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CHEM 1111

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An analysis of a Household Acid: Titrating Vinegar Lab Report

Introduction:

In order for an analysis of a sample to be performed, the chemical properties of the sample must be determined. Titration is a process that is used to find the molarity of an acidic solution. In order for an acid-base titration to work, a burette filled with a known concentration of base is used to gradually add its solution to the unknown acidic solution until a reaction occurs and the reactant is completely neutralized. The completed reaction is indicated by a color change from the indicator, phenolphthalein, which was added to the acidic solution. Phenolphthalein is an indicator that changes from colorless to magenta. The following equation shows the known base (NaOH) and the unknown acid ($HC_2H_3O_2$) reacting:

$$NaOH\ (aq) + HC_2H_3O_2\ (aq) \rightarrow NaC_2H_3O_2\ (aq) + H_2O\ (l) \qquad (1)$$

This experiment was divided into two parts (Part A and Part B) and designed to determine the molar concentration of acetic acid in a sample of vinegar by titrating it with a standard solution of NaOH. Alongside titrating the vinegar using a buret and indicator, a potentiometric probe (the pH meter) was used to measure the activity of

hydrogen ions in the acidic solution to determine its acidity. At the equivalence point, the number of moles of acid equals the number of moles of the base:

Volume acid • Molarity acid = Volume base • Molarity base (2)

Through this equation the molarity of the acid was determined by titrating a known volume of the acid solution with a known concentration and volume of a base. Once the vinegar concentration was determined it was compared to the listed value on the container. To determine the concentration of the NAOH solution the titration standard had to be stable and able to measure amounts very accurately. For Part B, using a calibrated drop counter, drops of NaOH were added to the vinegar and LoggerPro software recorded an Acid-Base Titration graph. The titration curve and the derivative gave the exact pH in which the equivalence point is met and the amount (mL) of NaOH that need to be added to meet that.

Procedure:

Part 1: Standardization of NaOH

First a 10 mL volumetric pipette, a 50 mL buret, two small beakers, and 250 mL Erlenmeyer flasks were obtained. Place the label "Vinegar" on one of the small beakers and pour 50 mL of commercial vinegar in it. Record its brand and listed concentration. Place the label "NaOH" on the other small beaker and pour 60 mL of standard base solution in it. Record the concentration from its container. Using a buret funnel, add 5-10 mL of the NaOH solution to the buret while the stopcock is closed. Rinse the buret by allowing all of the NaOH to drain out. Repeat this step to rinse the buret twice. Next, fill the buret to the 0.00 mL mark with the NaOH solution and open the stopcock to fill the tip. Close the stopcock and record the volume of the base to the nearest

0.01 mL. Next, draw some vinegar into a volumetric pipette using a pipette bulb. Allow it to drain into the waste beaker to rinse it. Weigh the 250 mL Erlenmeyer flask and record the mass. Pour 10.00 mL of vinegar into this flask using the volumetric pipette and weigh the flask again. Add about 50 mL of deionized water and 2-5 drops of phenolphthalein indicator to the vinegar sample and swirl the flask. Titrate the solution by slowly adding drops of NaOH into the vinegar solution until a faint pink color persists in the vinegar. Record the new volume of base remaining in the buret to the nearest 0.01 mL. Repeat the titration two more times recording the masses each time.

Part B: pH Meter/ Concentration of acetic acid in Vinegar:

Obtain one 10 mL volumetric pipette, two small beakers, three 200 mL beakers, and one large beaker for waste. Obtain a drop counter and pH meter as well. Label one of the beakers "Vinegar" and pour about 50 mL of commercial vinegar in it. Record the brand and listed concentration. Label the other small beaker "NaOH", and add 60 mL of standard base solution recording its concentration. Add about 5-10 mL of the NaOH solution to the reservoir and rinse it out twice. Calibrate the drop counter. Next, fill the reservoir with standard NaOH solution and close the bottom stoccock. Place the reservoir over the drop counter with a waste beaker below it. Wash the pH probe with deionized water and dry with a Kimwipe. Place the pH probe through the opening in the drop counter in the middle of the beaker so it doesn't touch the glass. Using a pipette bulb, draw vinegar into the volumetric pipette. Rinse the pipette with this solution. Drain into the waste beaker. Next, weigh a 200 mL beaker, and record the mas. Pour 10.00 mL of vinegar into the flask using a volumetric pipette and weigh again. Add about 50 mL of deionized water and swirl. Place the solution under the drop counter submerged the pH probe in the solution. Insert a magnetic stir bar and turn on the stir plate. On LoggerPro on the computer make sure the pH reading in the bottom left hand corner of the screen is reading acidic. Press the green collect button before starting the titration. Open the

