



pH Determination of Acetic Acid-Sodium Acetate Buffer: An Application of Henderson-Hasselbalch Equation at Room Temperature

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In article, we have reported the applying of Henderson-Hasselbalch equation in determination of pH of acetic acid and sodium acetate buffer solutions at about 298 Kelvin as room temperature. In preparation of these buffer solutions, we have taken 1.5 ml of glacial acetic acid into 100 ml of standard flask for making up 0.2M of acetic acid solution, and 0.64 gm of sodium acetate were dissolved into 100 ml distilled water. Now, we taken 36.2 ml prepared solution of sodium acetate

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into 100 ml of standard flask and added 14.8 ml of prepared acetic acid to make its volume 100 ml by using of distilled water, it is a buffer. In measuring of pH of prepared buffer solutions, we have been using a calibrated digital pen pH meter for accurate and quick reading. In observation, the pH of buffer solutions a quite fluctuation was appeared. But, it has gradually raised by adding small amount of basic 5N NaOH solution into buffer sample, and, an adjusted pH was being to 4.7 as well.

GRAPHICAL ABSTRACT



Keywords: Henderson-Hasselbalch equation; acetic acid; sodium acetate; pH; buffer solution.

1. INTRODUCTION

Indeed, the solubility of an ionic compounds in buffer solutions is decreased by the presence a common ions and it obey the Le Chatelier's principle [1]. These principle states that, if a dynamic equilibrium is disturbed by the changing the conditions, the equilibrium position is shifts to counteract the change to reestablish an equilibrium. The dissociation of any substances like as solute into solvents [2-6], was earlier proved by Nernst in 1891 with given partition law, $K = C_A/C_B$ [7]. A literature survey have reported about the determination of pH of buffer solutions with bellow described relationships as well [8-15]. A buffer solution contains either a weak acid and its salt with a strong base, or a weak base and its salt with strong acid. The buffer solution is a solution that can resist pH change by addition of an acidic or basic substances. Because of common ion effect in acetic acid-sodium acetate buffer solution which is the suppression of the degree of dissociation of a weak electrolyte by the addition of a strong electrolyte having an ion common with that of the weak electrolyte [16]. The general pH relation which was given by Peter Sorensen (1909) is,

$$\text{pH} = -\log [\text{H}^+] = \log 1/[\text{H}^+] \quad \dots\dots\dots (1)$$

Where, the log is the base -10 logarithm, and, the $[\text{H}^+]$ is stands for the concentration of H^+ ions in solution, as given in mole per litre. The pH or concentration of H^+ ions in solution is a measure of the acidity or basicity of solution. From equation (1), the pH is a negative logarithm of hydrogen (H^+) ions concentration. In our present article, we have reported the Handerson equation, which latter on modified by Hasselbalch for determination of potential of hydrogen (pH) of the acetic acid-sodium acetate buffer solutions at room temperature (298 Kelvin) by using of digital pH meter. According to the mass law, the ionization reaction of pure solution for a weak acid is as $\text{HA} = \text{H}^+ + \text{A}^-$, the equilibrium condition are defined by the equation of the concentration law, $K (\text{HA}) = (\text{H}^+)(\text{A}^-)$. Where, the enclosed quantities is stand for concentrations of the respective substances and K is the ionization constant of the acid. This relation may be written as in more convenient form is, $(\text{H}^+) = K (\text{HA}) / (\text{A}^-)$ [17]. For buffer solutions these described Henderson equation is modified as follows,

$$\text{pH} = \text{pKa} + \log [\text{salt/acid}] \quad \dots\dots\dots (2)$$

This above equation (2) is known as Henderson-Hasselbalch equation and it applicable for all

buffer solutions. Here, the [salt] and [acid] is the concentration of the salt and acid in buffer, respectively. And, the pK_a is the value of pK of acid and, when the concentration of acid and the salt is equal then pH of buffer solution is equal to the pK_a , ($pH = pK_a$). By applying equation (2) we can calculate the pH value of a given buffer solution [18]. For example, the buffer of acetic acid and sodium acetate is an acidic buffer with pH 5.36 and, the pK_a of acetic acid is given as 4.76. Hence, from equation (2) we get,

