Buffer Capacity

Buffer Capacity:

- Quantitative measure of buffer resistance to pH changes is called **buffer capacity.**

- Buffer capacity can be defined in many ways, **it can be defined as:**

➔ The number of moles of H^+/OH^- ions that must be added to one liter of the buffer in order to decrease /increase the pH by one unit respectively.

- The instantaneous buffer capacity is **expressed as β** and can be derived from Henderson Hasselbalch equation:

$$\beta = \frac{2.3\, K_a [H^+][C]}{(K_a + [H^+])^2}$$

From the equation ➔ the buffer capacity is directly proportional to the buffer concentration.

- **Where :**

β = the buffer capacity , [H+] = the hydrogen ion concentration of the buffer , [C] = concentration of the buffer and Ka= acid dissociation constant.

Practical buffer capacity:

- **Buffer capacity of acid and alkaline direction:**

➔ Buffer capacity $_a$ **(BC_a)** = the number of moles of H^+ that must be added to one liter of the buffer in order to decrease the pH by one unite.

This called buffer capacity in the ACID direction.

$$BC_a = \frac{9[HA]\,[A^-]}{10\,[HA] + [A^-]}$$

➔ Buffer capacity $_b$ **(BC_b)** = the number of moles of OH^- that must be added to one liter of the buffer in order to increase the pH by one unite.

This called buffer capacity in the ALKAILNE direction.

$$BC_b = \frac{9[HA]\,[A^-]}{10\,[A^-] + [HA]}$$

Buffer capacity in acid and base direction:

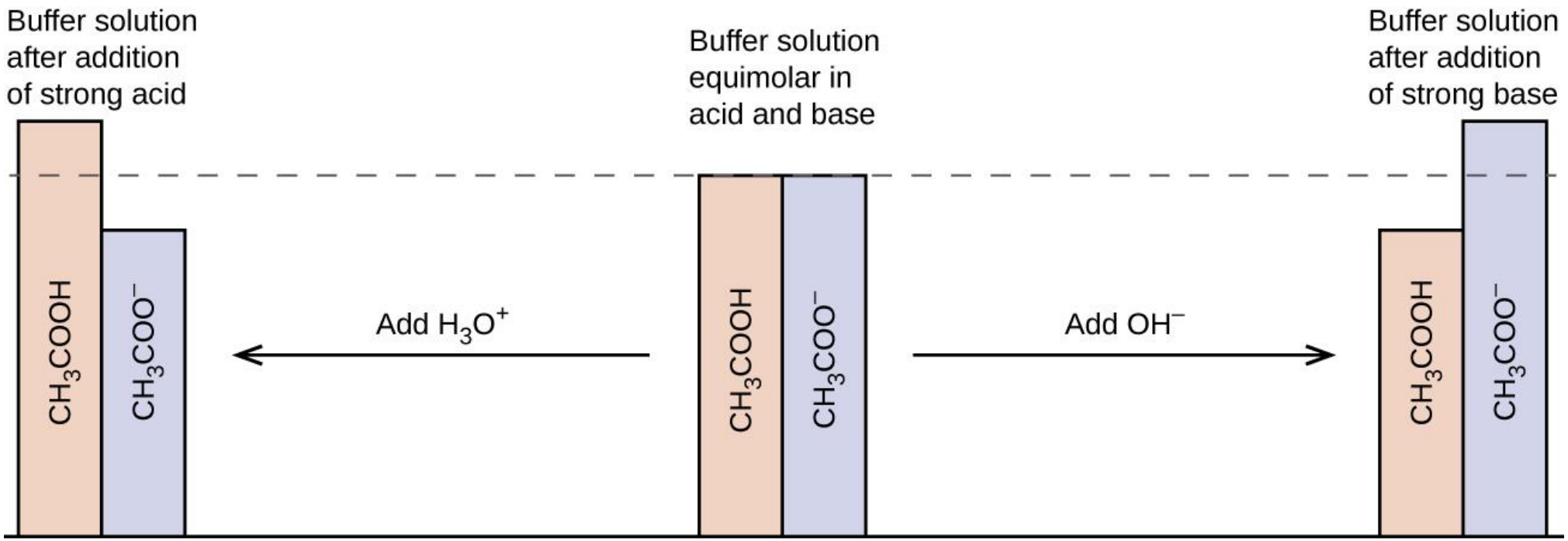
$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$$

