

# Buffer Solutions

①

Definition: A solution that resists change in pH on addition of limited amount of acid & base to it.

Why a buffer solution is needed?

→ In chemical, industrial & biological systems for certain rxns it is important to maintain the pH of the system.

For example: ① blood in human body is a buffer solution req. for body functioning  
[pH ~ 7.4]

② In pharmaceutical practice pH may affect the solubilities of drugs that are weak acids or bases. Also it may affect the stabilities of many drugs.

∴ during the drug design & its studies many reactions are required to be maintained at constant buffer pH. Therefore buffers are required.

How is a buffer made?

It is made by combining a weak acid or a weak base with its conjugate.

eg  $\text{CH}_3\text{COOH}$  (weak acid) +  $\text{CH}_3\text{COO}^- \text{Na}^+$  (its conjugate)

→ How is a buffer solution of a particular pH made? 2

Using Henderson-Hasselbalch equation

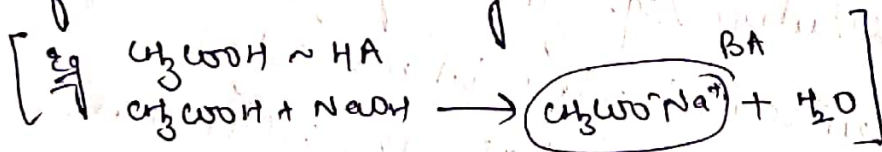
$$\text{pH} = \text{pK}_a + \log \frac{[\text{conjugate base}]}{[\text{acid}]} \quad \left[ \begin{array}{l} \text{conjugate base} \\ \text{or salt} \end{array} \right]$$

(of buffer)

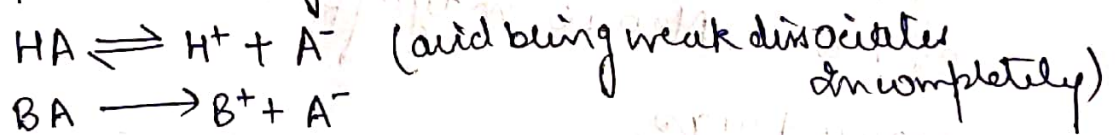
Now, what is this equation? & how is it derived?

Details of the equation are as follows:-

Let us assume HA is a monoprotic acid required for the synthesis of acidic buffer & BA is the salt of HA with a strong base



Then the equations may be written as:-



On applying law of chemical equilibrium on dissociation of weak acid,

$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

$$[\text{H}^+] = \frac{K_a[\text{HA}]}{[\text{A}^-]} \quad (1)$$

2 facts to be noted :-

- ① Due to common ion effect most of the ions are  $[\text{A}^-]$  are from BA only [Pls revise common ion effect]
- ② Since acid is mainly undissociated  $\therefore$  even at equilibrium the concentration of acid hardly changes

∴ If  $C_1$  is the initial concentration of acid  $\rightarrow$  HA (3)

at  $[HA] = C_1$ , [at  $t=0$ ]

which remains almost same at equilibrium due to suppressed dissociation

[common ion effect]  $\rightarrow$  fact (2)

Hence  $[HA]$  at equilibrium =  $C_1$

&  $[A^-] = C_2 =$  concentration of salt taken  
 = concentration of salt at equilibrium

[∴ most of the ions are coming from BA  $\rightarrow$  fact (1)]

Hence

~~$K_a = \frac{[H^+][A^-]}{[HA]}$~~   $K_a = \frac{[H^+][A^-]}{[HA]}$

$[H^+] = K_a C_1 / C_2$  (from equation (1) & 2 facts from above)

$\Rightarrow [H^+] = K_a \frac{[acid]}{[salt]}$   $\left\{ \begin{array}{l} [acid] = \text{initial concentration of acid} \\ [salt] = \text{initial concentration of salt} \end{array} \right.$

taking  $-\log$  on both sides

$\Rightarrow -\log [H^+] = -\log K_a - \log [acid] + \log [salt]$

$$pH = pK_a + \log \frac{[salt]}{[acid]}$$

Hence derived equa<sup>n</sup> to synthesise buffer of a particular pH.

Similarly if a basic buffer has to be synthesised

$$\text{then } \text{pOH} = \text{pK}_b + \log \frac{[\text{salt}]}{[\text{acid}]}$$

(4)

$K_b$  = dissociation of base constant

(\*) try to derive as above)

### Buffer capacity & Buffer index

→ the capacity of a solution to resist alteration in its pH; is known as buffer capacity.

$$\rightarrow \beta \text{ (buffer index)} = \frac{dB}{d(\text{pH})}$$

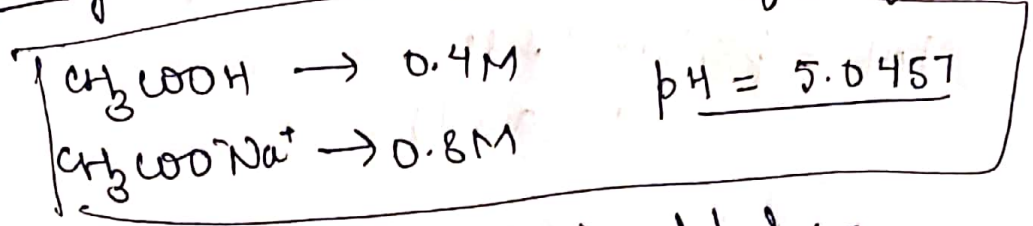
dB is the increment of strong base added to a buffer solution

d(pH) is the resulting increment in pH

### Physical meaning

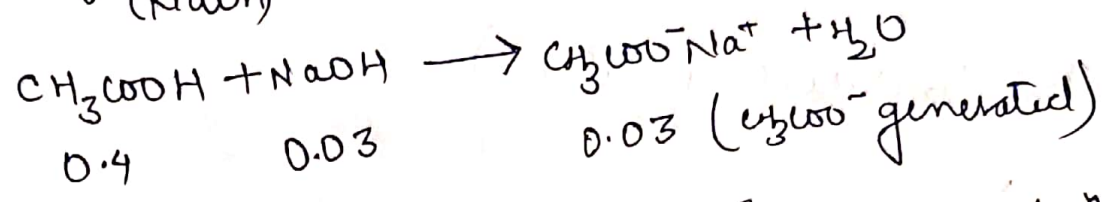
→ if concentration of acid of which buffer is made is higher the buffer capacity is high if it is low then ~~but~~ buffer capacity is low.

For eg let us consider a buffer of



given

⇒ Now, if base of 0.03M is added :-  
(NaOH)



∴  $[\text{CH}_3\text{COOH}] = 0.4 - 0.03 = 0.370$  New concentration of acid & salt  
 $[\text{CH}_3\text{COO}^-] = 0.003 + 0.8 = 0.803$

then New pH

$$\text{pH} = \text{pKa} + \log \frac{[\text{salt}]}{[\text{acid}]} = \boxed{5.0956}$$

initial pH = 5.0457 & now it is  $\boxed{5.0956}$

very less change in buffer ∴ if [acid] reduced then [salt] ↑ed by same am. Hence the ratio  $[\text{salt}]/[\text{acid}]$  didn't change to a very large extent & hence pH change is ↓

~~this is~~ since change is low ∴ buffer is said to have large buffer capacity.

$$\text{Buffer index} = \frac{0.03 \text{ (base added)}}{5.0956 - 5.045} = \boxed{0.6}$$

high buffer index means ↓ ΔpH means a good buffer