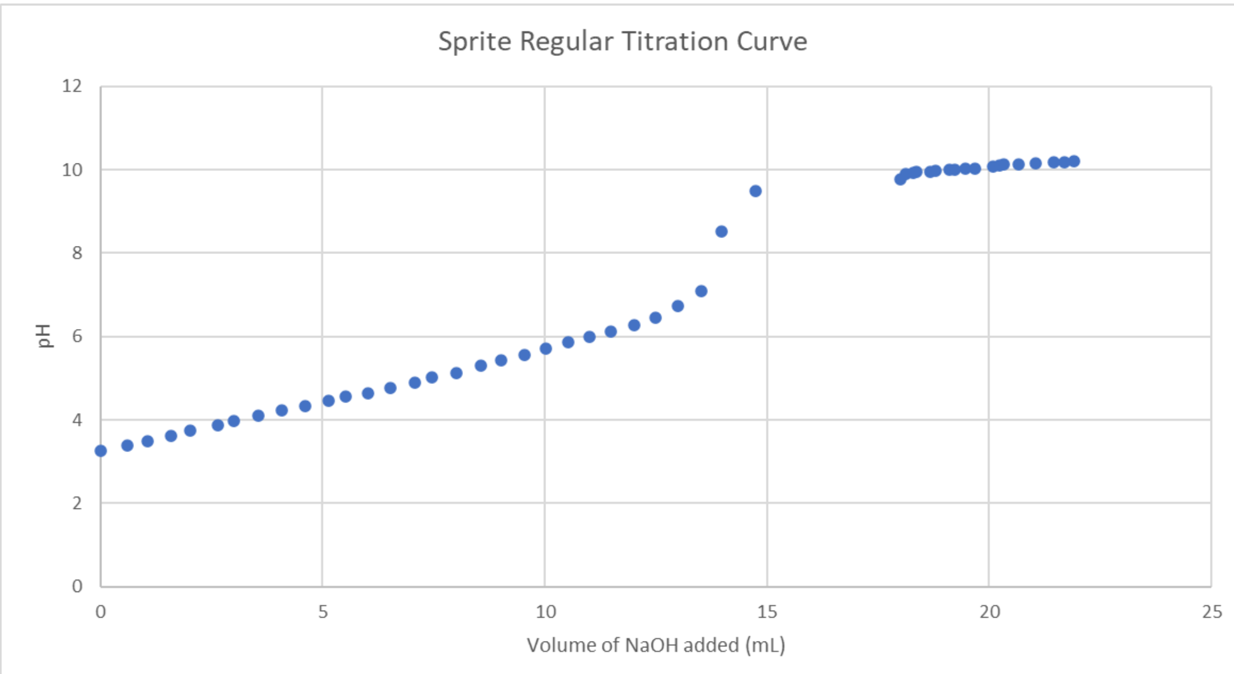

Regular Coke Titration Curve
pH
0
2
4
6
8
10
12
0
5
10
15
20
25
30
Volume of NaOH added (mL)


Diet Coke Titration Curve
pH
12
10
8
6
4
2
0
0
5
10
15
20
25
Volume of NaOH added (mL)


7-up Regular Titration Curve
pH
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Volume of NaOH added (mL)



Diet 7-Up Titration Curve
pH
Volume of NaOH added (mL)
0
2
4
6
8
10
12
0
5
10
15
20
25
30



Sprite Regular Titration Curve
pH
Volume of NaOH added (mL)
0
2
4
6
8
10
12
0
5
10
15
20
25

