

## Study of nature of chemical reactions using $pH$ –meter

### Abstract

In general, nature of chemical reactions are studied by separating the products followed by analyzing the products using different methods like spectroscopic method, chromatographic method etc. The objective of the present study is to investigate nature of chemical reactions using  $pH$  –meter. Two types of reactions are studied: (a) neutralization of a given  $Na_2CO_3$  solution by  $HCl$  solution and (b) neutralization of a given  $NaOH$  solution by oxalic acid solution. In both the cases, one component is acid and the other component is base. So, a salt is produced as the main product but the nature of the reaction, i.e., whether the reaction occurs in single step or multiple steps, cannot be identified by any standard methods.

In the present study the reaction is closely monitored using  $pH$  –meter. The detailed investigation clearly indicates that the neutralization reaction of a given  $Na_2CO_3$  solution by  $HCl$  solution occurs in two steps while neutralization reaction of a given  $NaOH$  solution by oxalic acid solution occurs in a single step.

On the basis of experimental studies, the probable steps of the reactions are proposed to explain the above neutralization reactions.

### Key words

$Na_2CO_3$ , oxalic acid,  $NaOH$ ,  $HCl$ ,  $pH$  –meter.  $NaHCO_3$ , sodium oxalate.

### Introduction

$pH$  –metric study is very useful to measure the acidity or alkalinity of different type of solutions. In acid-base titrations also  $pH$  meter is used to find out neutralization volume.  $pH$  –metric study is also useful in determining water quality as documented by several scientists<sup>1-2</sup>. Hossain et al.<sup>3</sup> and Kim et al.<sup>4</sup> studied the change in  $pH$  during different phases of waste water treatment process.  $pH$  –metric study of soil  $pH$  and quality of soil is reported by several authors<sup>5-6</sup>. Tania et al.<sup>7</sup> documented that  $pH$  –metric study is useful to determine  $pK_a$  value of mangosteen extract.  $pH$  –metric study in acid-base system has been reported by different authors<sup>8-9</sup>. Ishikawa et al.<sup>10</sup> reported that  $pH$  –metric method is useful to study the chemical interaction between solute and membrane.

The present work deals with study of nature of chemical reaction in acid-base system using  $pH$  –metric titration method. In strong acid-weak base-base neutralization reaction an acidic salt is produced. In case of  $Na_2CO_3$  and  $HCl$  neutralization reaction carbonic acid ( $H_2CO_3$ ) is formed. The  $pH$  –metric study of the

reaction shows that neutralization reaction occurs in two steps. Sodium carbonate is first converted to sodium bicarbonate, which is eventually converted to carbonic acid. However, in case of  $NaOH$  and oxalic acid neutralization reaction,  $pH$  –metric study clearly reveals that the reaction occurs in a single step. No sodium bi-oxalate is formed during the reaction.

## Materials

Following chemicals are used for this experiment.

1. Laboratory Grade  $Na_2CO_3$  crystals.
2. Laboratory Grade  $NaOH$  beads.
3. Laboratory Grade 12 (N) $HCl$ .
4. Laboratory Grade oxalic acid dehydrate crystals.

## Apparatus

1. 10 ml pipette
2. 50 ml burette,
3. 250 ml glass beaker
4.  $pH$  –meter (El-make)

