

Class: First Year MBBS

Timings 8am to 9am

Date : 15-3-2021

- ▶ Subject: Biochemistry
- ▶ Module: Foundation
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HENDERSON HESSELBALCH EQUATION AND BODY pH

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Three Models of Acids and Bases

Model	Definition of Acid	Definition of Base
Arrhenius	H ⁺ producer	OH ⁻ producer
Bronsted-Lowry	H ⁺ donor	H ⁺ acceptor
Lewis	Electron-pair acceptor	Electron-pair donor



Strong Acids and Weak acids

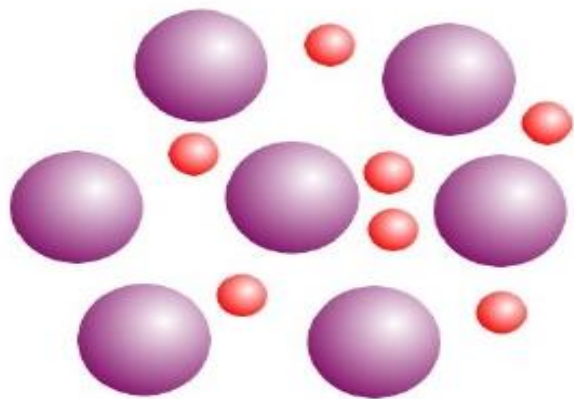
Strong Acids : Give up H^+ easily

Dissociate completely (100%) in water

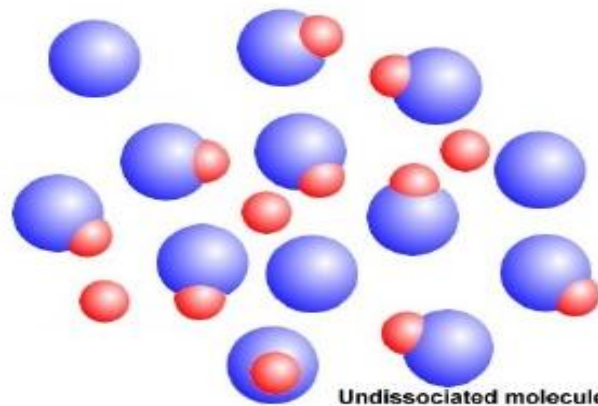
HCl, HBr, HI, HNO_3 , H_2SO_4 , $HClO_4$, $HClO_3$

- ▶ Weak acids: (all others)
- ▶ Hold onto H^+
- ▶ Few molecules dissociate
- ▶ Ex: $HC_2H_3O_2$





Strong acids are assumed to dissociate completely when in aqueous solution.



Weak acids dissociate only slightly in aqueous solution. The majority of molecules remain undissociated.

nitric acid dissociates *completely* in aqueous solution to produce hydronium cations, H_3O^+



every mole of nitric acid added to the solution will dissociate to produce 1 **mole** of hydronium cations.

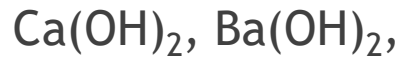
On the other hand, formic acid *does not* dissociate completely in aqueous solution to produce hydronium cations.



Strong Bases and Weak Bases

Strong Bases: Dissociate completely (100%) in water

- Group I metal hydroxides (NaOH, LiOH, etc.)
- Some Group II metal hydroxides

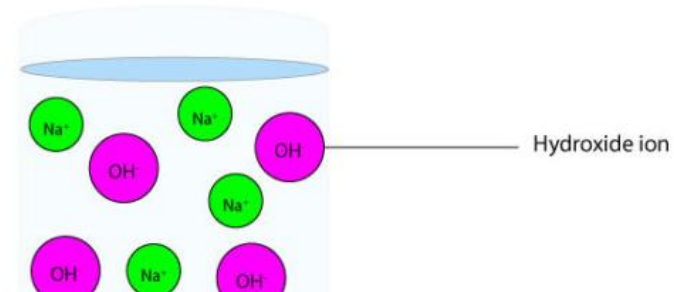
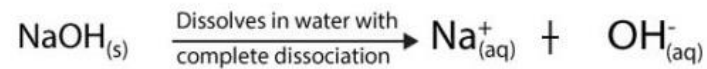


Weak Bases

Only a few ions dissociate

Ex: NH_3 (ammonia)

- ▶ Sodium hydroxide (NaOH) is strong base because it fully dissociates in water to produce hydroxide ions. While ammonia (NH_3) is weak base because it accepts protons from water to produce fewer hydroxide ions in solution. Because strong bases fully dissociate in water, they produce lots of hydroxide ions in solution, making the solution more basic. While weak bases produce fewer hydroxide ions, making the solution less basic.



