1.4: pH Buffers

Controlling pH is critically important in the qualitative analysis of cations. Often, pH needs to be maintained in a narrow range.

> A **pH buffer** is an aqueous solution consisting of a weak acid and its conjugate base or vice versa. It minimizes the pH change when a small amount of a strong acid or a strong base is added to it.

For example, adding 0.020 mol HCl into 1 L of water changes pH from 7 to 1.7, i.e., about 80% change in pH. Similarly, adding 0.020 mol NaOH to the same water changes pH from 7 to 12.3, i.e., about 80% change in pH. In contrast to pure water, 1 L of buffer solution containing 0.50 mol a week acid acetic acid ($\mathrm{CH_3COOH}$) and 0.50 mol of its conjugate base $\mathrm{CH_3COO^-}$ changes pH from 4.74 to 4.70 by the addition of the same 0.020 mol HCl and from 4.74 to 4.77 by the addition of 0.020 mol NaOH, i.e., about 1% change in pH, as illustrated in Fig. 1.7.1.

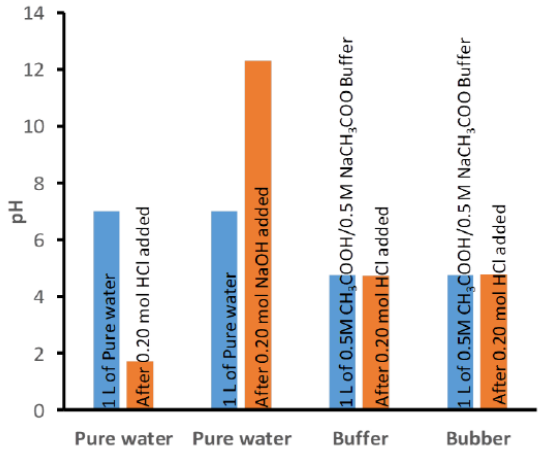

Figure 1.4.1: Effect of acid and base addition on pH change of pure water at pH 7.00 and acetic acid/sodium acetate buffer at pH 4.74.

The buffer contains a weak acid and its conjugate base in equilibrium. For example, **acetic acid/sodium acetate buffer** has the following equilibrium:

$$\mathrm{CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-}$$

The molar concentration of hydronium ions $[\mathrm{H_3O^+}]$ defines the pH of the solution, i.e., $\mathrm{pH} = -\log\left[\mathrm{H_3O^+}\right]$. The conjugate base consumes any strong acid added to the mixture:

$$\mathrm{HA + CH_3COO^- \longrightarrow CH_3COOH + A^-}$$

, where HA is any strong acid and $\mathrm{A^-}$ is its conjugate base. The concentration of $\mathrm{CH_3COOH}$ increases and $\mathrm{CH_3COO^-}$ decrease, but pH decreases little because $[\mathrm{H_3O^+}]$ is almost not affected. Similarly, the weak acid consumes any strong base added.

$$\mathrm{MOH + CH_3COOH \longrightarrow CH_3COO^- + M^+ + H_2O}$$

, where $\mathrm{M^+}$ is its conjugate acid. The concentration of $\mathrm{CH_3COOH}$ decreases and $\mathrm{CH_3COO^-}$ increases, but pH increases little because $[\mathrm{H_3O^+}]$ is almost not affected. Buffers are employed on several occasions during the qualitative analysis of cations.