By substituting of given values,

$$4.76 = 4.76 + \log [\text{salt}/\text{acid}]$$

$$\text{Or, } 4.76 - 4.76 = \log [\text{salt}/\text{acid}] = 0$$

Thus, $[\text{salt}] = [\text{acid}]$ as $\log 1 = 0$. For buffer solutions, the above equation (2) can be written as,

$$pH = pK_a + \log_{10} ([A^-]/[HA]) \quad \dots\dots\dots(3)$$

Where, $[A^-]$ and $[HA]$ is as concentration of weak acid with its salt or, conjugated acid-base pair in buffer solutions.

2. EXPERIMENTAL

In experimental, the all required materials, chemicals and reagents are being an analytical graded and laboratory based standard which have been used further as without purification for study. Here, the glacial acetic acid (CH_3COOH ; 99-100%) is of Merck Specialities Private Limited and the sodium acetate ($\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$) crystal pure of E. Merck (India) Pvt. Ltd., Worli, Mumbai-400018, India. Typically, the carbonate free a basic NaOH solution of 5N is prepared

well by adopting of Vogel procedure [19]. Here, firstly, we have prepared a 0.2M of acetic acid by taken 1.5 ml of glacial acetic acid into distilled water and make the total volume upto 100 ml. After then, for preparation of solution of sodium acetate we take a 0.64 gm of sodium acetate was dissolved into 100 ml distilled water. Now, we pipette out about 36.2 ml of prepared sodium acetate solution and poured it into a 100 ml of standard flask and added 14.8 ml of acetic acid, and by using distilled water make it volume 100 ml, respectively. These mixed both solutions are as buffer solution. Now, we measured the pH of this prepared buffer solution with using Wellon's digital pen pH meter for accurate and quick resolution of reading. Notably, before measuring of pH, the pH meter is standardized or calibrated first with its electrode tip and junction submerged in buffer and wash the electrode with distilled water and then introduced into prepared 0.2M acetic acid-sodium acetate buffer solutions.

3. RESULTS AND DISCUSSION

In pH measurement, we applied Wellon's digital pen type pH meter or tester, in these an electrical potential is developed by electrode pair pins when it dip into a buffer solutions (Fig. 1, (a)). A digital pH meter has a pH probe to conduct the electrical signals to pH meter that voltage count or display in the range of pH value for buffer solution [20]. These pH probe contain two electrodes naming as internal or sensor pH electrode and a reference electrode, as in Fig. 1, (b). Although, the electrode system of pH meter is sensitive to change in concentration of H^+ ion for taken solutions [21]. The potential of electrode is raise with pH value in respect of the concentration of H^+ of the solution.

