Standardization of a Solution of Sodium Hydroxide by Titration with Potassium Hydrogen Phthalate and Use of the Standardized Soduim Hydroxide Solution to Determine the Purity of Additional Potassium Hydrogen Phthalate Samples

The sodium hydroxide content of a solution containing approximately 75mL of ~1M sodium hydroxide (NaOH) in 675 mL dionized water was standardized by titration with potassium hydrogen phthalate (KHP). The standardized sodium hydroxide solution was then used to determine the KHP content in a sample of KHP known to contain impurities. The mechanism of the acid/base titration reaction and the implication of the results on the experiment to determine the purity of KHP are discussed.

Introduction

Neutralization of an acid takes place when the acid is reacted with a base. When the two are mixed directly, in large quantity, the reaction occurs almost instantaneously, making quantitative determination of the concentrations of the reactants difficult.

When knowledge of the exact concentration of an acid or base is required because either solution will be used in a subsequent quantitative experiment, a more measurable reaction is required.

Titration of an acidic solution of known concentration with a basic solution of unknown concentration will provide a precise determination of the concentration of the basic solution. When carried out specifically for this purpose, the titration process is known as standardization. [1]

Sodium hydroxide is typically standardized using an aqueous solution of pure grade potassium hydrogen phthalate (KHP). A few drops of an indicator, such

as phenolphthalein are added to the dissolved KHP. The indicator affects a color change in the solution when the acidic KHP solution has been neutralized.

This paper presents the results of a quantitative experiment to standardize an aqueous solution of NaOH with an aqueous solution of KHP, as well as results of further experiments in which the standardized NaOH solution was used to determine the purity of additional samples of KHP.

Experimental Section

Sample Preparation for the Standardization

A solution of approximately 0.10M NaOH was prepared by diluting 75mL of 1M NaOH to approximately 750 mL in a 1L nalgene bottle.

The KHP solutions were prepared by dissolving three samples of approximately .500g of KHP in 100mL of water in each of three 250mL Erlenmeyer flasks. These solutions were heated on a hot plate set to 135 degrees C, and swirled occasionally to facilitate the dissolution of the KHP. The KHP solution was removed from the hot plate, two drops of phenolphthalein indicator were added to each flask, and the solutions were allowed to cool before titrating.

Experimental Setup for the Standardization

The titration apparatus was set up, and the NaOH solution carefully added until the buret was filled to between 0mL and 3 mL.

The KHP was titrated to the endpoint with the NaOH solution. The endpoint was reached when the solution retained a slight pink color after the addition of one drop of NaOH.

Sample Preparation for the Determination of purity of KHP

The KHP solutions were prepared by dissolving three samples of approximately .700g of KHP in 100mL of water in each of three 250mL Erlenmeyer flasks. These solutions were heated on a hot plate set to 135 degrees C, and swirled occasionally to facilitate the dissolution of the KHP. The KHP solution was removed from the hot plate and allowed to cool before titrating.

Data and Calculations

Following the completion of the titrations, the samples were analyzed to determine the amount of sodium hydroxide consumed in the neutralization, and the amount consumed in the determination of purity of KHP. The volume of NaOH required was calculated by subtracting the initial volume of NaOH from the final volume. The results for the standardization are presented in table 1. The results for the determination of purity of KHP are presented in Table 2.

Table 1. Weights KHP and mL NaOH Consumed in Standardization

Trial	Weight KHP (g)	Initial volume NaOH (mL)	Final Volume NaOH (mL)	Volum NaoOH consumed (mL)
1	0.5005	0.14	24.65	25.51
2	0.5002	7.01	32.20	25.19
3	0.5001	3.90	29.29	25.39

Table 2. Weights KHP and mL NaOH Consumed in the Determination of Purity of KHP

Trial	Weight KHP (g)	Initial volume NaOH (mL)	Final Volume NaOH (mL)	Volum NaOH consumed (mL)
1	0.6997	11.49	22.62	11.13
2	0.6999	0.37	11.49	11.12
3	0.6996	22.62	33.79	11.17

The volume NaOH to mass KHP ratios were determined using equation 1, with the results for the standardization trials shown in Table 3, and the determination of purity of KHP in Table 4. It was expected that the ratios not vary by more than 1% between the trials. If the results of the three initial titrations did not meet the expected result, additional trials were completed, until acceptable results were returned.

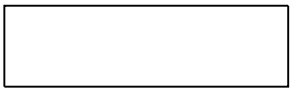
 (1)

Table 3. Volume to Mass ratios mL NaOH to g KHP in Standardization			
Trial	mL $NaOH_f$	Mass KHP (g)	Volume/Mass Ratio (mL NaOH:g KHP)
1	24.51	0.5005	50.97
2	25.19	0.5002	50.35
3	25.39	0.5001	50.77

Table 4. Volume to Mass ratios mL NaOH to g KHP in Determination of Purity of KHP			
Trial	mL $NaOH_f$	Mass KHP (g)	Volume/Mass Ratio (mL NaOH:g KHP)
1	11.13	0.6997	15.91
2	11.12	0.6999	15.88
3	11.17	0.6996	15.96

Standardization of NaOH

The amount (in moles) of KHP present in the aqueous solution in the standardization trials was calculated using equation 2. The results are contained in Table 5.

