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Donnan Membrane, Acid & Base, PH and Buffer

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Donnan Membrane Equilibrium

The presence of non-diffusible colloidal particles (e.g. protein) in the biological systems influences (alters) the concentration of diffusible ions across the membrane.

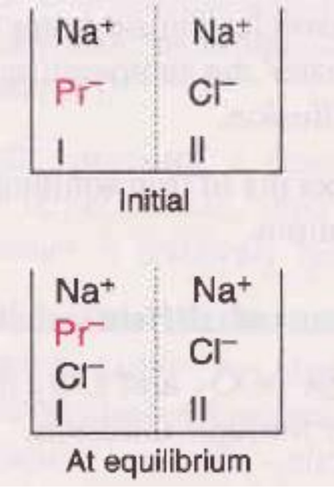
Membrane is freely permeable to ions (Na+, Cl-) and the concentration of ions on both the sides is different, the ions freely diffuse to attain equal concentration.

Gibbs-Donnan observed that the presence of a non-diffusible ion on one side of the membrane alters the diffusion of diffusible ions. In the molecule sodium proteinate (Na+Pr-), the protein

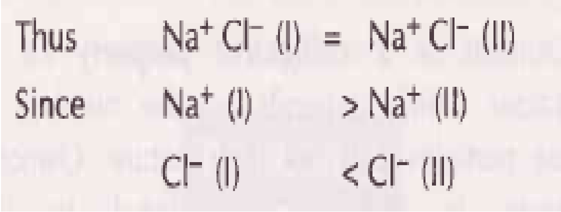
(Pr) ion is non-diffusable through the membrane. So on two sides of a compartment separated by a membrane.

- Initially, sodium proteinate is on side I while sodium chloride is on side II. Diffusible ions (Na+, Cl-) can freely pass through the membrane. On **side I, Na+** ions will balance the incoming Cl- ions **besides Pr ions**, while on **side II Na+** ions have to balance **only Cl- ions.**
- The concentration of Na+ on side I is greater than on side II, from the thermodynamical point of view, at equilibrium, the concentration of Na+ Cl- on both the sides should be the same.

A	B
K^+	K^+
Cl^-	Cl^-
Protein	



Consequently, the concentration of Cl- ions should be greater on side ll. Further, the total Concentration of ions on side I is higher than on side ll.



Thus $Na^+ Cl^- (I) = Na^+ Cl^- (II)$

Since $Na^+ (I) > Na^+ (II)$

$Cl^- (I) < Cl^- (II)$

Salient features of donnan membrane:-

1. The presence of a non-diffusible influences the concentration of diffusible across the membrane.
2. The concentration of oppositely charged ions (Na+), is greater on the side of the membrane containing non-diffusible ions (Pr).
3. The concentration of similarly charged ions (Cl-) is higher on the side of the membrane not containing non-diffusible ions (Pr).
4. The net concentration of total ions will be greater on the side of the membrane containing non-diffusible ions. This leads to a difference in the osmotic pressure on either side of the membrane.

Applications:-

1. **Difference in the ionic concentrations of biological fluids**:-

The lymph and interstitial fluids have lower concentration of inorganic cations(Na+, K+) and higher concentration of anions (Cl-) compared to plasma. This is attributed to the higher protein(Pr) content in the plasma.

2. **Membrane hydrolysis**:-

The relative strength of H+ and OH- ions and, therefore, the acidic or alkaline nature on either side of a membrane is influenced by the presence of non-diffusible ions. This phenomenon is referred to as membrane hydrolysis. Donnan membrane equilibrium explains the greater concentration of H+ ions in the gastric juice.

3. **Lower pH in RBC**:-

The hemoglob in of RBC is negatively charged and, therefore, causes the accumulation of positively charged ions including H+. Therefore, the pH of RBC is slightly lower(7.25) than that of plasma (7.4).

4. **Osmotic imbalance**:-

Donnan membrane equilibrium-which results in the differential distribution of ions in different compartments of the body partly explains the osmotic pressure differences.

ACIDS AND BASES

Some compounds can act as proton donor and proton acceptor and these compounds are known as ampholytes or are said to be amphoteric.

- As per the modern concept an acid is a proton donor and a base is a proton acceptor.
- On ionization, an acid donates a proton and a base (which is capable of accepting a proton). This base is known as a conjugate base.
- Acids and bases are classified into two groups depending on their tendency to lose proton or hydroxyl group respectively. They are strong acids and weak acids. Strong base and weak base.
- Strong acids or bases are those, which are completely ionized in solution.
- The weak acid or base dissociates only to a limited extend and the concentration of H^+ and OH^- depends on the dissociation constant of acid and base respectively
- The term alkali is reserved for those compounds that yield OH^- ions on dissociation