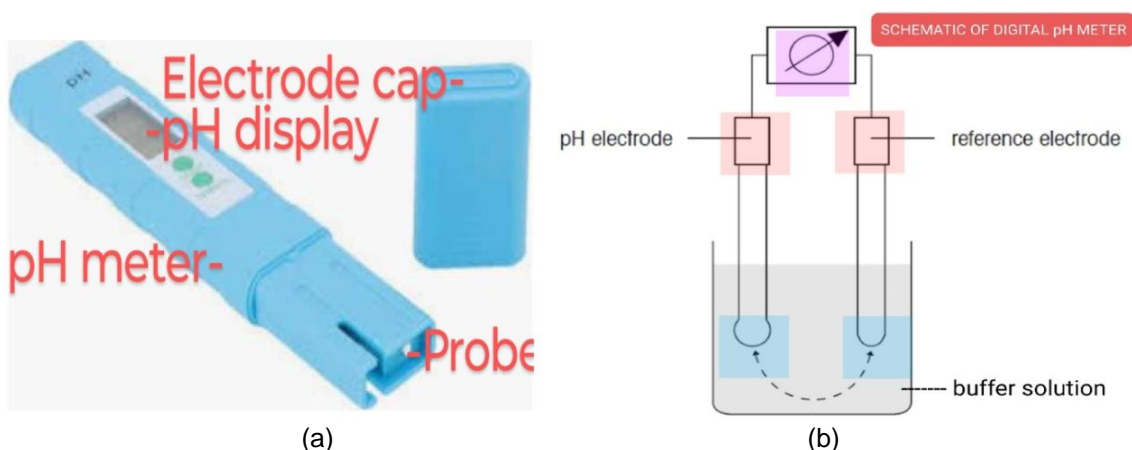
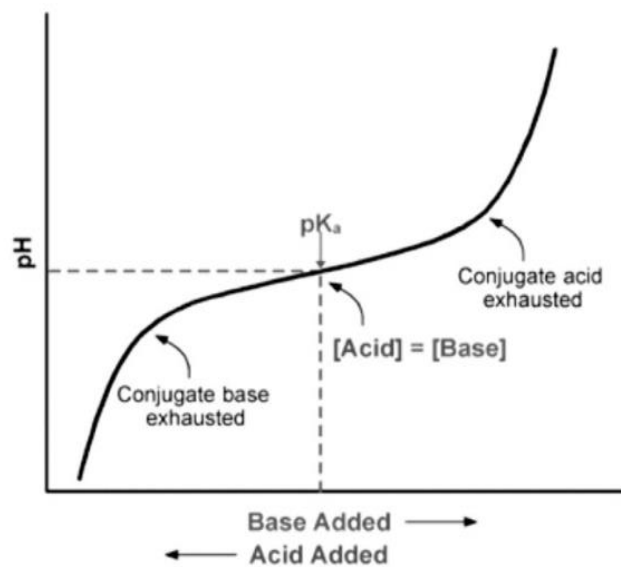
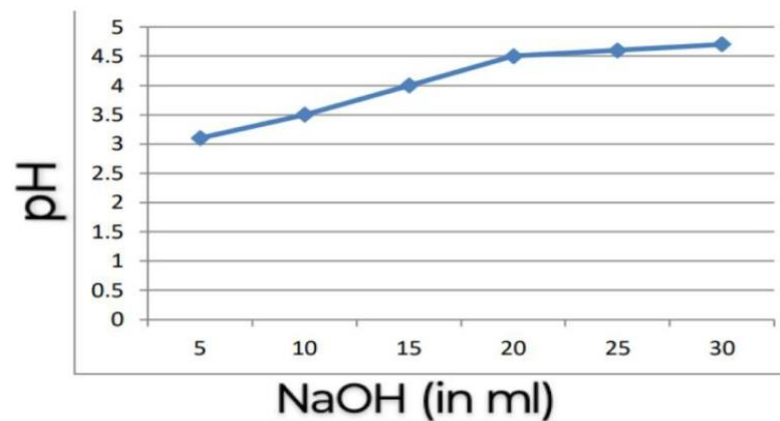


Fig. 1. (a)-A digital pen pH meter and, (b)- pH electrodes working representation scheme



(a)



(b)

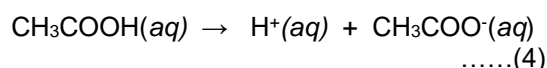
Fig. 2. (a)- A schematic graph of buffer solutions and, (b)- pH of buffer (acetic acid-acetate) solution against basic 5N NaOH, at 298 K

Hence, a slight variation is shown in pH range which provides a significant change in the quality of using solution. In preparation of 0.2M acetic acid-sodium acetate buffer solution we have taken about 36.2 ml of prepared sodium acetate and 14.8 ml of glacial acetic acid which were mixed well and buffer was prepared. Here, in measuring of pH value of buffer solution the electronic digital pen pH meter was used. In using pH meter, the pH value is measured an initial reading was observed 4.0, which raised upto 3.1 to 4.7 with 5N NaOH [22]. Initially, the pH is due to pure CH₃COOH (acetic acid) and as NaOH (sodium hydroxide) is added with CH₃COOH forming its conjugate base, the CH₃COONa salt. In other words, the buffer of acetic acid-sodium acetate (CH₃COOH-CH₃COONa) is composed of an equilibrium of weak acid (CH₃COOH) and its conjugate base (acetate ion from sodium acetate). When if adding an acid to buffer, the acetate ions neutralized the extra H⁺ ions to reform an acid and thus it prevents a decrease in pH [23].

