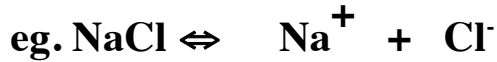


**Physiology Lecture 2 and 27**  
**Chapter 2: Acids, Bases and Salts REVIEW:**

1. *Salts* – an ionic compounds containing other than H<sup>+</sup> or OH<sup>-</sup>; can dissociate in water to form electrolytes. Electrolytes can conduct electrical currents. (See Table 2.2, page 35, and Figure 27.6, page 1042)

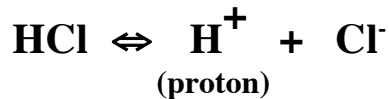


In their *ionized* state they play vital role in body functions,  
Eg. minerals are metal ions.

Common salts in the ICF/ECF regulated by the kidneys:



2. *Acids* – a sub. that releases H<sup>+</sup> ; “a proton donor”



The conc. of H<sup>+</sup> is what determines the acidity of a soln. The anion (Cl<sup>-</sup>) has no effect on acidity!

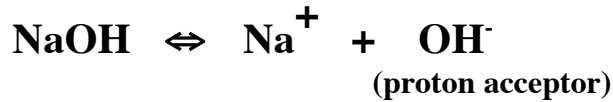
Strong acids – do dissociate readily ie, they do effect pH because many H<sup>+</sup> are donated in soln.

Weak acids – don't dissociate readily ie, they don't effect pH much because not a lot of H<sup>+</sup> are donated. They are excellent buffers!

Examples:

- \* HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> ; acetic acid (weak)
- \* H<sub>2</sub>CO<sub>3</sub> ; carbonic acid (weak)
- \* H<sub>2</sub>SO<sub>4</sub> ; sulfuric acid (strong)

3. *Bases* – a sub. that accepts  $H^+$ ; “proton acceptor”



\* Weak bases – don’t dissociate readily ie, they don’t accept  $H^+$  readily in soln. eg.  $HCO_3^-$

\* Strong bases – do dissociate readily ie, they do accept  $H^+$  most readily in soln. eg. NaOH

Examples:

$HCO_3^-$  (weak base) *bicarbonate ion*; most abundant in the blood and accepts  $H^+$  well enough to help maintain blood pH!

4. *pH: Acid & Base Concentration:* s(see pH scale on pages 42)

pH – a measure of  $[H^+]$  per liter of soln. (ICF/ECF)  
pH is logarithmic

5. *Buffers* – chemicals (weak acids) in the body that resist abrupt, large swings in body fluid pH.

\*(see *Buffer Systems* on page 42)

\*Cells are very sensitive to the slightest changes in pH; drastic changes in pH can damage cellular function.

\*Normal blood pH varies between 7.35 – 7.45 (a narrow range); extreme movements are FATAL!

\*Buffers resist pH change by accepting or donating  $H^+$

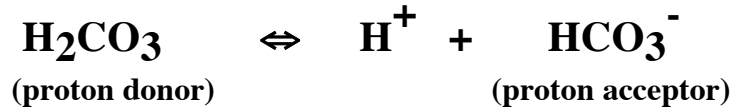
Example: *Carbonic acid*; a weak acid acting as a buffer



(100  $H_2CO_3$  molecules)

(10 $H^+$ ) (10bicarbonates)

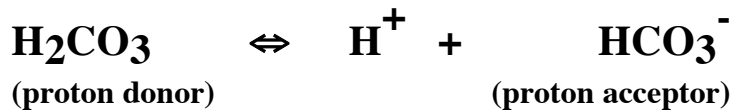
Weak acids don’t easily dissociate, so they react in a predictable way.... They are excellent buffers!



**Questions???**

So, if we .....

- 1) add  $\text{H}^+$  (acid) to the system the reaction shifts to the \_\_\_?\_\_\_
- 2) remove  $\text{H}^+$  (acid) from the system the reaction shifts to the \_\_\_?\_\_\_



- 3) How does the buffer system respond to an elevated pH?
- 4) How does the buffer system respond to depressed pH?

\*\*\*\*\*

**Chapter 27: Fluid, Electrolytes and Acid-Base Homeostasis**  
(see pages 1046 – 1051; Chap. 27)

**Q? What is the importance of regulating  $[\text{H}^+]$  anyway?**

**A: All biochemical rxns. are influenced by small pH changes!**  
Egs. enzymes, Hb, proteins, etc..

\* Acid subs. enter the body via food, exercise, drugs/alcohol, a low carbohydrate diet (ketones), and as metabolic byproducts (waste).

**I. Mechanisms for maintaining  $[\text{H}^+]$  in the body fluids, ie. ICF/ECF:**

**1) Buffer Systems – accepts or releases  $\text{H}^+$  in solution; the body's first line of defense. Operates w/in seconds.**

**2) Respiratory System – inhalation/exhalation of  $\text{CO}_2$ ; slow, but very powerful. Operates w/in 1-3 minutes.**

3) **Urinary/Excretory System** - eliminate  $H^+$  via the excretory system(urine); slow, but powerful. Operates w/in hours to days.

