Lab 4:
Acid-Base Balance

Introduction to pH

- **pH** is a measure of hydrogen ion concentration in a solution.
- It indicates acidity or alkalinity.
- pH scale ranges from 0 to 14:
- - **Acidic** < 7
- - **Neutral** = 7
- - **Alkaline** > 7

Physiological pH

- Normal blood pH: 7.4 (7.35–7.45)
- pH = -log[H^+]
- The pH scale is logarithmic, not linear
- A small change in pH reflects a large change in H^+ concentration and have major biological effects

Importance of Physiological pH

- Maintaining this range of Physiological pH is critical because:

➢ Enzymes function only within narrow pH limits

➢ Protein structure depends on pH

➢ Cellular metabolism requires stable pH

- Even slight deviations can be **life-threatening**.

Measurement of pH

- Methods include:

a. pH Meter

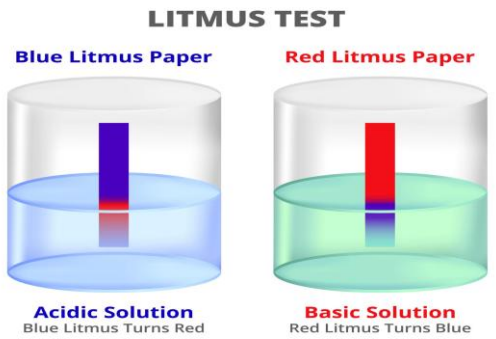
- Uses a **glass electrode** sensitive to hydrogen ions
- Measures electrical potential difference
- Provides **accurate readings**

b. Indicator Methods

- Litmus paper (qualitative)
- Indicator solutions

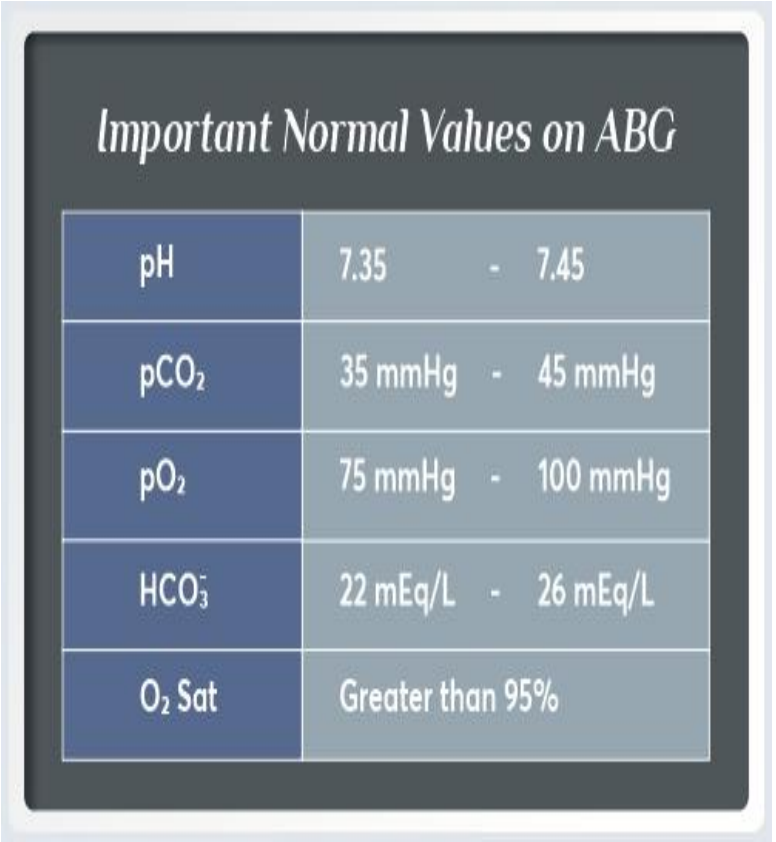
c. Clinical Method

- **Arterial Blood Gas (ABG)** analysis
  - Measures: pH, CO_2, HCO_3^-
  - Essential in critical care



Acid-Base Balance

- **Acid–base balance** is the process by which the body keeps the **pH of blood stable** within a narrow range (Normal blood pH = 7.35 – 7.45).
- Maintained by:
- - Buffer systems
- - Respiratory system (CO_2 control)
- - Renal system (H^+ and HCO_3^- regulation)



A- Buffer systems

(immediate Control)

- A **buffer** is a solution that keeps pH almost constant even when small amounts of acid or base are added. To **calculate the pH of a buffer**, we use a very important equation called the **Henderson–Hasselbalch Equation**

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

pKa → strength of the weak acid (**a constant**)

[A^-] → (**conjugate base**) **[HA]** → **weak acid**)

Types of Physiological Buffers

1- Bicarbonate Buffer (Most Important in Blood)

- Found in **blood and extracellular fluid**

Equation:

$$HCO_3^- + H^+ \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_2O$$

Normal ratio ≈ 20 : 1 (HCO_3^- : H_2CO_3) to maintains blood pH ≈ 7.4

Acid (H^+) is converted into CO_2 (which we breathe out)

- This buffer is the **first line defense** in blood works with:

Lungs → remove CO_2

Kidneys → control HCO_3^-

2- Phosphate Buffer

- Found mainly **inside cells and kidneys**
- **Equation:**
- $HPO_4^{2-} + H^+ \leftrightarrow H_2PO_4^-$
- Regulates **intracellular and kidney (urine) pH**.
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3- Protein buffer system

- Present in **hemoglobin and plasma proteins**
- Example: **Hemoglobin in blood**
- Maintains pH by **binding or releasing hydrogen** ions in **blood** and **cells** (especially **red blood cells**).

