# Theoretical Physiology

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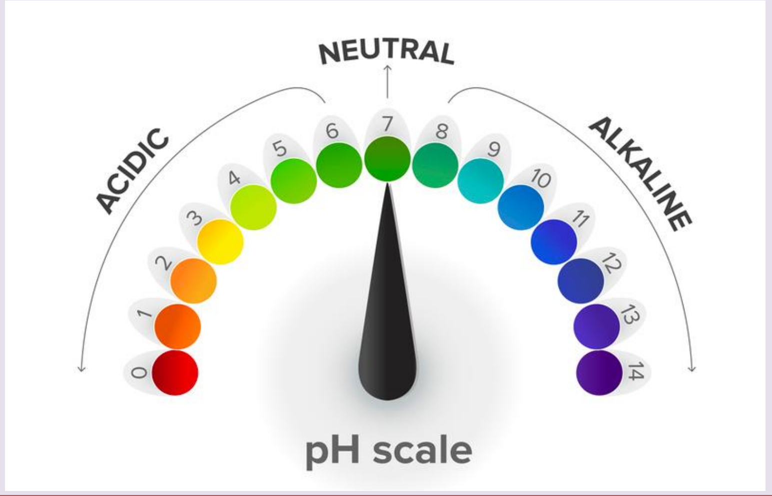
## Lecture 9 , 10 M.Sc. Awham Kareem

**First Stage**

***Acidic Base Balance**
***Buffer System**



**Lec 9**

# Introduction

The concept of **Acid-base balance is concerned with maintaining a normal hydrogen ion concentration in the body fluids**. Acid-base homeostasis is essential to **allow normal tissue and organ system function**. Specifically, intracellular enzyme systems require an appropriate PH for maintenance of activity. Regulation of hydrogen ion (H+) balance is similar in some ways to the regulation of other ions in the body. For instance, to achieve homeostasis, there must be a balance between the intake or production of H+ and the net removal of H+ from the body. **Extracellular fluid pH is normally maintained around**

**a level of 7.35-7.45**. This is achieved through **chemical buffer systems** and through homeostatic responses mediated by **the lungs** and **the kidney**

The limit of extracellular fluid pH compatible with life are about **6.8 to 8**

## The hydrogen ion (H*) concentration of the body And pH of Body Fluid

fluids The hydrogen ion (H*) concentration of the body fluids is **extremely low**. In arterial blood, the H* concentration is