Body Acids

- ▶ There are two types of acids

1: volatile acid (respiratory acid)

The acid is more correctly carbonic acid (H_2CO_3) but the term 'respiratory acid' is usually used to mean carbon dioxide. Although CO_2 itself is not an acid in the Bronsted-Lowry system as it does not contain a hydrogen so cannot be a proton donor. However CO_2 can instead be thought of as representing a potential to create an equivalent amount of carbonic acid. Carbon dioxide is the end-product of complete oxidation of carbohydrates and fatty acids. It is called a volatile acid meaning in this context it can be excreted via the lungs.

Basal CO_2 production is typically quoted at 12,000 to 13,000 mmols/day.

2: A **nonvolatile acid** (also known as a **fixed acid** or **metabolic acid**) is an **acid** produced in the body from sources other than **carbon dioxide**, and is not excreted by the lungs. They are produced from e.g. an incomplete metabolism of carbohydrates, fats, and proteins. All acids produced in the body are nonvolatile except **carbonic acid**, which is the sole **volatile acid**. Common nonvolatile acids in humans are **lactic acid**, **phosphoric acid**, **sulfuric acid**, **acetoacetic acid**, and **beta-hydroxybutyric acid**.



pH

- ▶ Sorenson defined pH as the logarithm of the reciprocal of the hydrogen ion concentration.
- ▶ Mathematically pH is expressed as a

$$\text{pH} = \log \frac{1}{[\text{H}_3\text{O}^+]/ [\text{H}^+]}$$

- ▶ may be rearranged as: $\text{pH} = \log 1 - \log[\text{H}_3\text{O}^+]$



pH

- ▶ Since $\log 1$ is zero, so it is written as :

$$pH = -\log[H_3O^+]$$

Thus , pH defined as negative logarithm of hydrogen ion concentration.

$$pH = \log \frac{1}{[H^+]} = -\log[H^+]$$

Sorensen established the term pH , to represent hydrogen ion potential.

The term p used to express the negative logarithm .

The concentration of the H_3O^+ is expressed in

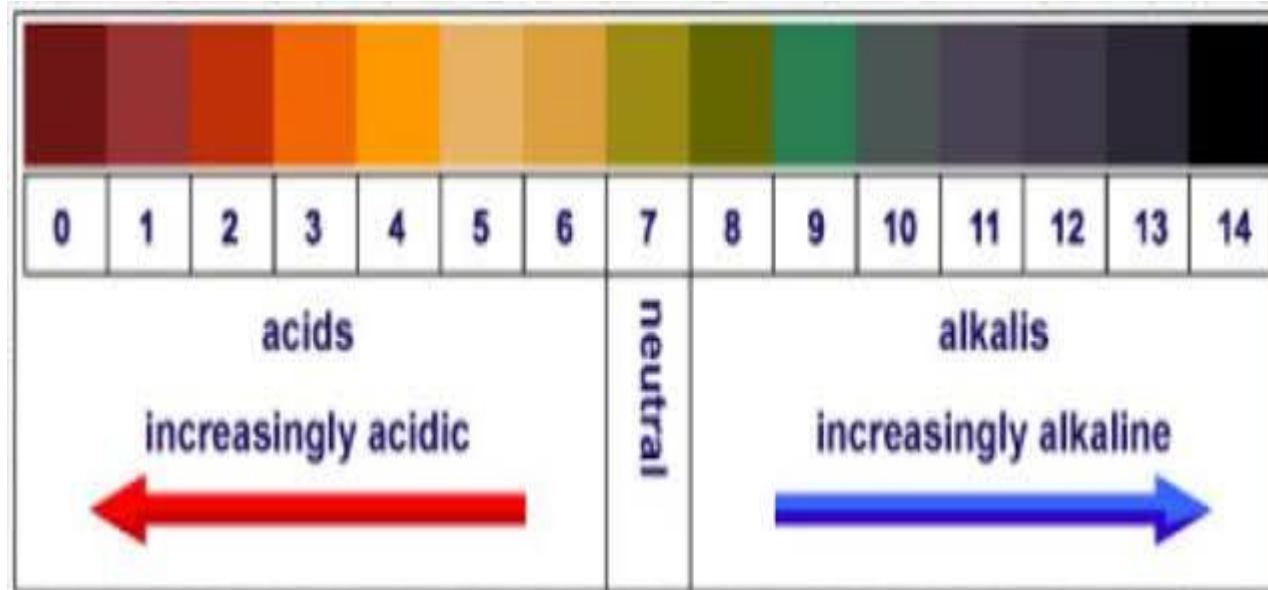


Why in pH symbol p is small and H is capital?