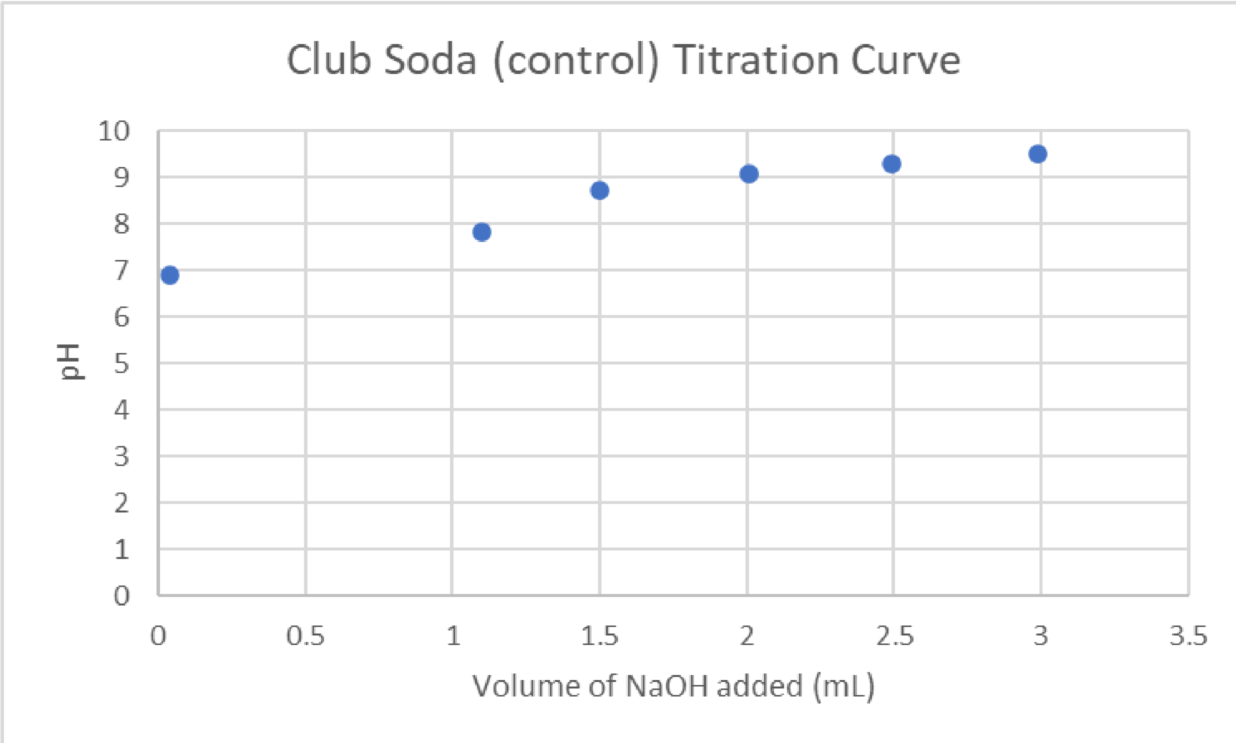

Club Soda (control) Titration Curve
pH
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
Volume of NaOH added (mL)

Table: 6

Sample by its Official Name	**pKa1**	**Volume of base added (mL)**	**pKa2**	**Volume of base added (mL)**	**pKa3**	**Volume of base added (mL)**
Non-flavored Club Soda (control)					8.25	1.13
Coke			4.95	5.00	8.40	11.75
Coke Zero			5.10	4.90	8.35	13.67
Dr. Pepper Diet			6.02	3.20	7.80	4.30
Dr. Pepper			5.20	2.00	9.60	6.00
7-up	4.20	5.20			7.80	15.00
7-up Lite	4.10	5.30			8.40	20.10
Sprite	4.38	5.10			8.20	14.9
Sprite Lite	3.55	4.90			8.35	26.80

Table: 7

Sample by its Official Name	**Volume of base added (mL)**	**Concentration (M)**	**Concentration Expected (M)**
Non-flavored Club Soda (control)	1.3	7.80×10^{-3}	0.00×10^{-2}
Coke	5	3.00×10^{-2}	4.00×10^{-2}
Coke Zero	4.9	2.94×10^{-2}	4.00×10^{-2}

Dr. Pepper	2	1.20×10^{-2}	4.00×10^{-2}
Dr. Pepper Diet	3.2	1.92×10^{-2}	4.00×10^{-2}
7-up	5.2	3.12×10^{-2}	1.30×10^{-2}
7-up Lite	5.3	3.18×10^{-2}	1.30×10^{-2}
Sprite	5.1	3.06×10^{-2}	1.30×10^{-2}
Sprite Lite	4.9	2.94×10^{-2}	1.30×10^{-2}

Table: 8

	Dark		Light	
	Coke	Dr. Pepper	7-up	Sprite
Regular	3.00×10^{-2}	1.20×10^{-2}	3.12×10^{-2}	3.06×10^{-2}
Sugarfree	2.94×10^{-2}	1.92×10^{-2}	3.18×10^{-2}	2.94×10^{-2}

