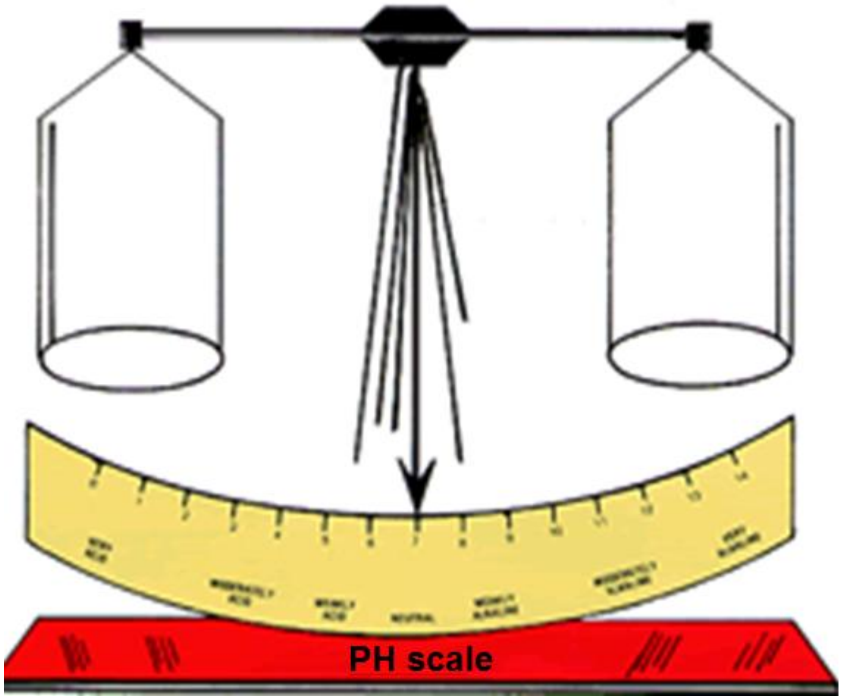

Lecture 17: Acid-Base Balance

Code: RRS-209

By

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Learning Objective:

Knowledge:

- Know the acid-base homeostasis.
- Understand role of respiratory system in acid-base balance
- Understand how ph can affect the regulation of respiration.
- know the definitions and causes of the respiratory alkalosis , acidosis

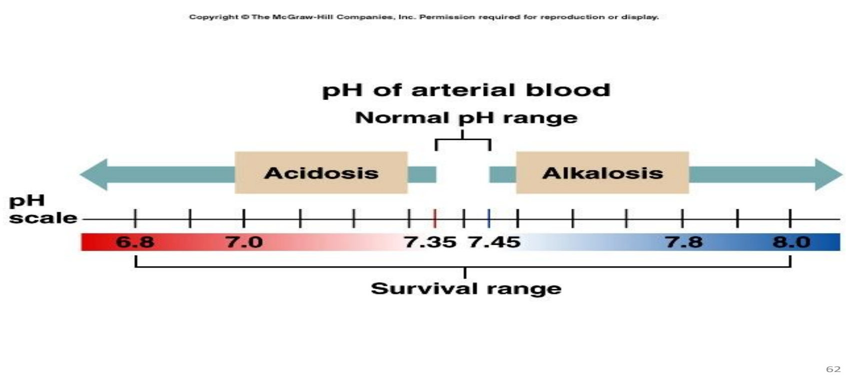
Intellectual:

- Can compare between the respiratory alkalosis , acidosis

Acid-Base Balance

- Acid-base balance is defined by the concentration of hydrogen ions in the blood.
- In order to achieve homeostasis, there must be a balance between the intake or production of hydrogen ions and the net removal of hydrogen ions from the body.
- The blood plasma within arteries normally has a pH between 7.35 and 7.45, with an average of 7.40
- *<u>How is Acid-Base balance measured ?</u>*

Hydrogen ion concentration is 40 mEq /L and expressed on a logarithm scale using pH units. $pH = \log \frac{1}{H^+} = -\log H^+$.



- ***Why pH must be kept tightly within normal range ?***

Small changes in pH can produce major disturbances, because:

1- Most enzymes act within a narrow pH ranges.

2-The pH can also affect electrolytes (Na+, K+, Cl-). 3-pH can affect function of hormones. 4-pH affects the excitability of nerve and muscle cells.

