BUFFER SOLUTIONS

Buffer solutions

solution which can resist the addition of a strong acid or a strong base or water. Its' pH changes very slightly.

- + 1 drop of base $[H^+]$ ↓ in 1000 000 times
- + 1 drop of acid $[H^+]$ ↑ in 5000 times

(from 10^{-7} to 5×10^{-4})

In buffer solution from 1.00×10^{-7}

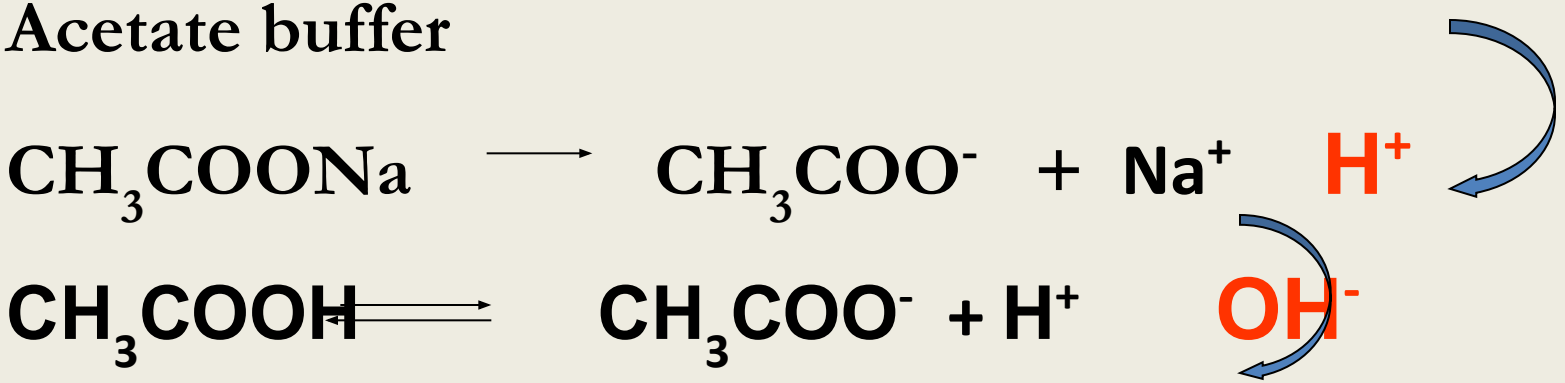
to 1.01×10^{-7}

Classification

Acidic Weak acid and its' salt	Amfoteric Aminoacids, proteins	Basic Weak base and its' salt
Acetate CH_3COOH CH_3COO^- Hydrocarbonate H_2CO_3 HCO_3^- Phosphate $H_2PO_4^-$ HPO_4^{2-}	$(H_3N^+)m - Prot - (COO^-)n$ $HA \Longleftrightarrow H^+ + A^-$ Acid base	Ammonia Donor NH_4^+ Acceptor NH_3

Mechanism of buffer action

Acetate buffer



+ 1 mole NaOH

1 mole

$$CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$$

+1 mole HCL

(weak electrolite)

$$CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$$

1 mole (weak electrolite)

pH formulas are derived from K_{dis}.

$$CH_3COOH \leftrightarrow CH_3COO^- + H^+$$

$$CH_3COOK \rightarrow CH_3COO^- + K^+$$

$$К_{\text{д кисл}} = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$[CH_3COO^-] = C_{\text{с}}, \quad [CH_3COOH] = C_{\text{к}}$$

$$[H^+] = \frac{К_{\text{д кисл}} \cdot C_{\text{кисл}}}{C_{\text{с}}} \qquad -\lg[H^+] = -\lg К_{\text{д кисл}} - \lg\frac{C_{\text{к}}}{C_{\text{с}}}$$

$$pH = pК_{\text{а}} + \lg\frac{C_{\text{с}}}{C_{\text{к}}}$$

$$pH = pK_{\text{д кисл}} + \lg\frac{N_{\text{с}} \cdot V_{\text{с}}}{N_{\text{к}} \cdot V_{\text{к}}} \qquad pH = pK_{\text{кисл}} + \lg\frac{n_{\text{с}}}{n_{\text{к}}}$$

HOW TO PREPARE BUFFER

1. Mixing the components:

-for **acidic** buffer

$$pH = pK_a + \lg N_s \cdot V_s / N_a \cdot V_a$$

-for **basic** buffer

$$pH = 14 - pK_B - \lg N_s \cdot V_s / N_b \cdot V_b$$

2. Partial neutralization

- **For acidic buffer**

$n_{acid} = n_{base} = n_{salt}$

$CH_3COOH + NaOH = CH_3COONa + H_2O$

(exsess)

$$pH = pKa + \lg N_b \cdot V_b / (N_a \cdot V_a - N_b \cdot V_b)$$

- **For basic buffer**

$NH_4OH + HCL = NH_4Cl + H_2O$

(exsess)

$$pH = 14 - pK_B - \lg N_a \cdot V_a / (N_b \cdot V_b - N_a \cdot V_a)$$

Buffer capacity

$$B_a = n_{acid} / |\Delta p\,H| \cdot V_{buf.sol}$$

$$B_b = n_{base} / |\Delta p\,H| \cdot V_{buf.sol}$$

n – mole equivalents of a strong acid or a strong base

$V_{buf.sol}$ - volume of a buffer solution

ΔpH – pH change as a result of acid or base addition

Buffer capacity depends on :