**40 x 10 $^{-9}$ Eq/L (0.00000004 Eq/L or 40 nEq/L).**

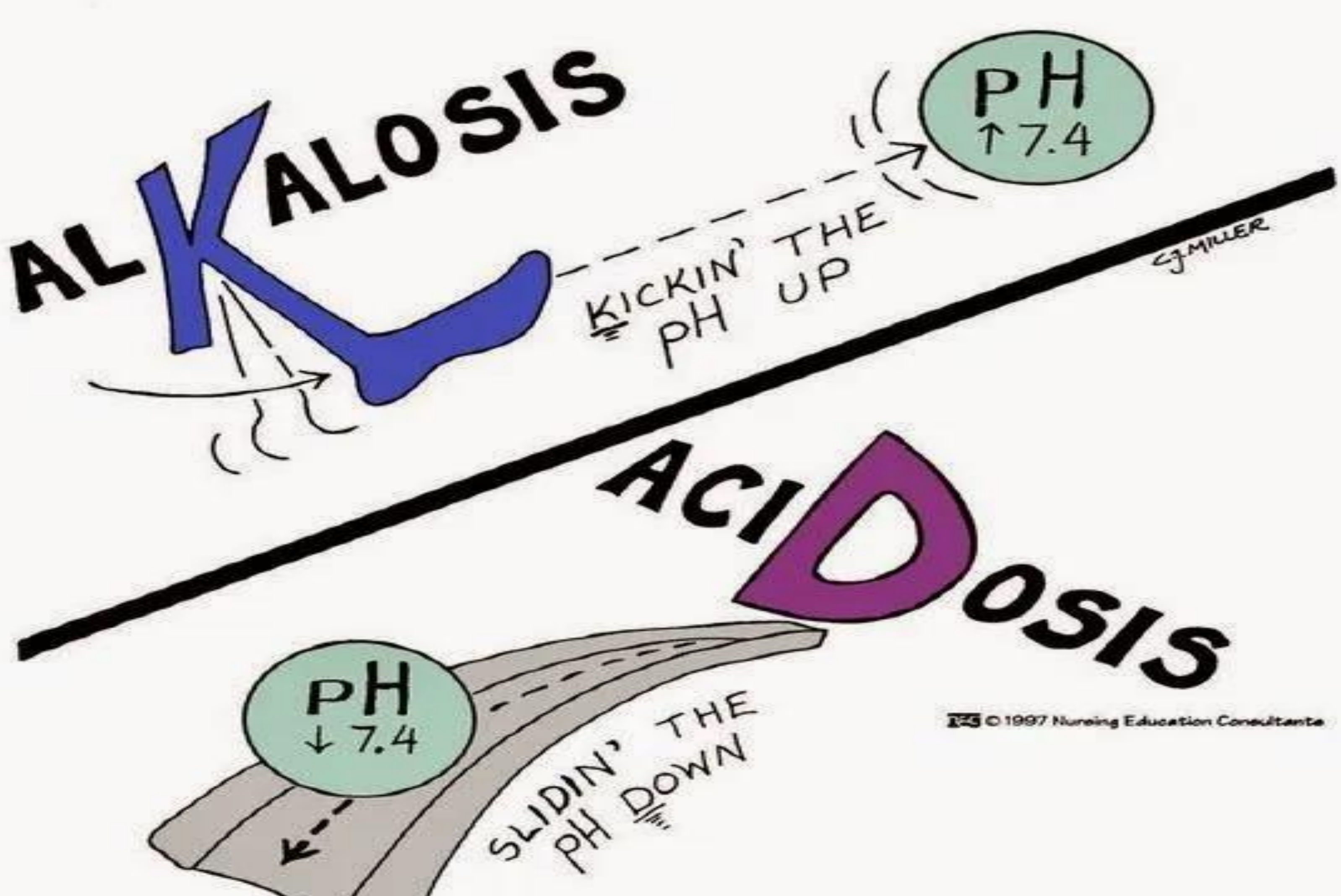
(H*) concentration is routinely expressed as pH The pH is the negative logarithm to base 10 of H ion activity

PH=- log10[H*] pH=-log10[40x 10 Eq/L] **pH 7.4**

***** The pH scale is an exponential scale, where a 0.3 unit fall in pH reflects a doubling of hydrogen ion concentration