Although, there are various factors which influence the pH of buffer solution like as the temperature, ionic strength, activity of H⁺ ions, dilution of buffer and addition of electrolyte salt etc. A buffer can prevent a sudden drop or increase in the pH of a solution after the addition of a strong base or acid up to its buffering capacity [24]. On dipping a pH meter into buffer solution of acetic acid-sodium acetate there was the pH value of sample solution is suddenly decrease before in fast and then after some gradually increase. But, when we pour the drop by drop of solution of 5N NaOH then the range of pH is raised from below 3.1 to 4.0 and upto 4.7. In graphically, the Fig. 2 (a) have shown the schematic diagram of acid-base solutions in which the plot is raised in forward for pK_a value, and, (b) a pH of buffer (acetic acid-acetate) with 5N basic NaOH solution, at room temperature (298 K). Here, in our present observation a quite fluctuation were appeared. This fluctuation may occurs when so much acid or base are added to the buffer solution they become the excess reactants. If a preparing buffer having more acid than base, a more H⁺ ions are likely to be present and then pH fall, and, if a buffer have more base than acid, more OH⁻ ions are present thus pH rise. The acetic acid-sodium acetate buffer is a buffer and having the ability to resist in changing of pH at certain pH range. When we added a small volume (5.0 to 30 ml) of 5N NaOH solution then it effectively provided the OH⁻ ions and increasing the pH of the buffer solution.

Thus, by addition of a salts of the conjugate acid-base pair to a solution increase the pH range due to the common ion effect [25]. This observation has reported for CH₃COONa (sodium acetate) which act as base and by adding base to a solution of weak acid (CH₃COOH) may increase the pH [26,27].

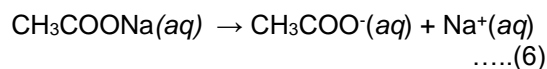
The acetic acid (CH₃COOH) is a weak acid and undergoes ionization in small extent to give the common acetate (CH₃COO⁻) ion with H⁺ ion as showing in the following reaction [28,29].



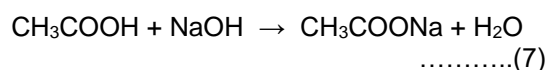
Where, the equilibrium or dissociation constant of acetic acid (CH₃COOH) is as –

$$K_a = [\text{CH}_3\text{COO}^-] [\text{H}^+] / [\text{CH}_3\text{COOH}] \quad \dots\dots(5)$$

When, a strong electrolyte such as sodium acetate (CH₃COONa) is added to that acetate ion, then CH₃COONa get ionizes as-



And,



By that ionization process, the concentration of CH₃COO⁻ ions is increases and equilibrium (equation 4) shifted in backward direction. Hence, the degree of dissociation of CH₃COOH is suppressed. Resulting, the concentration of H⁺ ions is decreases and thus concentration of OH⁻ ions increases [30,31]. And, therefore, the pH of buffer solution is increases. In buffer, the sodium hydroxide (NaOH) is reacts with acetic acid, a sodium acetate and water (H₂O) as product (a typical neutralization reaction). Notably, in CH₃COOH-CH₃COONa (acetic acid-sodium acetate) buffer solution the role of sodium (Na⁺) ions are as a spectator ion and it has no effect on position of equilibrium, so can be ignored [32-34].

4. CONCLUSIONS

In conclusions, we have reported the applying of Henderson-Hasselbalch equation for determination of pH of acetic acid and sodium acetate buffer solutions at 298 Kelvin as room temperature. In the preparation of buffer solutions, firstly, we have taken 1.5 ml of glacial

acetic acid into 100 ml of standard flask for making up 0.2M of acetic acid solution, and 0.64 gm of sodium acetate were dissolved into 100 ml distilled water. After then, a prepared 36.2 ml of sodium acetate solution into 100 ml of standard flask and added 14.8 ml of prepared acetic acid to make its volume 100 ml by using distilled water, it is a buffer. In measuring the pH of this prepared buffer solutions, we have been using a calibrated digital pen pH meter for accurate and quick resolution reading. In observation, a quite fluctuation was appeared. But, by adding basic 5N NaOH solution in acetic acid-acetate buffer solutions the pH of buffer sample have adjusted to shown about 4.7.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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