CALCULATIONS

Dr. Pepper (sample)

Moles of NaOH (mol) = Volume (L) * Molarity (M)

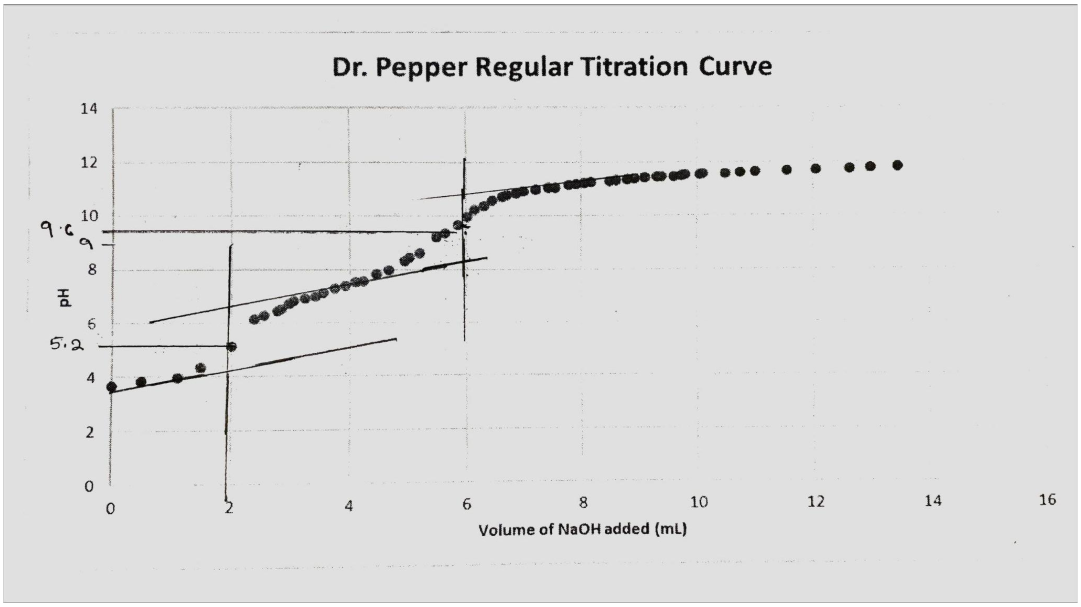
Moles of NaOH (mol) = $2.00 \times 10^{-3} L \times 0.15 M$

Moles of NaOH (mol) = $3.00 \times 10^{-4} mol$

3 moles of NaOH= 1 mole of H_3PO_4

Molarity of Dr. Pepper (M) = $\frac{moles\ of\ H3PO4}{Volume\ in\ Litres}$

Molarity of Dr. Pepper (M) = $\frac{3.00\times10^{-3}\times3}{75\times10^{-3}L}$ = $1.20\ \times\ 10^{-2}$M



Although the results were all consistent, there might still be a few possible sources of errors. One major error can occur while degassing. Since all the samples used are carbonated beverages, they were degassed for quality control. Insufficient removal of carbon dioxide might produce a lower pH as there was some carbonic acid still present in the solution.

Another source of error could be the concentration of NaOH solution changing due to chemical decomposition and evaporation fluid. Since the experiments were conducted over a period of time, the concentration of NaOH might vary from 0.15M. To make sure sure that did not happen, the NaOH solution was some carbonic acid was standardized against KHP a few times throughout the course of the experiment.

Few inevitable sources of errors include human error such as time error and parallax error i.e misreading the volume for both titrant and analyte. Equipment error includes inefficiency of the pH meter and leaks in the buret which can affect the value deduced.

CONCLUSIONS

The two major deductions from this experiment were inferred. Firstly, the acid concentration imparted in light sodas such as Sprite and 7-up is relatively lower than dark sodas. Secondly, the acid concentration is also lower in the sugar-free version than its regular for Coke and Sprite. However, in 7-up and Dr. Pepper the regular version has higher acid concentration than sugar-free.

REFERENCES

Works Cited

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Department of Chemistry, University of Idaho, Moscow, https://www.webpages.uidaho.edu/chemlabservices/Chem%20111%20Lab/labs/Titration.pdf