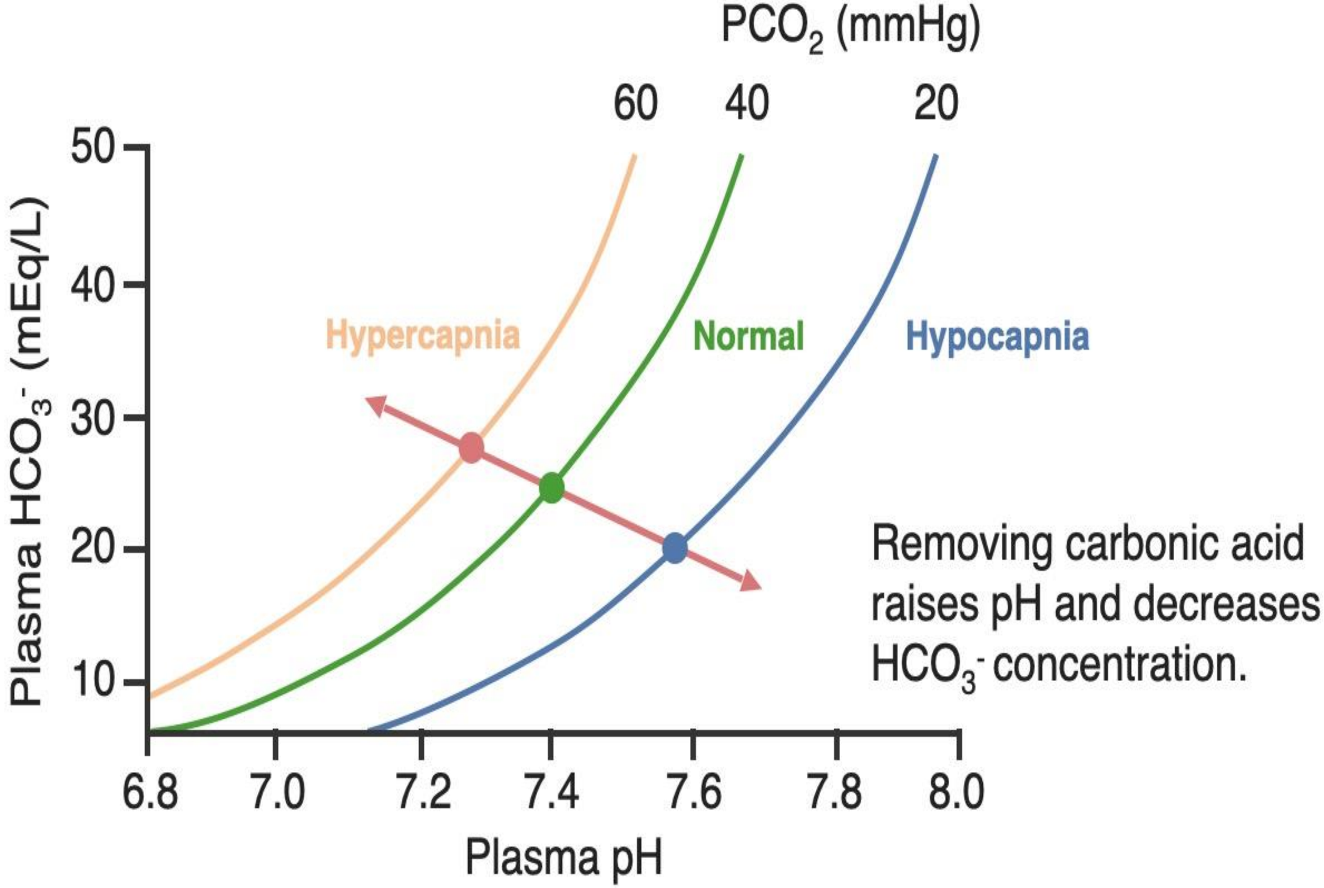
*__As H+ concentration increases, pH decreases, and conversely.__

# ACIDOSIS – ALKALOSIS



Adding carbonic acid to plasma lowers pH and increases $HCO_3^-$ concentration:

$H_2O + CO_2 \rightarrow H^+ + HCO_3^-$



# Acidosis and Alkalosis

Normal human physiological pH is **7.35 to 7.45**. A decrease in pH below this range is **Acidosis**, an increase over this range is **Alkalosis**.

**Alkalosis is defined as a disease state where the body's pH is elevated to greater than7.45secondary to some metabolic process.**

HCO3 functions as an alkalotic substance. CO2 functions as an acidic substance. Therefore, increases in HCO3 or decreases in CO2 will make blood more alkalotic. The opposite is also true where decreases in HCO3 or an increase in CO2 will make blood more acidic. CO2 levels are physiologically regulated by the pulmonary system through respiration, whereas the HCO3 levels are regulated through the renal system with reabsorption rates. Therefore, metabolic alkalosis is an increase in serum HCO3

The primary pH buffer system in the human body is the bicarbonate ($HCO_3$)/carbon dioxide ($CO_2$) chemical equilibrium system. Where:

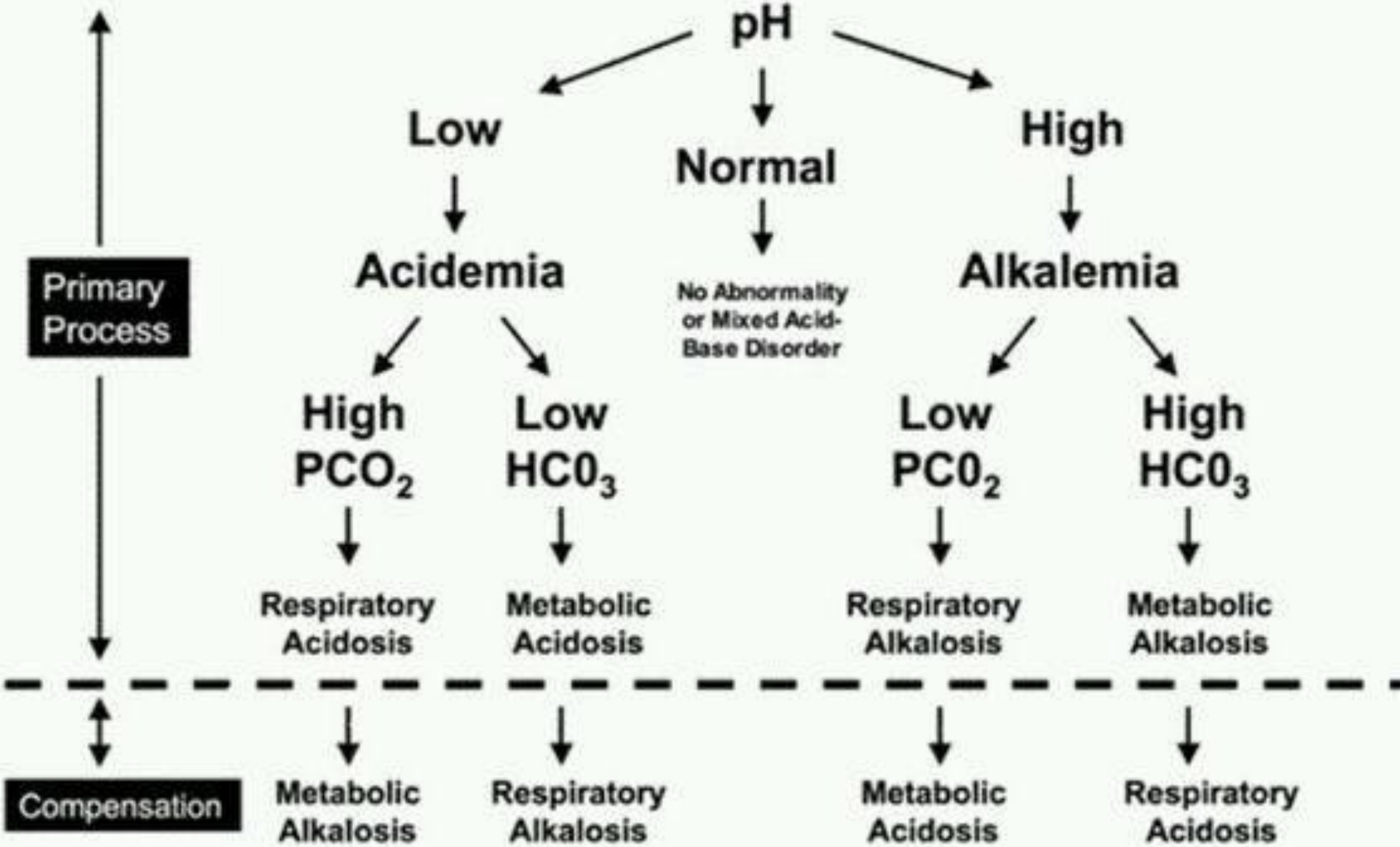
- $H + HCO_3 \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_2O$

## Measurement of Arterial pH (ABGO)

An Arterial Blood Gas is a laboratory test used for the measurement of arterial pH , the arterial partial pressure of $O_2$ ($PaO_2$),the arterial partial pressure of $CO_2$ ($PaCO_2$), bicarbonate ($HCO_3$), base excess, total $CO_2$, and $O_2$ saturation

Venous blood can be used for the test, but the result will be more acidic (more than normal)