- Acid-Base homeostasis involves **chemical (buffers)** and **physiologic** processes. The c**hemical processes** represent the first line of defense to an acid or base load and include the extracellular and intracellular buffers.
- The **physiologic processes** modulate acid-base composition by **excretion** of volatile acids by the **lungs** and fixed acids by the **kidneys.**

N.B. *carbonic acid can be reconverted to carbon dioxide, which is a gas. So, carbonic acid is referred to as a volatile acid, and its concentration in the blood is controlled by the lungs through ventilation (breathing). All other acids in the blood (e.g. lactic acid, fatty acids, ketone bodies, and so on) are nonvolatile acids.*

Role of buffers

- *The buffers act as a first line of defense and rapidly within seconds.*
- *Characters of buffers:*

1-Buffers are solutions of : Weak acid and its salt with strong base OR Weak base and its salt with strong acid .

2-Buffer is able to bind or release H^+ in solution.

3-The buffer is most effective when the pH of the solution ***equal or near its pk*** .

- For any buffer to work most efficiently at reducing changes of pH in either direction there should be equal amounts of acid or salt. So, in the ideal state for resisting changes of pH in either direction, the system is ' in the middle with the buffer salt and the acid both dissociated; the pH at which a buffer system is in this ideal state is called its **pK** .

pK of the buffer**:** It is the pH of the buffer at which the buffer exists in equal amount of acidic and basic form.

a-Bicarbonate buffer system:

- *Its pK is 6.1, It acts in ECF and plasma (pH ≈ 7.4)*
- It consists of H_2C0_3 and Na HCO_3

When a strong acid is added: $HCl + NaHCO_3 \leftrightarrow H_2C0_3 + NaCl$

$H_2C0_3 \rightarrow CO_2 + H_2O$

CO_2 released stimulates the respiration which eliminate the C02 from the ECF.

So the buffer can replace the strong acid into a weak acid and alkali

When a strong base is added (NaOH) : $NaOH + H_2CO_3 \leftrightarrow NaHCO_3 + H_2O$

Inspite of low pk pf bicarbonate buffer compared to pH of ECF and plasma, Bicarbonate buffer is the most important Buffer in plasma and ECF. Explain

1- HCO_3 is present in high concentration (as CO_2 is formed by oxidative metabolism).

2- The lung controls the resulted CO_2 3- The kidney can control HCO_3

b- The Phosphate buffer:

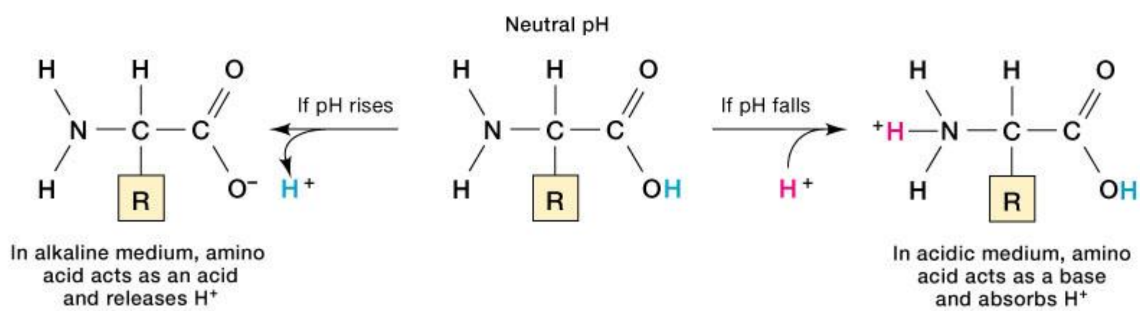
- The major components are : HPO_4 and H_2PO_4 . **pK: 6.8**
- In plasma, phosphate buffers are not very important because its concentrations are small. It acts intracellular fluids, **BUT** it is very important buffer in renal tubules. **WHY**

1- Phosphate becomes greatly concentrated in the tubules, so increasing its power.

2- The renal tubular fluid has a lower ph than that of the ECF, bringing the ph of the media close to the pK of the phosphate buffer.

