# Study on Estimation of Alkalinity of Water Sample using a novel technique metric method

# Abstract

The alkalinity of water is one of the important parameters of water quality. The volumetric titration method using a standardized hydrochloric acid solution is a prevalent technique to estimate individual concentrations of basic radicals, like, , , and ions, which are primarily responsible for the alkalinity of water. However, the method needs two external indicators, namely phenolphthalein and methyl red to mark the end points of titrations. Furthermore, accuracy of the method is sacrificed due to inevitable parallax errors during marking of the end point of titration.

This present work reports that during titration of a given water sample with a standardized acid solution, preferably solution, changes continuously. This change in is closely monitored and recorded herbalically. Sharp change in is observed near the end point of titration and hence neutralization volume can be obtained from the corresponding curve. The nature of the curve clearly indicates the type of basic radical/radicals present in the water sample. The neutralization volume, thus obtained, is used to calculate the individual concentration of each basic radical present in the water sample. This novel technique obviates the use of any external indicators and eliminates any possible parallax error.

# Key Words

Alkalinity of water, Basic radicals, Volumetric titration, metric titration, Phenolphthalein, Methyl Red.

# Introduction

Alkalinity of water refers to amount of acid consumed to neutralize a given water sample. Alkalinity of water arises due to the presence of three major basic radicals, namely, , , and . The degree of alkalinity of a given water sample depends on the source of water. High degree of alkalinity may be observed in some industrial effluents. Detailed study on alkalinity of industrial effluents is well documented in the literature [5,6]. Catherine et al. reported the impact of municipal solid waste on the water quality of river [7]. Stefen at al. reported the effect of change of pH of water on plant growth [8]. Dykstra documented that during desalination and deionization processes of water changes significantly as alkalinity decreases sharply during the processes [9]. Nick Gray documented the detailed study of estimation of alkalinity of water [10].Another researcher Panchagnula et al. documented that various natural extracts can be used as indicators in the determination of alkalinity of water [4]. The details of water sampling and analysis of water hardness, alkalinity, corrosion and scaling are well documented in the literature [11]. The volumetric method of determination of alkalinity of different groundwater and sub-surface water is well documented in the literature [2,3], which claims that two different indicators, phenolphthalein and methyl red, are required to identify type of basic radicals present in the water sample and hence concentrations of those basic radicals can be estimated. However, volumetric method of determination of alkalinity of water sample is believed to be inaccurate due to unavoidable parallax errors during marking of end point of titration.

This present work proposes a novel technique, the metric method, to estimate the concentrations of basic radicals present in a water sample or in other words, to estimate the alkalinity of a given water sample. Sharp change in is observed near the end point of titration and hence neutralization volume can be calculated. Mallick reported that solution, during titration with a standard acid solution, is neutralized in two steps, which are clearly reflected in the corresponding curve [1]. So, any water solution, containing at least ion, always results two sharp changes in . Using this concept, the metric method is proposed to identify type of basic radicals present in the water sample as well as to determine concentrations of those basic radicals without using any external indicators.

**Chemicals and alkaline water samples**

**1. Details of chemicals used in this research work**

1. Dilute solution of strength

2. Double distilled water.

3. LR grade sodium bicarbonate powder (MW = 84).

4. LR grade sodium carbonate (MW = 106).

5. LR grade sodium hydroxide beads (MW = 40).

6. LR grade Phenolphthalein indicator.

7. LR grade Methyl Red indicator.

**2. Details of alkaline water samples**

Three different alkaline water samples are prepared as shown in the Table 1.

**Table 1 Composition of alkaline water samples**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Serial No. | Sample Code | beads | powder | powder | Double Distilled water |
| 1 | SAL-90 |  |  |  |  |
| 2 | SAL-80/106 |  |  |  |  |
| 3 | SAL-106/168 |  |  |  |  |

# Experimental Methods

**1. Volumetric titration**

(a) standard solution of strength is prepared. of it is poured into a burette.

(b) of water sample, SAL-90, is taken into a conical flask. drop phenolphthalein indicator is added into the conical flask. The solution turns to a light pink colour. It is then titrated against solution, running from the burette. At the end point light pink colour changes to colourless. The initial and final burette readings are noted. Triplicate readings are recorded. The mean burette reading is . The solution is only 50% neutralized and corresponding alkalinity, can be calculated using the mean burette reading.

(c) of same water sample, SAL-90, is taken into a conical flask. drop methyl red indicator is added into the conical flask. The solution turns to a light yellow colour. It is then titrated against solution, running from the burette. At the end point light yellow colour changes to light pink. The initial and final burette readings are noted. Triplicate readings are recorded. The mean burette reading is . The solution is 100% neutralized and corresponding alkalinity, can be calculated using the mean burette reading.

(d) The processes (b) and (c) are followed separately for the remaining two alkaline water samples SAL-80/106 and SAL-106/168. In both the cases and are calculated using the corresponding mean burette readings. The relation between and values indicates the type of basic radicals present in the given alkaline water sample.