## Methods

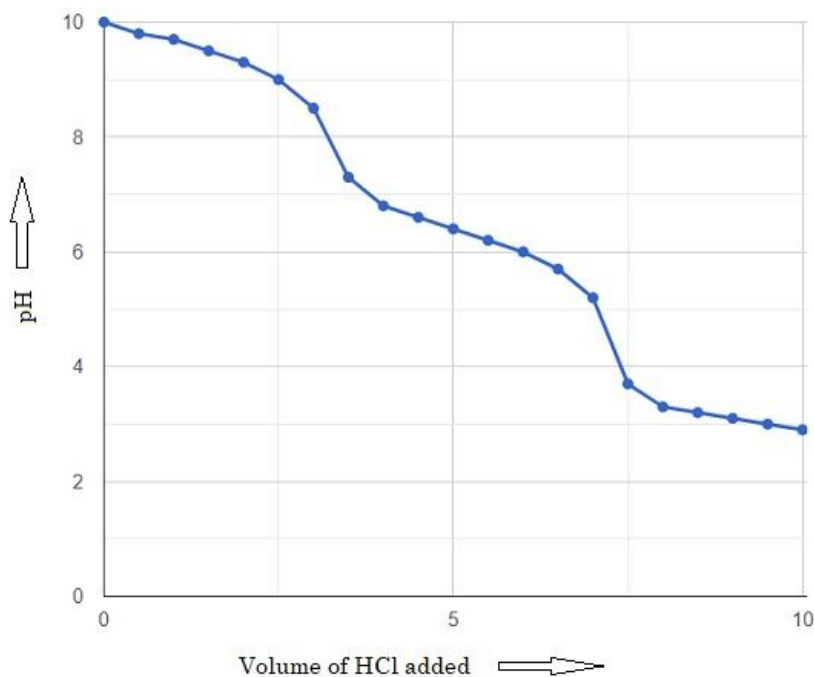
1. 100 ml of  $\left(\frac{N}{10}\right) Na_2CO_3$  solution is prepared using double distilled water.
2. 100 ml of 0.9384  $\left(\frac{N}{5}\right) HCl$  solution is prepared using double distilled water.
3. 100 ml of  $\left(\frac{N}{10}\right) NaOH$  solution is prepared using double distilled water.
4. 100 ml of 0.9835  $\left(\frac{N}{5}\right)$  oxalic acid solution is prepared using double distilled water.
5. In the first set of experiment, freshly prepared 0.9384  $\left(\frac{N}{5}\right) HCl$  solution is poured in a 50 ml burette. 10 ml freshly prepared  $\left(\frac{N}{10}\right) Na_2CO_3$  solution is taken in a 250 ml beaker by a 10 ml pipette. 90 ml distilled water is added into it. The electrode-set of  $pH$  –meter is immersed into the solution. The  $pH$  –meter reading is noted. 0.5 ml  $HCl$  solution is added to it from the burette. Gently stir the solution and corresponding  $pH$  reading is noted. Then continue addition of 0.5 ml  $HCl$  solution and take the  $pH$  reading in each case. The process is continued until  $pH$  reading shows around 2.5.
6. In the 2<sup>nd</sup> set of experiment, freshly prepared 0.9835  $\left(\frac{N}{5}\right)$  oxalic acid solution is poured in a 50 ml burette. 10 ml freshly prepared  $\left(\frac{N}{10}\right) NaOH$  solution is taken in a 250 ml beaker by a 10 ml pipette. 90 ml distilled water is added into it. The electrode-set of  $pH$  –meter is immersed into the solution. The  $pH$  –meter reading is noted. 0.5 ml oxalic acid solution is added to it from the burette. Gently stir the solution and corresponding  $pH$  reading is noted. Then continue addition of 0.5 ml oxalic acid solution and take the  $pH$  reading in each case. The process is continued until a constant  $pH$  reading is observed.

## Results and Discussion

1. In case of  $Na_2CO_3$  versus  $HCl$  titration process, the recorded  $pH$  –values are given in the Table-1.  $pH$  –values are plotted against volume of  $HCl$  solution added. It is shown in the Figure-1.

**Table-1: Change in  $pH$  –values on addition of  $HCl$  solution to  $Na_2CO_3$  solution**

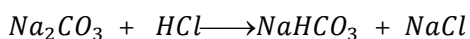
Volume of HCl solution added (ml)	$pH$	Volume of HCl solution added (ml)	$pH$	Volume of HCl solution added (ml)	$pH$
0	10	4.5	6.6	9	3.1
0.5	9.8	5	6.4	9.5	3
1	9.7	5.5	6.2	10	2.9
1.5	9.5	6	6		
2	9.3	6.5	5.7		
2.5	9	7	5.2		
3	8.5	7.5	3.7		
3.5	7.3	8	3.3		
4	6.8	8.5	3.2		



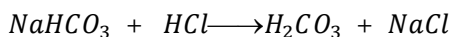
**Figure 1: Change in  $pH$  values during reaction between sodium bicarbonate and  $HCl$**

Two sharp decrease in  $pH$  (one around  $pH = 9$  and another around  $pH = 5.7$ ) are quite discernible. 1<sup>st</sup> sharp decrease is observed in alkaline region, indicating that neutralization reaction is only partially completed. It is believed that during this sharp decrease total  $Na_2CO_3$  is converted to  $NaHCO_3$ , which is still

alkaline and hence the sharp decrease is observed in alkaline  $pH$  range. The following reaction is believed to take place during 1<sup>st</sup> phase of neutralization process.



2<sup>nd</sup> sharp decrease is observed in acidic region, indicating that the reaction is completed and it is believed that total  $NaHCO_3$  is converted to  $H_2CO_3$ . The following reaction is believed to take place during 2<sup>nd</sup> phase of neutralization process.