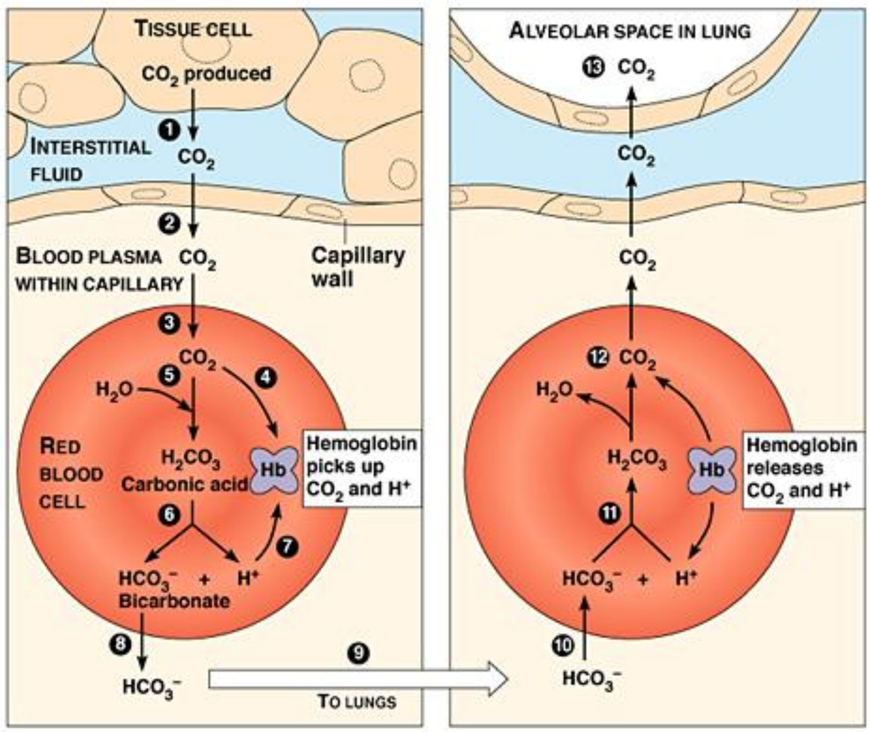
c- Protein Buffer System:

- Plasma proteins and haemoglobin constitute the major **chemical** blood buffers. Haemoglobin is more important than plasma protein, because there is more of it (150 g/ L for Hb, compared to 40 g L plasma protein) Hemoglobin, works Intracellulary and It is important because it is present in high concentration inside the cell its **pK = close to 7.4**



Role of Haemoglobin:

- **Most** of tidal CO_2 are buffered by K+ to form K HCO_3.
- At the tissue level, When $\mathbf{H^+}$ generated from the dissociation of $\mathbf{H_2CO_3}$ inside RBCs due to the addition of CO_2 from the tissues. It binds with reduced **Hb** and this helps to keep the ph constant. So does not increases the acidity of blood.
- At the lung level, H^+ Hb release H^+ and the affinity of Hb to O_2 increases so it picks up O_2 from the lung.



(a) CO_2 transport from tissues (b) CO_2 transport to lungs

2-Role of respiration in regulation of Acid-base balance :

The PCO_2 of ECF is affected by:

1- The metabolic formation of CO_2. 2- The rate of pulmonary ventilation .

When metabolic formation of Co2 is constant. Pulmonary ventilation is the determinant of PCO_2 .

- If pulmonary ventilation is increased → causes decreases of CO_2 and H^+ concentration which leads to ↑ pH.
- If pulmonary ventilation is decreased → causes increases of CO_2 and H^+ concentration which leads to decrease of pH.
- When the pH drops, the respiration rate increases (State the mechanism) and this hyperventilation increases the wash out of CO_2 and decreased CO_2 in the blood so the carbonic acid formation in the blood decreased and PH is increased to ward normal levels which inhibit the hyperventilation so ,restoring homeostasis.
- **On other hand:** When pH increases, the respiration rate decreases. This hypoventilation increases the amount of CO_2 retained in the blood which stimulate respiration thereby the respiration rate increases and ,restores the homeostasis.

There are 2 Types of Respiratory Acid-base Imbalances:

Disturbances in the normal acid – base situation may be **acidosis** or **alkalosis** and results from: *Respiratory* malfunction, where ventilation is too great (respiratory alkalosis) or too little (respiratory acidosis).

2-Respiratory Alkalosis:

There is a decreased in PCO_2, decreased in H^+ and increased in pH. **Respiratory alkalosis** Caused by an **increase in alveolar ventilation**(hyperventilation) and a loss of CO2 **($PaCO_2$< 40 mm Hg)** leading to a decrease in blood [H+] and [HCO3⁻].

■ ***Renal compensation:*** *Decreased excretion of H^+ and NH4 $^+$, decreased reabsorption of HCO3.*

Causes: 1- Physiologically: Severe exercise and Persons who attend high altitudes

2- Diseases : Psychoneurotic patients.

Respiratory acidosis

Caused by a **decrease in alveolar ventilation** (hypoventilation) and retention of CO2 **(Paco2 > 40 mm Hg),** leading to an increase in blood [H+] and [HCO3⁻].

■ ***Renal compensation:*** *Increased excretion of H^+ and NH_4^+ and increased reabsorption* *of HCO^-_3*

1- Obstruction of passages of respiratory tracts.

2- Pneumonia , decreased pulmonaey surface area, and any factor interferes with gas exchange.