1.Components amount

2.n_{salt}/n_{acid} or

n_{salt}/n_{base}

B_{max}

- for ***acidic*** buffer

at $n_{salt} = n_{acid}$

$pH = pK_a$

- for ***basic*** buffer

at $n_{salt} = n_{base}$

$pH = 14 - pK_b$

$$pH = pK_a + \lg n_{salt}/n_{acid}$$

$$pH = 14 - pK_b - \lg n_{salt}/n_{base}$$

Mechanism of buffer action

Acetate buffer

$CH_3COONa \longrightarrow CH_3COO^- + Na^+$ H^+

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ OH^-

Buffer capacity

$n_{salt} > n_{acid}$ ⇒ $B_a > B_b$

$n_{salt} < n_{acid}$ ⇒ $B_a < B_b$

$n_{salt} = n_{acid}$ ⇒ $B_a = B_b = B_{max}$

$pH = pK_a + \lg n_{salt}/n_{acid}$

- Choose the buffer with maximum capacity and **pH = 7.36** :

1) acetic pK = 4.75;

2**) phosphate pK = 7.21**;

3) hydrocarbonate pK = 6.37.

Buffer systems of a body

1.Mineral

Hydrocarbonate H_2CO_3

HCO_3^-

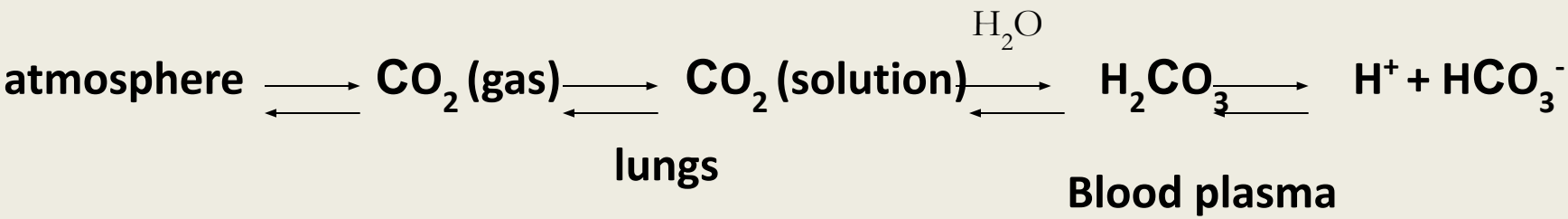
Phosphate $H_2PO_4^-$

HPO_4^{2-}

2. Protein and aminoacidic.

Hydrocarbonate buffer

(K) $NaHCO_3/H_2CO_3$



$$pH = pKa_{(H_2CO_3)} + lg\ C_{(NaHCO_3)}/C_{(H_2CO_3)} =$$

$$= 6{,}1 + lgC_{(HCO_3^-)} - lg\ P_{(CO_2)}$$

P - CO_2 pressure in lungs

Buffer capacity **Ba = 40 ммоle/L** **Bb = 1-2 ммоle/L**

pH of blood plasma

$$7.4 = 6.1 + \lg [HCO_3^-]/[CO_2]$$

$[HCO_3^-]:[CO_2] = 20:1$ ⟹ **Ba** > **Bb**

H_2CO_3 – 13 mole/ day

Other acids – from 0.03 to 0.08 mole/ day

1. A buffer consists of 0,5 moles of equivalent NH_3 and 0,5 moles of equivalent NH_4Cl. Which buffer component must be added to change pH to 9? $K_b(NH_3)=1,8*10^{-5}$

2. What is the pH of buffer made of

60 ml of 0,10M NH_3 with 40 ml of 0,10M NH_4Cl. $K_b=1,8*10^{-5}$.

3. What volume of 0,6M CH_3COONa must be added to 600 ml of 0,2M CH_3COOH to produce a buffer with pH=4,75? $K_a(CH_3COOH)=1,75*10^{-5}$.

4. What volume of 0,01M NaOH should be added to 100 ml of 0,5M CH_3COOH solution to produce a buffer with pH 4,75?
$pK_a(CH_3COOH)=4,75$

5. A buffer was prepared of 500 ml NaH_2PO_4 and 500 ml Na_2HPO_4 . After addition of 1 ml 0.1N HCl the change of buffer pH = 0.03. Calculate buffer capacity **B**a.

6. Choose a buffer with **B**a > **B**b:

a). 100 ml 0.2M $NaHCO_3$ + 100ml 0.4M H_2CO_3

b). 100 ml 0.4M $NaHCO_3$ + 100ml 0.2M H_2CO_3

c). 100 ml 0.2M $NaHCO_3$ + 100ml 0.2M H_2CO_3