# ARTERIAL BLOOD GAS INTERPRETATION



# ARTERIAL BLOOD GAS INTERPRETATION

| 1° DISORDER | pH | $P_aCO_2$ | $[HCO_3^-]$ | COMPENSATION |
|---|---|---|---|---|
| AG/non-AG Metabolic Acidosis | ↓ | ↓ (2°) | ↓ (1°) | **$P_aCO_{2,\ expect} = 1.5\ [HCO_3^-] + 8 \pm 2$**<br>If $P_aCO_{2,\ actual} < P_aCO_{2,\ expect}$ also **1° respiratory alkalosis**<br>If $P_aCO_{2,\ actual} > P_aCO_{2,\ expect}$ also **1° respiratory acidosis** |
| AG Acidosis "Delta/Delta" | For AG metabolic acidosis, calculate **$\Delta AG / \Delta[HCO_3^-]$ = (AG - 12) / (24 - $[HCO_3^-]$)**<br>if **< 0.8, non-AG acidosis**; if **> 2, metabolic alkalosis** | | | |
| Metabolic Alkalosis | ↑ | ↑ (2°) | ↑ (1°) | **$P_aCO_2 = 0.7 \times [HCO_3^-] + 20 \pm 5$**<br>If $P_aCO_{2,\ actual} < P_aCO_{2,\ expect}$ also **1° respiratory alkalosis**<br>If $P_aCO_{2,\ actual} > P_aCO_{2,\ expect}$ also **1° respiratory acidosis** |
| Respiratory Acidosis | ↓ | ↑ (1°) | ↑ (2°) | **For each ↑ 10 mmHg in $P_aCO_2$**<br>Acute: ↑ $[HCO_3^-]$ 1 mmol/L and ↓ pH 0.08<br>Chronic: ↑ $[HCO_3^-]$ 4 mmol/L and ↓ pH 0.03 |
| Respiratory Alkalosis | ↑ | ↓ (1°) | ↓ (2°) | **For each ↓ 10 mmHg in $P_aCO_2$**<br>Acute: ↓ $[HCO_3^-]$ 2 mmol/L and ↑ pH 0.08<br>Chronic: ↓ $[HCO_3^-]$ 5 mmol/L and ↑ pH 0.03 |

Primary disorder (**1**°), compensation (**2**°); arrows relative to "normal" baseline values:
**pH** 7.35 - 7.45, **$P_aCO_2$** 35 - 45 mmHg and **$[HCO_3^-]$** 22 - 26 mEq/L

## *Causes Of Alkalosis

### 1.Gastrointestinal Loss of Hydrogen

Stomach fluids are highly acidic at a pH of approximately 1.5 to 3.5. Hydrogen secretion is accomplished via parietal cells in the gastric mucosa. Therefore, the large volume loss of gastric secretions will correlate as a loss of hydrogen chloride, an acidic substance, leading to a relative increase in bicarbonate in the blood, thus driving alkalosis. Losses can occur pathologically via vomitus or nasogastric suctioning.

### 2.Intracellular Shift of Hydrogen

Anytime that hydrogen ions are shifted intracellularly, this imbalance in the buffer system has a relative increase in bicarbonate. Processes that drive hydrogen intracellularly include hypokalemia.

## 3.Renal loss of hydrogen

Hydrogen is used within the kidneys are an antiporter energy gradient to retain a multitude of other elements. Of interest here, sodium is reabsorbed through an exchange for hydrogen in the renal collecting ducts under the influence of aldosterone. Therefore, pathologies that increase the levels of mineralocorticoids or increase the effect of aldosterone, such as Conn syndrome will lead to hypernatremia, hypokalemia, and hydrogen loss in the urine. In a similar vein of thought, loop and thiazide diuretics are capable of inducing secondary hyperaldosteronism by increasing sodium and fluid load to the distal nephron, which encourages the renin-angiotensin-aldosterone system .

## 4.Retention/Addition of Bicarbonate

Several etiologies lead to increases in bicarbonate within the blood. The simplest of which is an overdose of exogenous sodium bicarbonate in a medical setting. Milk-alkali syndrome is a pathology where the patient consumes excessive quantities of oral calcium antacids, which leads to hypercalcemia and varying degrees of renal failure. Additionally, since antacids are neutralizing agents, they add alkaline substances to the body while reducing acid levels thus increasing pH. A pathology that is in line with normal physiology is the body's natural compensation mechanism for hypercarbia .

When a patient hypoventilates , $CO_2$ retention occurs in the lungs and subsequently reduces pH.  Over time, the renal system compensates by retaining bicarbonate to balance pH. This is a slower process.  Once the hypoventilation is corrected, such as with a ventilator-assisted respiratory failure patient $CO_2$ levels will quickly decrease, but bicarbonate levels will lag in reducing. This causes post-hypercapnia metabolic alkalosis, which is self-correcting

# Alkalosis

is a relatively common diagnosis in medicine. The biological effects of metabolic alkalosis are directly resultant to associated problems such

as hypovolemia and potassium and chloride depletion.