(e) Using the values of and of the processes (b), (c) and (d) individual concentrations of basic radicals, present in each of the three water samples, can be calculated.

**2. metric titration**

(a) of prepared solution is poured into another burette.

(b) of alkaline water sample, SAL-90, is taken into a beaker. distilled water is added into it in order to immerse the electrodes safely into the solution. The solution is shaken gently and the electrode-set is immersed into it. The 1st reading is taken. The beaker is taken out and solution is added to it from the burette. The mixture is shaken gently and electrode-set is again immersed into it. The 2nd reading is taken. The process is continued till the reads around .

(c) The readings are plotted against the volume of solution added.

(d) The step (b) is repeated for the other two alkaline water samples, SAL-80/106 and SAL-106/168. In each case, readings are plotted against volume of solution added.

(e) For each alkaline water sample, the and values are obtained from the corresponding curve and hence and values can be calculated.

# Results and Discussion

**1. Alkaline water sample SAL-90**

This sample water contains only ion. It is documented that titration of solution with solution occurs in two steps [1] as follows

⎯→

⎯→

The results of volumetric titration of the sample are shown in the Table 2.A and 2.B.

**Table 2.A Volumetric titration for the alkaline water sample SAL-90**

**using phenolphthalein indicator**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of observations | Volume of SAL-90 alkaline water sample taken | Volume of solution consumed | | | |
| Initial | Final | Difference | Mean  Volume |
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Phenolphthalein indicator can detect only 1st part of titration reaction or 50% of the total neutralization reaction as shown below

⎯→

So, .

**Table 2.B Volumetric titration for the alkaline water sample SAL-90**

**using methyl red indicator**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of observations | Volume of SAL-90 alkaline water sample taken | Volume of solution consumed | | | |
| Initial | Final | Difference | Mean  Volume |
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Methyl red indicator detects the end point of titration, indicating the completion of neutralization process as shown below.

⎯→

So, .

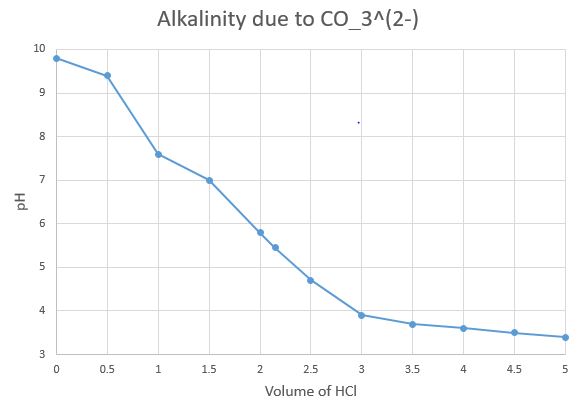
As the water sample contains only ion, it is expected that . The results of Tables 2.A and 2.B show that , which is much lower than the theoretical value.

The metric titration results of the same water sample are shown in the Table 3.

**Table 3 metric titration for the alkaline water sample SAL-90**

|  |  |  |  |
| --- | --- | --- | --- |
| No. of  observations | Volume of solution added (ml) | Total volume of solution added (ml) | reading |
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The corresponding curve is shown in the Fig.1.



**Figure 1 metric titration of alkaline water sample (SAL-90) using as titrant.**

The Fig.1 shows that formation is completed at at . So, . Another sharp decrease in is observed between and . Neutralization volume is calculated at the average values of 7 and 3.9. Average is 5.45 and corresponding volume of is . So, . So, . The result is close to the theoretical value and hence method is more accurate than the corresponding volumetric titration method.

**2. Alkaline water sample SAL-80/106**

This sample water contains both and ions. For this sample water also, and values are obtained using the volumetric titration method as well as metric titration method. The relation between and is that .

The results of volumetric titration of the sample are shown in the Table 4.A and 4.B

**Table 4.A Volumetric titration for the alkaline water sample SAL-80/106**

**using phenolphthalein indicator**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of observations | Volume of SAL-80/106 alkaline water sample taken | Volume of solution consumed | | | |
| Initial | Final | Difference | Mean  volume |
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Phenolphthalein indicator can detect 50% of and total . So, the partial strength of alkaline water sample using phenolphthalein indicator is

The value of can be calculated using the result of Table 4.A .

**Table 4.B Volumetric titration for the alkaline water sample SAL-80/106**

**using methyl red indicator**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of observations | Volume of SAL-80/106 alkaline water sample taken | Volume of solution consumed | | | |
| Initial | Final | Difference | Mean  volume |
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Methyl red indicator can detect total and ions. So the total strength of alkaline water sample using methyl red indicator is

The value of can be calculated using the result of Table 4.B. .