bottom stopcock to start the titration. Stop the titration (press the stop button) after the graph has leveled off at a basic pH. Repeat this titration two additional times rinsing and blotting the pH probe in between trials. Make sure to "Store the latest Run" for each trial. Place the pH sensor back into its storage solution. To determine the equivalence volume for each curve (the volume of base required to neutralize an acid at the inflection point on the graph) the first derivative of the graph must be found. Right click on the graph and choose, "Graph Options". In the Graph Options Window under the "Graph Options" tab, make sure the following boxes in the "Appearance" Section are checked: Connect Points, Y Error Bars, and X Error Bars. Next, switch to the "Axes Options" tab of the Graph Options Window. Under "Y-Axis Columns", check the boxes for pH and 1st Derivative for each trial. Click Done. Lastly, move your cursor over the maximum point of the first derivative curve and record the equivalence volume. Do this for each trial.

Results:

	Trial 1	Trial 2	Trial 3
1. Volume of vinegar transferred (mL)	10	10	10
2. Mass of empty flask (g)	109.25	109.25	109.25
3. Mass of flask and vinegar sample (g)	119.25	119.23	119.44
4. Mass of vinegar transferred (g)	10	9.98	10.19
5. Density of vinegar (g/mL)	1	0.998	1.019
6. Concentration of NaOH standard solution (mol/L)	0.2004	0.2004	0.2004
7. Final buret reading (mL)	42.56	43.42	43.125
8. Initial buret reading (mL)	0.00	0.00	0.01
9. Volume of NaOH transferred (mL) (Equivalence Volume)	42.56	43.42	43.125
10. Number of moles of NaOH used	0.0085	0.0087	0.0086
11. Number of moles of $HC_2H_3O_2$ in sample	0.0085	0.0087	0.0086
12. Mass of $HC_2H_3O_2$ in sample	0.5101	0.520	0.517
13. Molar concentration of $HC_2H_3O_2$ in sample (mol/L)	0.85	0.87	0.86
14. Percent by weight concentration [% (w/w)] of $HC_2H_3O_2$in vinegar sample	5.12	4.87	4.75
15. Average % (w/w) concentration of $HC_2H_3O_2$in vinegar sample	4.91%		

Theoretical concentration of vinegar	(w/w)	5
Actual concentration of vinegar	(w/w)	4.91
Percent Error	%	1.83

Table 1: Raw Data for titration with indicator

Listed concentration of HC2H2O2: 5%

	Trial 1	Trial 2	Trial 3
Volume of Vinegar transferred (mL)	**10 mL**	**10 mL**	**10 mL**
Mass of empty beaker (g)	**109.25**	**109.25**	**109.25**
Mass of beaker and vinegar sample (g)	**119.25**	**119.23**	**119.44**
Mass of vinegar transferred (g)	**10**	**9.98**	**10.19**
Volume of NaOH transferred	**45.40**	**46.10**	**43.70**

Table 2: Titration with pH meter and Drop counter

Calculations:

42.56 mL NaOH	**1 L**	**0.1996 moles NaOH**	**= 0.008495 moles NaOH**
	100 mL	**1 L**	

0.008495 mol NaOH	**1 mole HC2H3O2**	**= 0.008495 mol HC2H3O2/**
	1 mol NaOH	**0.01 Liters**

= 0.849 M HC2H3O2

0.51015 g

Average volume of NaOH transferred (mL) (Equivalence Volume	**43.035**
The average density of vinegar (g/mL)	**1.0057**

HC2H3O2/ 9.956 * 100 = 5.1%

Discussion and Conclusions:

The acid and base titrations used the Arrhenius theory. This theory states that acids and bases produce hydrogen ions in solution. The experiment performed turned out reasonable, though there was room for improvement. In Part A, a sodium hydroxide solution was prepared with distilled water and standardized using titration. A solution was prepared with vinegar, phenolphthalein, and water all thoroughly swirled. The brand of vinegar was recorded as *Great Value* and its listed concentration was 5%. The concentration of the NaOH was listed as 0.1991 M. The average equivalence volume for NaOH was 43.035. The average density of the vinegar was 1.0057 g/mL. So equation (1) shows the reaction between the phenolphthalein solution and NaOH. In Part B, the vinegar solution is analyzed for its concentration. It uses reaction (1), which involves a strong base and weak acid. The following shows the acid-base titration curve:

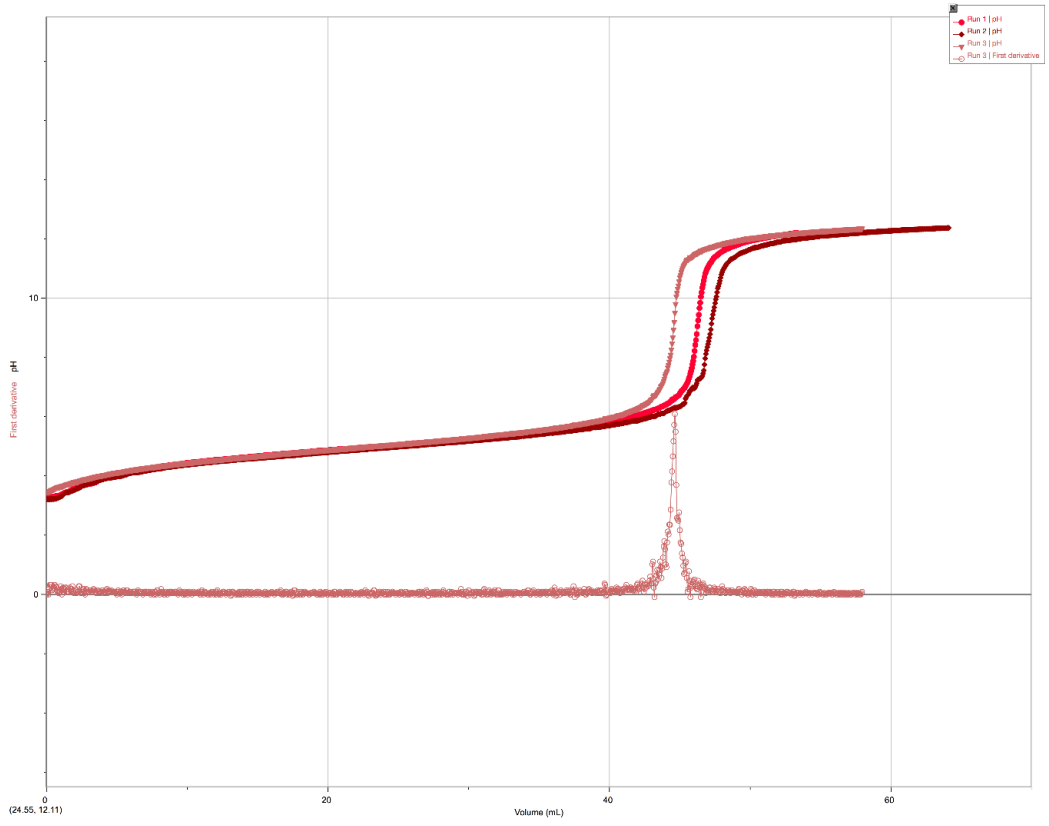

Figure 1: Acid-Base Titration Graph for Vinegar and NaOH

Based on the curve above, the pH starts at about pH 2.8 because of the presence of a weak acid. As NaOH is added to the solution, the pH increases slowly. There is a sharp increase in pH between pH 4 and pH 10.3 which is between 42 and 45 mL of NaOH added. This is the equivalence point. At the equivalence point the vinegar solution turned a faint pink. This is where the source of error occurred, because the solution made was faint but not exactly the faintest pink so the accuracy wasn't one hundred percent correct. The calculated percent error was 1.83% so, even though the difference between each trial was less than a 0.1 to 0.4 mL difference the accuracy could have improved. Another source of error could have been difference in the rate of swirling each solution, the electronic balance's weight measurement, or recording incorrect values for the initial and final volumes of NaOH. Overall, the purpose of the experiment – to determine the concentration of acetic acid by acid-base titration was achieved and the concentration proved to be slightly different then the listed concentration from the manufacturer.