- ▶ The p in pH stands for "potenz" meaning "power" in Danish.
- ▶ Since the scale was given by a Danish Chemist Sorensen.
- ▶ H stands for Hydrogen and is its symbol. Hence H is written in capital letter.



pH Scale by Sorenson's



**Acid, Base, Universal
Indicator and PH Scale**



pH Scale by Sorenson's

$[H^+] (M)$	pH	$[OH^-] (M)$	pOH*
$10^0 (1)$	0	10^{-14}	14
10^{-1}	1	10^{-13}	13
10^{-2}	2	10^{-12}	12
10^{-3}	3	10^{-11}	11
10^{-4}	4	10^{-10}	10
10^{-5}	5	10^{-9}	9
10^{-6}	6	10^{-8}	8
10^{-7}	7	10^{-7}	7
10^{-8}	8	10^{-6}	6
10^{-9}	9	10^{-5}	5
10^{-10}	10	10^{-4}	4
10^{-11}	11	10^{-3}	3
10^{-12}	12	10^{-2}	2
10^{-13}	13	10^{-1}	1
10^{-14}	14	$10^0 (1)$	0



pH values of some fluids

- ▶ Blood plasma 7.35 - 7.45
- ▶ Milk 6.6 - 6.9
- ▶ Urine 4.8 - 7.5
- ▶ Gastric juice 1.2 - 3.0
- ▶ Saliva 6.35 - 6.85



Significance of PH

- ▶ We defined PH as negative log to the base ten of molar concentration of Hydrogen ions

$$\text{PH} = - (\log \text{H}^+)$$

- ▶ Therefore, each degree decrease or increase in PH value means 10 time more or less number of H⁺ respectively.
- ▶ If a solution have PH 6 has 10 time more H⁺ as compared of water and a solution having PH 2 has 10⁵ time more H⁺ as compared of water and solution having PH10 will have 1/ 1000 less H⁺ as compared to water.
- ▶ Blood plasma PH **7.35 -7.45**
- ▶ PH less than 7.35 means **acidosis.**
- ▶ PH more than 7.45 means **alkalosis.**



APPLICATION OF pH

- ▶ Enhancing solubility
- ▶ Increasing stability
- ▶ Improving purity
- ▶ Optimizing biological activity
- ▶ Comforting the body
- ▶ Storage of products



Indicator & PH Metry:

1. LITMUS PAPER

2. INDICATOR :

Indicator are used to find out the acidic or alkaline reaction of solution .

- ▶ An indicator is a weakly ionized acid or base having distinct colour in the unionized state and a different colour in ionized state.
- ▶ Indicator has a definite PH range over which it will completely dissociate and un dissociated , increasing or decreasing the PH beyond this range will not have any further effect i.e.
- ▶ **Congo red**: PH range 3.0 to 5.0 , yellow at PH 3.0 or less and red at PH5 or above
- ▶ **Phenolphthalein** PH range 8.3 to 10.0 , colourless at PH 8.3 or below and Red at PH 10.0 or above.

3. PH METRY : It determine the exact PH of the solution.



MAINTANENCE OF NORMAL PH

▶ There are three natural systems in our body which regulate and maintain the normal PH and also provide defense against change in the PH of the body.

- 1 . Acid base Buffer System (Chemical)
- 2 . Respiratory System
3. Renal System



The Henderson-Hasselbalch Equation

- ▶ Describes the derivation of pH as a measure of acidity in biological and chemical systems.
- ▶ The equation is also useful for estimating the pH of a buffer solution.
- ▶ It is widely used to calculate the isoelectric point of proteins(point at which protein neither accept nor yield proton).



The Henderson hasselbalch equation for acid

$$\text{pH} = \text{pKa} + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

Here, $\text{pKa} = -\log(\text{Ka})$

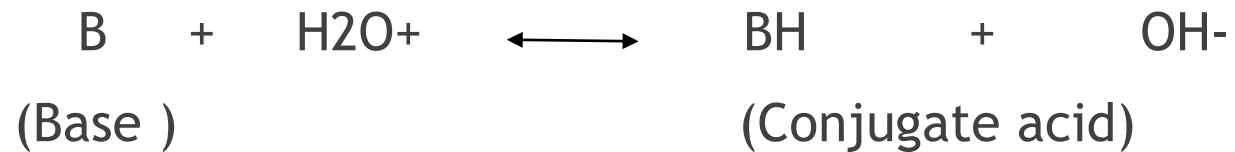
where Ka is the acid dissociation constant



The Henderson Hasselbalch Equation for base

$$\text{pOH} = \text{pK}_b + \log \frac{[\text{BH}^+]}{[\text{B}]}$$

where BH⁺ denotes the conjugate acid of the corresponding base B.