B- Respiratory System

(Fast Control)

- **Function:**
- Controls carbon dioxide (CO_2) levels

- **How it works:**
- $CO_2 + H_2O \rightarrow$ carbonic acid $\rightarrow$ affects pH
- If CO_2 increases: pH $\downarrow \rightarrow$ Acidosis
- If CO_2 decreases: pH $\uparrow \rightarrow$ Alkalosis

- **Response**: Fast (minutes)
- Controlled by breathing
- Example: Fast breathing (Hyperventilation) $\rightarrow$ removes CO_2 $\rightarrow$ raises pH

C- Renal System

(Slow but Powerful)

- **Function:**
- Controls of Hydrogen ions (H^+) and Bicarbonate (HCO_3^-)
- **How it works:**
- Kidneys excrete H^+ (acid) and reabsorb HCO_3^- (base)
- **Response**:
- Acts slowly (**hours to days**) but gives long term control

Acid-Base Disturbances

- Disturbances occur when pH deviates from normal range

Types of Acid–Base Disturbances

1. Metabolic Disturbances

- **Definition:** Primary change in **HCO_3^- (bicarbonate)** due to kidney or metabolic causes

Types:

- Metabolic Acidosis (↓ HCO_3^-, ↓ pH)
- Metabolic Alkalosis (↑ HCO_3^-, ↑ pH)

2. Respiratory Disturbances

- **Definition:** Primary change in **$PaCO_2$** due to altered ventilation (lungs)

Types:

- Respiratory Acidosis (↑ CO_2, ↓ pH)
- Respiratory Alkalosis (↓ CO_2, ↑ pH)

Metabolic Acidosis

- Caused by decreased HCO_3^-
- **pH:** low (< 7.35)

Common Causes

- Diarrhea
- Kidney failure
- Diabetic ketoacidosis
- Lactic acidosis

Compensation

- Lungs increase breathing (**hyperventilation**) to blow off (remove) CO_2

Metabolic Alkalosis

- Caused by increased HCO_3^-
- **pH:** High (> 7.45)

Common Causes

- Vomiting
- Diuretics (e.g., Furosemide)
- Excess antacids
- Primary hyperaldosteronism

Compensation

- Lungs slow breathing (**hypoventilation**) to retain CO_2

Respiratory Acidosis

- Caused by increased CO_2
- **pH: low (< 7.35)**

Common Causes

- Lung disease (e.g., COPD)
- CNS depression (e.g., anesthesia, drugs)
- Chest wall and Neuromuscular disorders (e.g., muscle weakness)

Compensation

- Kidneys retain **HCO_3^-**

Respiratory Alkalosis

- Caused by decreased CO_2
- **pH:** High (> 7.45)

Common Causes

- Anxiety
- Hyperventilation
- High altitude

Compensation

- Kidneys excrete **HCO_3^-**

Interpretation of the ABG results

- **pH → cause → compensation**

Step 1: Look at pH

- ↓ pH → **Acidosis**
- ↑ pH → **Alkalosis**

Step 2: Identify the Cause

- Compare pH with:
  - **$PaCO_2$** (respiratory)
  - **HCO_3^-** (metabolic)
- The value that **matches the pH change** is the **primary disorder**

Step 3: Check Compensation

- The other parameter shows **compensation**
- If normal → likely **acute**
- If changed → **compensated**

Example

- pH ↓
- HCO_3^- ↓
- $PaCO_2$ ↓
- **Metabolic acidosis with respiratory compensation**

Case Scenario

- A 22-year-old medical student presents to the emergency department with:
- Rapid breathing
- Dizziness
- Tingling in fingers
- Feeling anxious before an exam
- **Vital signs:**
- Respiratory rate: 30/min (normal: 12–20/min)
- Heart rate: 100/min (normal: 60–100/min)
- **Arterial Blood Gas (ABG):**
- pH = **7.48** *(normal: 7.35–7.45)*
- CO_2 = **30 mmHg** *(normal: 35–45 mmHg)*
- HCO_3^- = **24 mEq/L** *(normal: 22–26 mEq/L)*

Discussion

- The patient has a **pH** of 7.48 (normal: 7.35–7.45), indicating **alkalosis**.
- The **CO_2** level is **low** at 30 mmHg (normal: 35–45 mmHg), which points to a respiratory cause because decreased CO_2 reduces carbonic acid and increases pH.
- The **bicarbonate** (HCO_3^-) level is **normal** at 24 mEq/L (normal: 22–26 mEq/L), indicating that there is no metabolic compensation and the condition is **acute**.
- The patient's history of anxiety and rapid breathing suggests hyperventilation, leading to excessive loss of CO_2. Therefore, the diagnosis is **acute respiratory alkalosis due to hyperventilation**, and **management** includes **reassurance** and **breathing control**.

Good luck