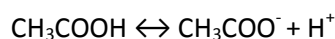


Question:

Calculate the pH of 1.0 M solution of acetic acid. To what volume one liter of this solution be diluted so that the pH of the solution that is formed will be twice of original volume. [$K_a = 1.8 \times 10^{-5}$]

Answer:

Acetic acid CH_3COOH is a weak acid and it dissociated in water solution to some extent according to equation:



Since the process is reversible, the constant of equilibrium of this process $K_a = \frac{[\text{H}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$

The degree of dissociation for CH_3COOH is not great, than we can neglect the amount of CH_3COOH that was ionized comparing with the initial concentration. And, according to the reaction equation, the amount of H^+ and CH_3COO^- formed are the same. Using this consideration:

$$K_a = \frac{[\text{H}^+]^2}{[\text{CH}_3\text{COOH}]_0} \Rightarrow \sqrt{[\text{H}^+]} = K_a \times [\text{CH}_3\text{COOH}]_0$$

We have, that $[\text{CH}_3\text{COOH}]_0 = 1.0 \text{ M}$ and $K_a = 1.8 \cdot 10^{-5}$. Therefore,

$$[\text{H}^+] = \sqrt{K_a \times [\text{CH}_3\text{COOH}]_0} = \sqrt{1.8 \cdot 10^{-5} \times 1.0} = 0.0042 \text{ M}$$

pH function is a negative logarithm from $[\text{H}^+]$:

$$\text{pH} = -\log[\text{H}^+] = -\log(0.0042) = 2.38$$

pH after the dilution has to be twice of original volume $\text{pH} = 2.38 \times 2 = 4.76$. The corresponding H^+ concentration is:

$$\text{pH} = -\log[\text{H}^+] \Rightarrow [\text{H}^+] = 10^{-\text{pH}} = 10^{-4.76} = 1.74 \cdot 10^{-5} \text{ M}$$

The corresponding initial concentration of CH_3COOH , which produced this amount of H^+ :

$$[\text{H}^+] = \sqrt{K_a \times [\text{CH}_3\text{COOH}]_0} \Rightarrow [\text{CH}_3\text{COOH}]_0 = \frac{[\text{H}^+]^2}{K_a} = \frac{(1.74 \cdot 10^{-5})^2}{1.8 \cdot 10^{-5}} = 1.68 \cdot 10^{-5} \text{ M}$$

The amount of moles remains constant, only volume of the solution has changed. If the initial volume $V_1 = 1 \text{ L}$, hence:

$$C_1V_1 = C_2V_2 \Rightarrow V_2 = \frac{C_1V_1}{C_2} = \frac{1 \times 1.0}{1.68 \cdot 10^{-5}} \approx 6 \cdot 10^5 \text{ L}$$