The Henderson-Hasselbalch Equation

- ▶ Lawrence Joseph Henderson wrote an equation, in 1908, describing the use of carbonic acid as a buffer solution.
- ▶ Karl Albert Hasselbalch later re-expressed that formula in logarithmic terms, resulting in the Henderson-Hasselbalch equation.
- ▶ Hasselbalch was using the formula to study metabolic acidosis.



Henderson-Hasselbalch Equation Derivation

- ▶ According to the Brønsted-Lowry theory of acids and bases,
an acid (HA) is capable of donating a proton (H^+) and a base (B) is capable of accepting a proton.
- ▶ After the acid (HA) has lost its proton, it is said to exist as the conjugate base (A^-).
- ▶ Similarly, a protonated base is said to exist as the conjugate acid (BH^+).



- ▶ In reversible reactions, the rate of a chemical reaction is directly proportional to the concentration of reactants

For a reaction $AB \rightleftharpoons C + D$

- ▶ Rate of forward reaction = $K_1[AB]$
- ▶ Rate of backward reaction = $K_2[C][D]$
- ▶ At equilibrium

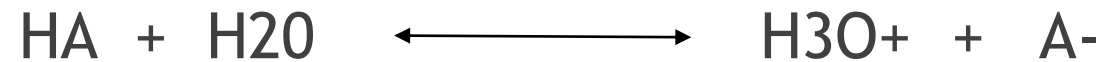
$$K_1[AB] = K_2[C][D]$$

$$K_a = \frac{K_2}{K_1} = \frac{[C][D]}{[AB]}$$

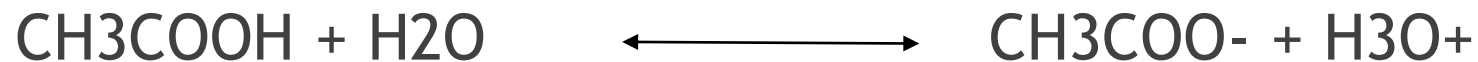


The Henderson-Hasselbalch Equation

- ▶ The dissociation of an acid can be described by an equilibrium expression:



- ▶ Consider the case of acetic acid (CH_3COOH) and acetate anion (CH_3COO^-):



The Henderson-Hasselbalch Equation

- ▶ Acetate is the conjugate base of acetic acid. Acetic acid and acetate are a conjugate acid/base pair.
- ▶ We can describe this relationship with an equilibrium constant:

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

1: Cross multiplies gives,

$$[H_3O^+][A^-] = [HA] K_a$$

2: Divide both sides with $[A^-]$,

$$[H_3O^+] = K_a \frac{[HA]}{[A^-]}$$

3: Taking the negative log of both sides of the equation gives

$$-\log [H_3O^+] = -\log K_a - \log \frac{[HA]}{[A^-]}$$

4: Substitute pH and pKa

$$pH = pK_a - \log \frac{[HA]}{[A^-]}$$

5: Inversion of last term removes the - sign

$$pH = pK_a + \frac{[A^-]}{[HA]}$$



The Henderson-Hasselbalch Equation

This equation can then be rearranged to give the Henderson-Hasselbalch equation:

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]} \quad = \text{pK}_a + \log \frac{[\text{conjugate base}]}{[\text{acid}]}$$



The Henderson hasselbalch equation for acid

$$\text{pH} = \text{pKa} + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

Here, $\text{pKa} = -\log(\text{Ka})$

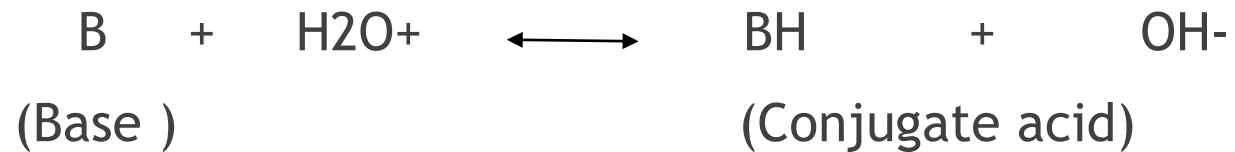
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The Henderson Hasselbalch Equation for base

$$\text{pOH} = \text{pK}_b + \log \frac{[\text{BH}^+]}{[\text{B}]}$$

where BH⁺ denotes the conjugate acid of the corresponding base B.



Estimating Blood pH

- ▶ A modified version of the Henderson-Hasselbalchequation can be used to relate the pH of blood to constituents of the bicarbonate buffering system.

$$\text{pH} = \text{pKa (H}_2\text{CO}_3) + \log \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$$

where:

pKa H₂CO₃ is the acid dissociation constant of carbonic acid. It is equal to 6.1.

[HCO₃⁻] is the concentration of bicarbonate in the blood is 20.

[H₂CO₃] is the concentration of carbonic acid in the blood is 1.



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THANKS