H_3O^+ added, equilibrium position shifts to the left

$$CH_3COOH(aq) \leftarrow CH_3COO^-(aq) + H_3O^+$$

OH^- added, equilibrium position shifts to the right

$$OH^- + CH_3COOH(aq) \rightarrow H_2O(l) + CH_3COO^-(aq)$$



Buffer capacity in acid and base direction:

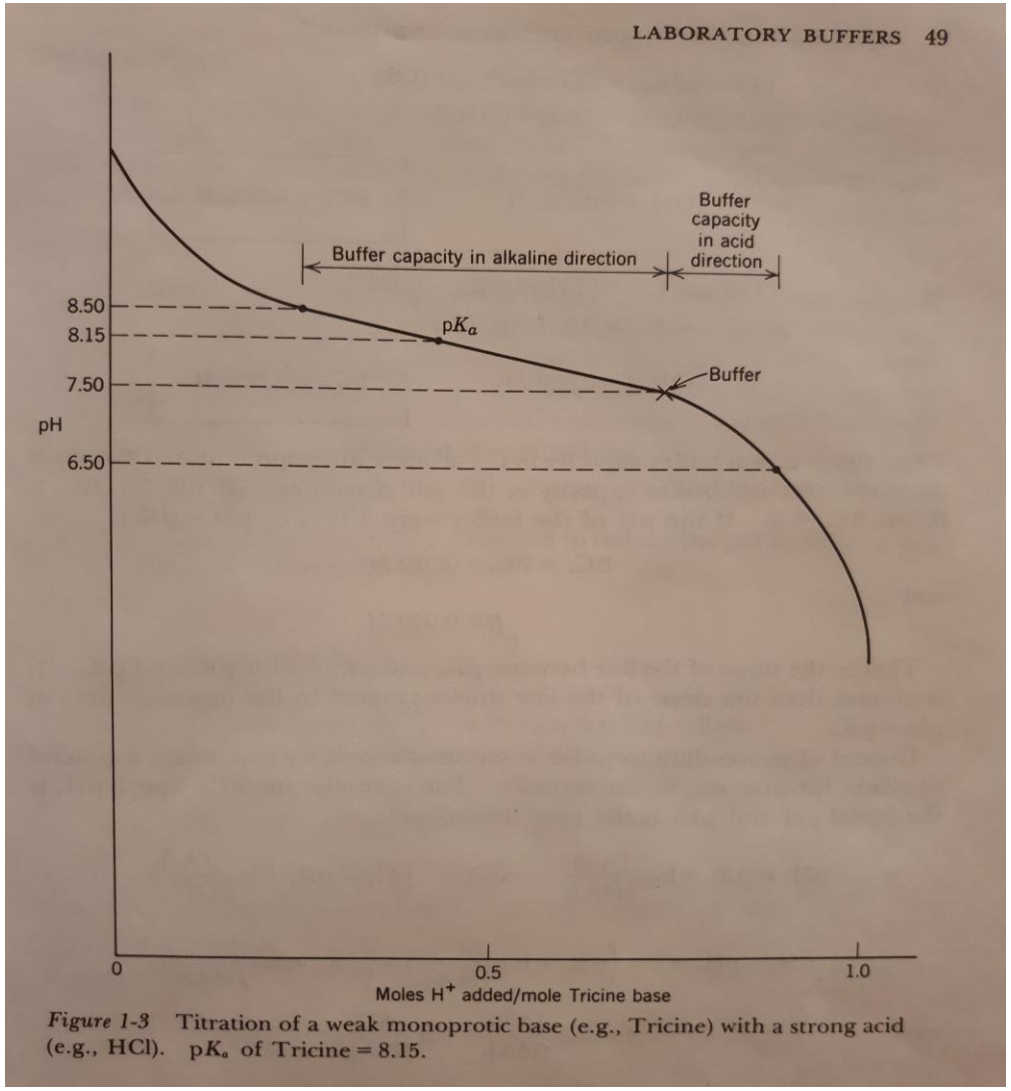


Figure 1-3 Titration of a weak monoprotic base (e.g., Tricine) with a strong acid (e.g., HCl). pK_a of Tricine = 8.15.