PH

- It is a unit that describes the acidity and alkalinity of a solution.
- The biochemical processes such as transport of oxygen in the blood, the catalysis of reactions by enzymes and the generation of metabolic energy are strongly affected by the concentration of H^+ ion.
- Many biological reactions are dependent on the charge on the molecules (+ ve or -ve charge).
- The charge on the molecule is determined by the ability of molecule to release or accept a proton, which in turn depends on the pH of the solution. So, in biological experiments it is necessary to measure the concentration of H^+ ion.
- The H^+ ion concentration of most of the biological solutions is very low and is in the range of 10^{-1} to 10^{-14} gram ions/L, which is very difficult to measure and express in conventional method of expression.
- Sorenson in 1909 introduced the term pH, to express the hydrogen ion concentration in a logarithmic manner, which is defined as **pH = -log of $[H^+]$ or log 1 / $[H^+]$.** According to this the $[H^+]$ concentration of 10^{-8} g /L will be pH 8.0. The 'p' denotes 'negative logarithm of ','p' also stands for power. pH is the abbreviation of 'power of hydrogen'

- The pH scale is the useful way of expressing acidity, which in turn dependent on $[H^+]$. pH is generally in the range of 0 - 14, as the dissociation constant of water at 25^0C is 10^{-14}.
- An acidic solution has a pH below 7 and a basic solution has a pH above 7. Pure water is neither acidic nor basic and is said to be neutral $[H^{+]} = [OH^-] = 10^{-7}$ M
- pH is inversely related to hydrogen ion concentration. That is lower the pH the higher the H^+ ion concentration.
- The pH scale is logarithmic (exponential) not arithmetic (linear). This means that when a solution changes from pH 7 to pH 6, the H^+ion concentration increases by 10 fold. When it goes from pH 7 to pH 5 it increases by 100 fold. The pH of water is 7.0 that means water contains $1x10^{-7}$ g of H^+ ions/L.
- The pH of an aqueous solution can be approximately measured using various indicator dyes, including litmus, phenolphthalein and phenol red, which undergo colour changes as a proton dissociate from the dye molecule.
- Accurate determination of pH in chemical and clinical laboratory is made with a glass electrode that is sensitive to H^+ ion concentration. Measurement of pH sometimes used in the diagnosis of diseases.
- The normal pH of human plasma is 7.4, which is referred to as physiological pH. The blood of patients suffering from certain diseases such as diabetes can have a lower pH, a condition called acidosis. The condition in which the pH of the blood is higher than 7 is called alkalosis.

Buffer

- A buffer solution is one that resists pH change on the addition of a small quantity of acid or alkali. Such solutions are used in biochemical experiments, where the pH is to be accurately controlled.
- Body fluids must be protected against change in pH. Because most enzymes are pH sensitive.
- During metabolism acids and bases are produced. In the long run, excess acids or base is eliminated via kidney and lungs. In the short run the body is protected against pH change by buffering systems. Acids produced by the body are carbonic acid, sulfuric acid, phosphoric acid, lactic acid, citric acid, ammonium ions Ketone bodies: acetoacetic acid and β-hydroxybutyric acid.
- Bicarbonate buffer is the major extracellular buffer and phosphate buffer is the major intracellular buffer in the body, which protects the body against the pH change.
- A buffer solution consists of a weak acid and its salt, the conjugate base (the proton acceptor). For e.g. acetic acid and sodium acetate or a weak base and its salts (e.g. ammonium hydroxide and ammonium chloride).

- Buffering capacity is the efficiency of the buffer solution to resists the change in pH when acid or base is added
- Assuming the buffer pair of **acetic acid and sodium acetate.**
- When an acid say Hcl is added, the acetate ion of the buffer binds with H^+ of Hcl to form acetic acid, which is weakly ionized. Therefore the buffer resists the pH change due to acid.
- When a base say NaOH is added the H^+ ions of the buffer acetic acid combines with OH^- ions to form water, which is weakly ionized. Thus the pH change due to base addition is also prevented.

HENDERSON - HASSELBALCH EQUATION

A weak acid HA ionizes as follows

$HA \rightarrow H^+ + A^-$

The equilibrium constant for this reaction is written as follows

$K_a = [H^+][A^-] / [HA]$

The value of te dissociation constant (Ka) indicates the tendency of the acid to lose its proton. Stronger acids have a grater tendency to dissociate and therefore have higher dissoiation constant

$[HA]$ = concentration of the undissociated acid, $[H^+]$ = concentration of hydrogen ion and $[A^-]$ = concentration of the conjugate base.

Cross multiplying:

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

$[H^+] = K_a * ([HA] / [A^-])$

Taking -log of both sids

$-\log [H^+] = -\log K_a - \log ([HA] / [A^-])$

Substitute pH and pK for $-\log[H^+]$ and $-\log K$ respectively. The -log of the dissociation constant is defined as the pKa.

$pH = pK_a - \log ([HA] / [A^-])$ (The stronger the acid ,lower is its pKa)

Then to remove the -sign invert the last term

$pH = pK_a + \log ([A^-] / [HA])$

When the pH is equal to pKa, the concentration of conjugate base is equal to concentration of undissociated acid.

THANKS