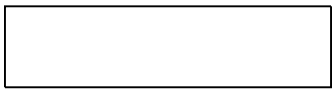
 (2)

Table 5. Moles KHP in Aqueous Solution		
Trial	Mass KHP (g)	Moles KHP
1	0.5001	2.451×10^{-3}
2	0.5002	2.449×10^{-3}
3	0.5001	2.449×10^{-3}

At the endpoint of the titration, moles KHP = moles NaOH. Therefore the [NaOH] can be calculated by using the moles KHP from Table 5 as the moles NaOH consumed in the titration, converting the mL NaOH consumed to L, and substituting these values into equation 3. The results are shown in Table 6. From these results, the mean [NaOH] and standard deviation were calculated.

 (3)

Table 6. [NaOH]			
Trial	Moles NaOH	NaOH consumed (L)	[NaOH] (M)
1	2.451×10^{-3}	0.02551	0.09610
2	2.449×10^{-3}	0.02519	0.09722
3	2.449×10^{-3}	0.02539	0.09646

Mean [NaOH] (M) = 0.09660

Standard Deviation $\pm 3X10^{-7}$

Standardized [NaOH] = $0.09660 \pm 3X10^{-7}$

Determination of Purity of KHP

The amount (in moles) of NaOH consumed in the titrations to determine the purity of the KHP samples was calculated using equation 4. The results are contained in Table 7.

 (4)

At the endpoint of the titration, moles KHP = moles NaOH. Therefore the grams KHP present in aqueous solution can be calculated by using the moles NaOH from Table7 as the moles KHP present using equation 5. These results are presented in Table 7.

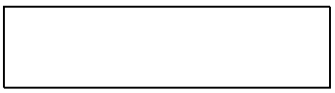
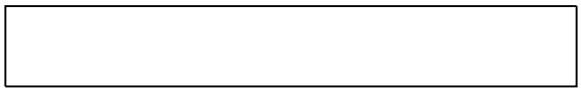
 (5)

Table 7. Moles NaOH Consumed, g KHP in Aqueous Solution, and Percent Purity KHP				
Trial	mL NaOH consumed	Moles NaOH	g KHP	% Purity KHP
1	11.13	1.075×10^{-3}	0.2195	31.37
2	11.12	1.074×10^{-3}	0.2193	31.33
3	11.17	1.079×10^{-3}	0.2204	31.50

Percent purity of KHP was calculated using equation 6. The results are shown in table 7.



From these results, the mean % purity of KHP and standard deviation were calculated.

Mean % Purity KHP = 31.40%

Standard Deviation = ± 0.1

Results and Discussion

Standardization

Three titrations were carried out on the weighed samples of KHP. The titrations were undertaken slowly and carefully in order to ensure accurate results.

The amount of KHP expected to be present in solution, based on a sample weight of 0.500 g, was calculated using equation 2, and determined to be 0.0244 moles. Since the approximate concentration of the NaOH solution of 0.1M, the expected endpoint was somewhere between 23mL and 25mL. As the volume of titrant neared the expected endpoint, titrant was added carefully, either dropwise, or by partial drops, achieved by carefully touching the inside of the mouth of the Erlenmeyer flask to a partial drop clinging to the tip of the buret.

In Trial 1, the initial of NaOH used was recorded as 24.51 mL. Using equation 1, the ratio of NaOH to KHP was recorded as 48.97. The same ratio for the two successive trials returned mL NaOH used of 25.19 and 25.39 with NaOH to KHP ratios of 50.35 and 50.77. These results are within 1% of each other, as required, [1] however, the variance between these and the initial trial is greater than 1%, indicating the introduction of error. Since the mass of KHP used in the first trial was larger than the masses of the successive trials, the expectation would be that more titrant would be required to neutralize the acidic solution.

However, the experimental results reflect that this initial trail required the least amount of NaOH solution to reach its endpoint. At the endpoint, the color of the solution very closely matched the color of the second and third trials, which consumed over 25 ml NaOH. It is believed that experimental error was introduced in this trial through a misreading of the buret and the amount of titrant consumed was in fact 25.52 mL. Using this estimated result, the calculated mL NaOH to mass KHP ratio was determined to be 50.97, which is within the required 1% variation between trials.

Determination of Purity of KHP

As in the titrations for the standardization of NaOH, three titrations were carried out on the weighed samples of KHP. The titrations were undertaken slowly and carefully in order to ensure accurate results. However, in these titrations the endpoint was initially unknown. As a result, in the first trial, titrant was added carefully, either dropwise, or by partial drops, achieved by carefully touching the

inside of the mouth of the Erlenmeyer flask to a partial drop clinging to the tip of the buret.

The endpoint of the first trial, measured as approximately 11mL, was assumed to be the expected endpoint for all remaining trials, thus, the remaining trials proceeded more quickly, with dropwise addition of titrant occurring close to the expected endpoint only.

In the trials to determine the purity of KHP, the sample masses were all similar, the color of the solutions at the endpoint closely matched one another, and the mL of NaOH determined to have been consumed in each trial were approximately equal, leading to the conclusion that the results are accurate as recorded.

Conclusions

The standardization of a solution of NaOH and the determination of the purity of KHP were carried out using the acid-base titration method. Quantitative analysis shows this to be an effective method for determining the concentration of solutions, or for determinng the amount of acid or base present in aqueous solution.

References

1. Anlker, K;,Breen, N, Nuygen,M; Experimental Chemistry II, p. 47-48; 2008; Hayden-McNeil, Plymouth, MI