Titration of buffer with acid and base:

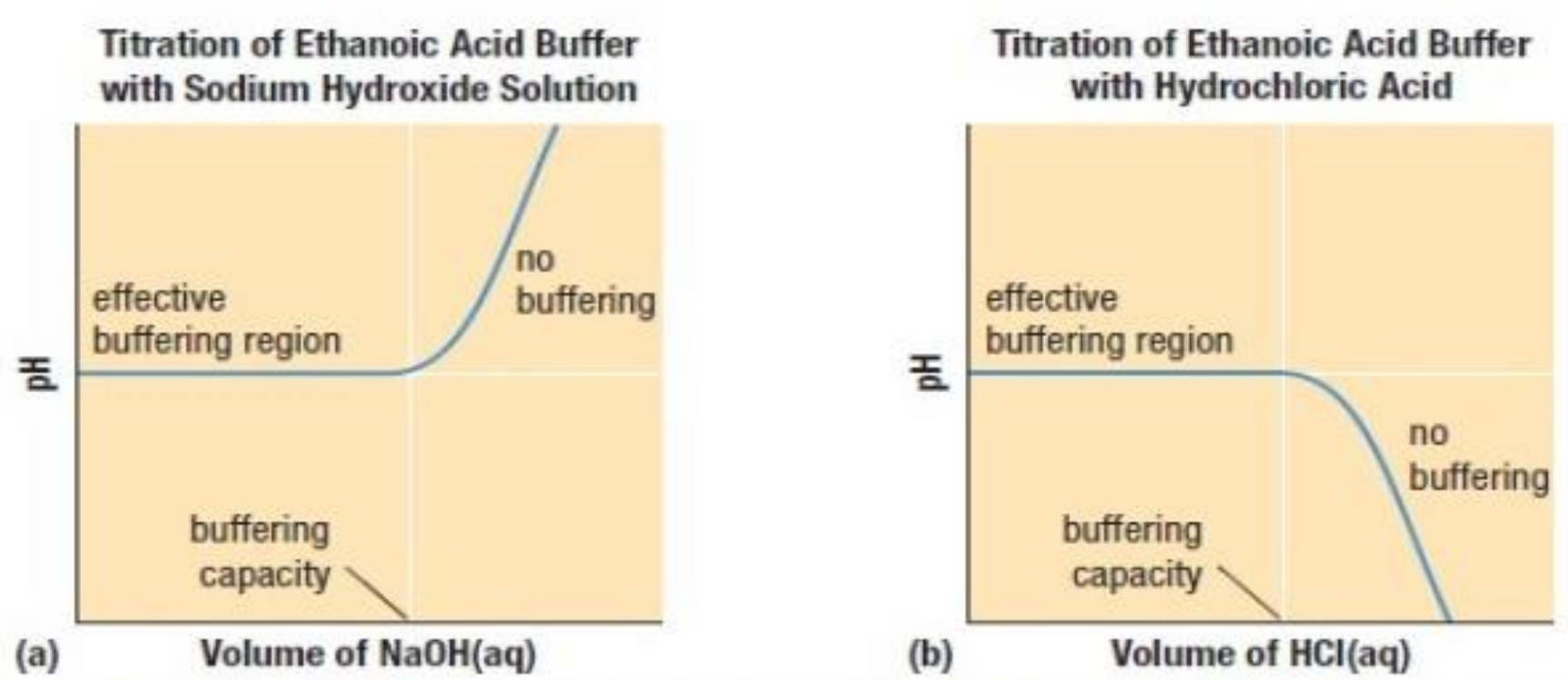


Figure 6 (a) Ethanoic acid buffer with a strong base added (b) Ethanoic acid buffer with a strong acid added. The pH changes quickly once all of the available buffer is depleted.

Example: **Calculate the instantaneous (β) and the practical buffer capacity in both directions of a 0.05 M Tricine buffer, pH 7.5, pKa = 8.15.**

First calculate the concentration of the weak base and its conjugated acid that make up the buffer with 0.05M:

$7.5 = 8.15 + \log \frac{[A^-]}{[HA]}$ ➔ $-0.65 = \log \frac{[A^-]}{[HA]}$ ➔ Anti log for both sides ➔ $0.224 = \frac{[A^-]}{[HA]}$

SO: $[A^-] = \frac{0.224}{1.224} \times 0.05 = 0.009\ M$, $[HA^-] = \frac{1}{1.224} \times 0.05 = 0.041\ M$

* since the pH < pKa , the [HA] will be higher than $[A^-]$.