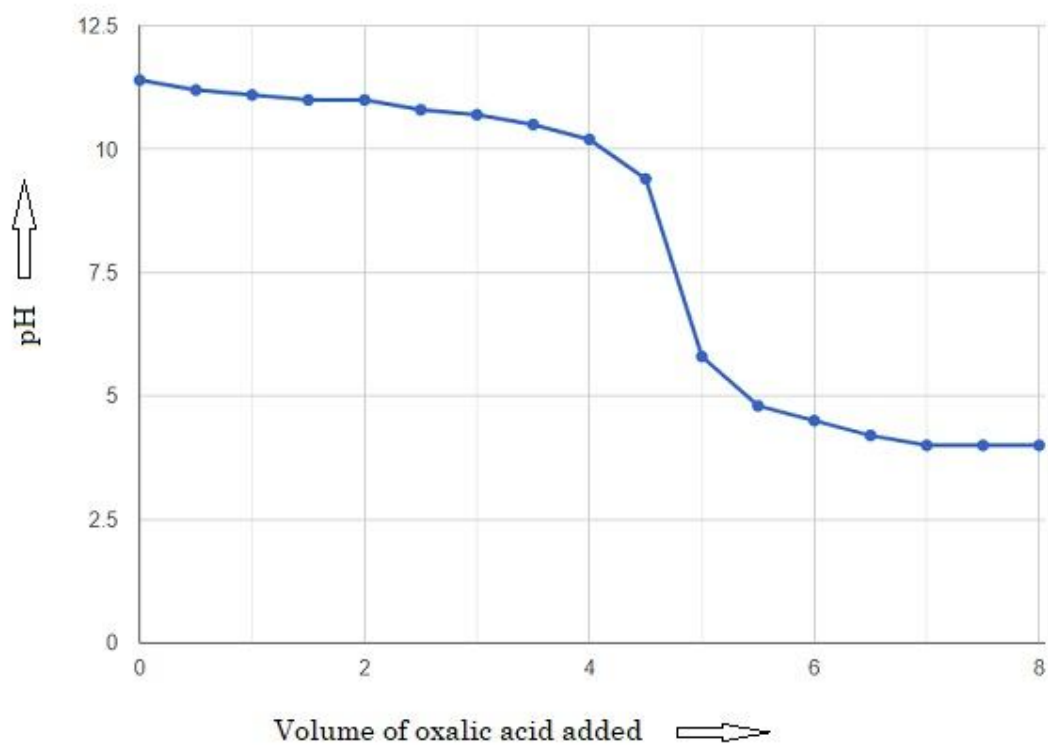
As the neutralization is completed in the 2<sup>nd</sup> phase, neutralization volume should be calculated on the basis of 2<sup>nd</sup> sharp decrease in acidic region.

2. In case of  $NaOH$  versus oxalic acid titration process, the recorded  $pH$  –values are given in the Table-2.  $pH$  –values are plotted against volume of oxalic solution added. It is shown in the Figure-2.

**Table-2: Change in  $pH$  –values on addition of oxalic acid solution to  $NaOH$  solution**

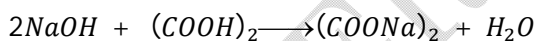
Volume of oxalic acid solution added (ml)	$pH$
0	11.4
0.5	11.2
1	11.1
1.5	11
2	11
2.5	10.8
3	10.7
3.5	10.5
4	10.2
4.5	9.4
5	5.8
5.5	4.8
6	4.5
6.5	4.2
7	4

7.5	4
8	4



**Figure 2: Change in pH values during reaction between sodium hydroxide and oxalic acid**

Only one sharp decrease is observed in the alkaline *pH* range, indicating that the neutralization reaction occurs in one step. The following reaction is believed to take place during neutralization process.



Unlike  $\text{Na}_2\text{CO}_3 / \text{HCl}$  titration, no sodium bi-oxalate is formed. Only sodium oxalate is formed.

### Conclusion

The reaction between  $\text{Na}_2\text{CO}_3$  and  $\text{HCl}$  occurs in two steps. In the 1<sup>st</sup> step sodium bicarbonate ( $\text{NaHCO}_3$ ) is formed. It is alkaline and finally sodium bicarbonate is converted to carbonic acid ( $\text{H}_2\text{CO}_3$ ) on further addition of  $\text{HCl}$ . However, the reaction between  $\text{NaOH}$  and oxalic acid occurs in one step without formation of any sodium bi-oxalate.

## References

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