So, . Actual concentration of

. Actual concentration of

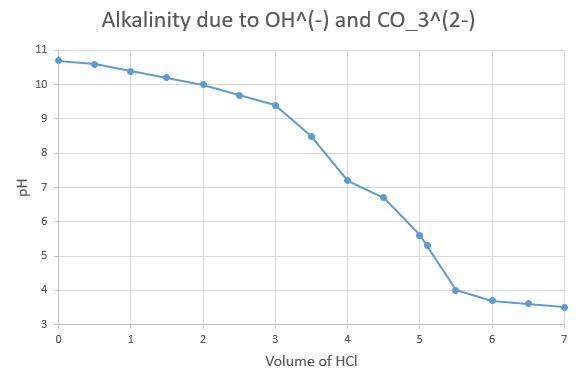
So significant deviation from actual results is observed in volumetric titration method.

The metric titration results of the same water sample are shown in the Table 5.

**Table 5 metric titration for the alkaline water sample SAL-80/106**

|  |  |  |  |
| --- | --- | --- | --- |
| No. of  observations | Volume of solution added (ml) | Total volume of solution added (ml) | reading |
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The corresponding curve is shown in the Fig.2.



**Figure 2 metric titration of alkaline water sample (SAL-80/106) using as titrant.**

The Fig.2 shows that formation is completed at at . So, . At this point all ions are neutralized and all ions are converted to ions. The partial strength of alkaline water sample is expressed as , which can be calculated using .

Another sharp decrease in is observed between and . Neutralization volume is calculated at the average values of 6.7 and 4. Average is 5.3 and corresponding volume of is . At this point neutralization process is completed and corresponding total alkalinity is expressed as , which can be calculated using .

So, . Actual concentration of

. Actual concentration of

It is evident that metric titration results are close to the actual values compared to the corresponding volumetric titration results.

**3. Alkaline water sample SAL-106/168**

This sample water contains both and ions. For this sample water also and are obtained after the volumetric and metric titration. The relation between and is that .

The results of volumetric titration of the sample are shown in the Table 6.A and 6.B.

**Table 6.A Volumetric titration for the alkaline water sample SAL-106/168 using phenolphthalein indicator**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of observations | Volume of SAL-106/168 alkaline water sample taken | Volume of solution consumed | | | |
| Initial | Final | Difference | Mean  volume |
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Phenolphthalein indicator can detect 50% of ions only and unable to detect ions. So, the partial strength of alkaline water sample using phenolphthalein indicator is

The value of can be calculated using the result of Table 6.A .

**Table 6.B Volumetric titration for the alkaline water sample SAL-106/168 using methyl red indicator**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Number of observations | Volume of SAL-106/168 sample water taken | Volume of solution consumed | | | |
| Initial | Final | Difference | Mean  volume |
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Methyl red indicator can detect total and ions. So the total strength of alkaline water sample using methyl red indicator is

The value of can be calculated using the result of Table 6.B. .

. Actual concentration of

So, . Actual concentration of

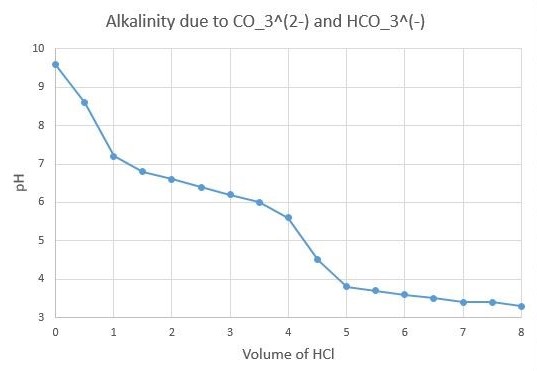
So significant deviation from actual results is evident in volumetric titration method.

The metric titration results of the same water sample are shown in the Table 7.

**Table 7 metric titration for the alkaline water sample SAL-106/168**

|  |  |  |  |
| --- | --- | --- | --- |
| No. of  observations | Volume of solution added (ml) | Total volume of solution added (ml) | reading |
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The corresponding curve is shown in the Fig.3.



**Figure 3 metric titration of alkaline water sample (SAL-80/106) using as titrant.**

The Fig.3 shows that formation is completed at at . So, . At this point all ions are converted to ions. The partial strength of alkaline water sample is expressed as , which can be calculated using .

Another sharp decrease in is observed between and . Neutralization volume is calculated at the average values of 5.6 and 3.8. Average is 4.7 and corresponding volume of is . At this point neutralization process is completed and corresponding total alkalinity is expressed as , which can be calculated using .

So, . Actual concentration of

. Actual concentration of .

It is evident that metric titration results are close to the actual values. So, it is believed that metric titration method is more accurate than corresponding volumetric titration method to determine alkalinity of a given water sample.

# Conclusions

1. The alkalinity of a given water sample can be estimated accurately using meter.

2. The metric method of estimation of alkalinity of a given water sample is more accurate than the volumetric method of determination of the same as the end point of titration in metric method is obtained from the graph without any parallax error.

3. No indicator is required in the metric method of determination of alkalinity of water, which is considered a distinct advantage over the corresponding volumetric titration method.

4. This novel technique of determining alkalinity of water sample is expected to explore future research works, based on meter.

# Disclaimer (Artificial intelligence)

The Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**COMPETING INTERESTS DISCLAIMER**:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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