These changes lead to decreased myocardial contractility, arrhythmias,

decreased cerebral blood flow,

confusion,

increased neuromuscular excitability,

hypoxia

# Acidosis

Any process that increases the serum hydrogen ion concentration is an acidotic process. The term acidemia is used to describe serum that is abnormally acidic, and this can be due to a respiratory acidosis, which involves changes in carbon dioxide, or a metabolic acidosis which is influenced by decreased bicarbonate. Metabolic acidosis is characterized by an increase in the hydrogen ion concentration in the systemic circulation that results in an abnormally low serum bicarbonate levels

# Strong Acidic and Strong Alkaline

Acids are molecules that release H+ in solution

Alkaline (Bases) are molecules that can accept H +.

**Strong Acid** is one that rapidly dissociates and releases large amounts of H + in solution. Ex .. **HCl-** Strong Bases

**Strong Base** is one that reacts rapidly and strongly with H + in solution.And quickly remove H+from solution EX **HCO3 -**

# Buffer System

Any substance that can reversibly bind H+.buffer system Is a system one or more compounds that act to resist change in PH.

There are three systems that regulation of H concentration.

**1.The chemical acid base buffer system of the body fluids.**

**A. Bicarbonate buffer** 24 to 26( $CO_2$ , $H_2O$ )

**pka of the system** the nearer the value of pka of buffer system to blood PH 7.4 the greater the buffering effect of the system ,the pka of bicarbonate buffer system is 6.1 so its far from PH ,so its weak buffer system.( Bicarbonate is ECF Buffer)

**B . Phosphate buffer**

ICF buffer (found in the cells ) , it has pka 6.8. play role in renal tubular fluid

## C. Protein buffer

Its ICF buffer system , protein can function as both acids and bases ( amphoteric ) , pka of protein fairly close to 7.4

It's the best chemical buffer system.

## 2.The respiratory system( the lungs) (change ventilation)

The second line of defense against acid-base disturbances is control of extracellular fluid $CO_2$ concentration by the lungs. Reflex changes in ventilation help to defend blood pH. By changing the $PCO_2$ and, hence, $[H_2CO_3]$ of the blood, the respiratory system can rapidly and profoundly affect blood pH. An elevated arterial blood $PCO_2$ is a powerful stimulus to increase ventilation; it acts on both peripheral and central chemoreceptors, but primarily on the latter.

$CO_2$ diffuses into brain interstitial and cerebrospinal fluids, where it causes a fall in pH that stimulates chemoreceptors in the medulla oblongata.

When ventilation is stimulated, the lungs blow off more $CO_2$, making the blood less acidic. Conversely, a rise in blood pH inhibits ventilation; the consequent rise in blood ($H_2C03$] reduces the alkaline shift in blood pH.

**Buffering power of the respiratory system.**

Respiratory regulation of acid-base balance is a physiologic type of buffer system because it acts rapidly and keeps the $H^+$ concentration . In general, the overall buffering power of the respiratory system is one to two times as great as the buffering power of all other chemical buffers in the extracellular fluid combined.

# 3. The renal system ( the kidney)

Renal Regulation of Acid-Base Balance The kidneys play major role in the maintenance of normal acid-base balance. The kidneys perform this task by:

**(1) secretion of $H^+$.**

**(2) reabsorption of filtered $HCO_3^-$**

**(3) production of new $HCO_3^-$**

The addition of a bicarbonate to the plasma lowers the plasma hydrogen-ion concentration just as if a hydrogen ion had been removed from the plasma. Sources of hydrogen-ion gain or loss Gain of $H^+$

**Gain of H+**

Generation of hydrogen ions from $CO_2$.

Production of nonvolatile acids from the metabolism of protein and other organic molecules.

Gain of hydrogen ions due to loss of bicarbonate in diarrhea.

Gain of hydrogen ions due to loss of bicarbonate in the urine

**Loss of H+**

Utilization of hydrogen ions in the metabolism of various organic anions. Loss of hydrogen ions in the urine , vomitus and Hyperventilation .

# Thank you