Calculate the instantaneous buffer capacity:

$$\beta = \frac{2.3\ Ka\ [H^+][C]}{(Ka + [H^+])^2} \rightarrow \frac{2.3 \times 7.08 \times 10^{-9} \times 3.16 \times 10^{-8} \times 0.05}{(7.08 \times 10^{-9} + 3.16 \times 10^{-8})^2} \rightarrow \boxed{\beta = 0.017\ M}$$

OR

$$\beta = \frac{2.3\ [HA]\ [A^-]}{[HA] + [A^-]} \rightarrow \frac{2.3 \times 0.041 \times 0.009}{0.041 + 0.009} \rightarrow \boxed{\beta = 0.017\ M}$$

Example cont': Calculate the instantaneous (β) and the practical buffer capacity in both directions of a 0.05 M Tricine buffer, pH 7.5, pKa = 8.15.

Calculate the practical buffer capacity in both directions:

$$BC_a = \frac{9[HA]\,[A^-]}{10\,[HA] + [A^-]} \rightarrow \frac{9 \times 0.041 \times 0.009}{(10 \times 0.041) + 0.009} \rightarrow BC_a = 0.008\ M = [H+]$$

$$BC_b = \frac{9[HA]\,[A^-]}{10\,[A^-] + [HA]} \rightarrow \frac{9 \times 0.041 \times 0.009}{(10 \times 0.009) + 0.041} \rightarrow BC_b = 0.026\ M = [OH-]$$

Practical Part

Objective:

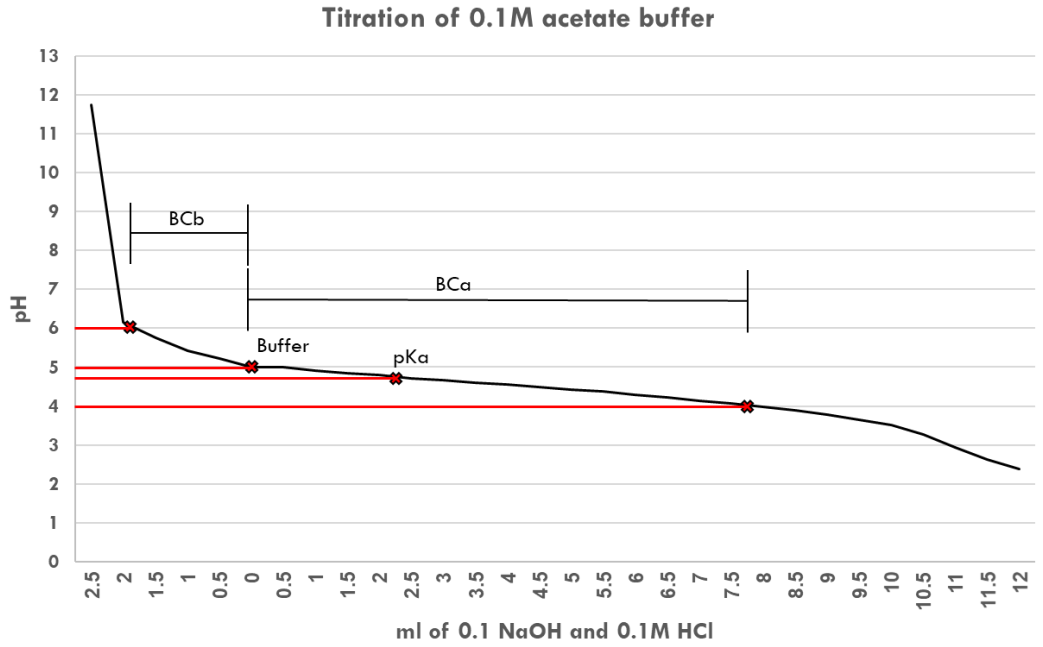
- To understand the concept of buffer capacity.
- To determine the buffer capacity in alkaline and acid directions.

Method:

- You are provided 0.1 M acetate buffer (pH=5).
- In two beakers add 8ml of the 0.1 M acetate buffer.
- Titrate the first beaker by adding 0.5 ml of 0.1 M HCl and the second one by 0.1 M NaOH from the burette and determine the pH of the solution after each addition.
- Continue adding the acid/base until you record a notable change in the pH.
- Record the titration table.

Results:

- Plot a curve of pH against the volume (ml) of HCl and NaOH added. calculate pH after addition of 0.5 ml , 2ml of HCl.
- Calculate the buffer capacity in both direction from the graph and the formula.
- Determine the buffering region.



Discussion:

- Compare between the value of the buffer capacity you got from the curve and formula.
- Did your buffer have a larger capacity for acid or base? Why?
- How can you relate your results with the buffer pH.