## **II. Buffer Systems:**

**Buffer system** - a chemical mechanism in the body fluids that maintain homeostatic pH of ECF & ICF, ie. weak acids.

**3 buffer systems in the body:** (See Table 27.3, page 1049)

1. phosphate buffer system - ICF
2. protein buffer system – ICF/ECF; (most powerful buffer system!)
3. carbonic acid-bicarbonate buffer system – ECF

**They all work together to maintain pH!**

### **Two Main Functions of Buffers:**

1) any substance that releases or accepts excess  $H^+$  to maintain body fluid pH.

2) helps stabilize  $[H^+]$  in the body ...

A) when  $[H^+] \uparrow$  then buffer systems accepts  $H^+$

B) when  $[H^+] \downarrow$  then buffer systems donates  $H^+$

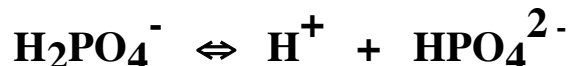
**\*Buffers are like chemical sponges; they can soak up or wring out  $H^+$**

**A. Buffers are conjugate pairs, ie. an acid and its conjugate base**  
(weak acids)

$\downarrow$                        $\downarrow$   
proton donor          proton acceptor

1. **Intracellular Buffers** - inside cells \*(ICF)

a) **Phosphate buffer pair** – subject to excretory/urinary control  
(kidney tubules)



b) **Proteins** - most abundant in body cells & plasma. \*\* (ICF/ECF)  
Also, Hb inside RBC's is an excellent protein buffer.



\* Proteins are made-up of long chains of amino acids.

\* Amino acids are made of two parts:

*carboxyl group* - acts as an acid (proton donor) -COOH

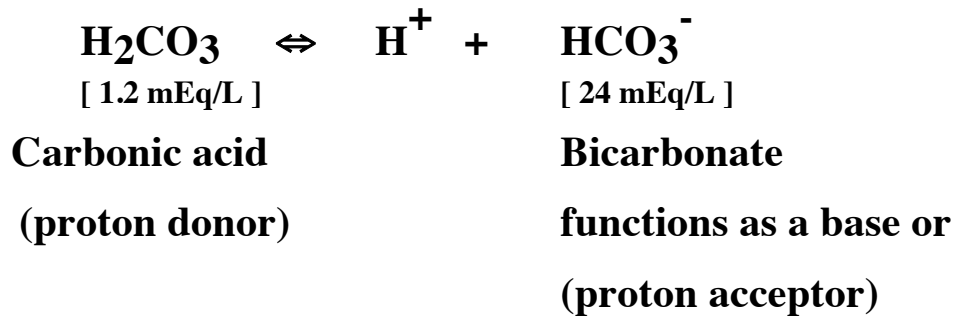
*amino group* - acts as a base (proton acceptor) -NH<sub>2</sub>

\* Amino acids make excellent buffers! They are *amphoteric*!

Question?? Why are amino acids excellent buffers???

2. Extracellular Buffers - outside the cell. \*(ECF)

a) Carbonic Acid- Bicarbonate System - most abundant buffer pair in the ECF & regulator of blood pH; subject to respiratory control.



NOTE: strong acids & bases w/ respect to body fluids are not real low pH & real high pH. We are talking about shifts of 0.1 +/-

Continue on Extracellular Buffers - outside the cell. \*(ECF)

b) Plasma (ECF of the blood)- has an abundance of *proteins*.  
(See proteins above!)

Question? How is too much acid [H<sup>+</sup>] produced in the body?

**Chief sources of acid produced in the body:**

1. Lactic acid - waste from *anaerobic metabolism* in skeletal muscle tissue.
2. Carbonic acid - CO<sub>2</sub> (cellular waste) in the blood combines with H<sub>2</sub>O in plasma.
3. HCl – “gastric juice” or stomach acid secretions.
4. Fatty acids and ketone acids – produced from fat metabolism in the absence of carbohydrates (low carb. diet), or starvation.
5. Phosphoric acid – metabolism of cellular proteins, i.e cell parts

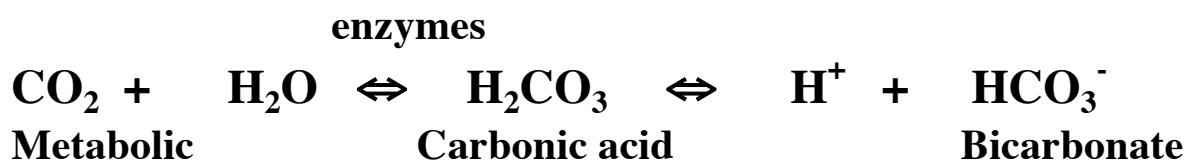
**Sample condition: Respiratory Acidosis;**

results from an elevated ppCO<sub>2</sub> (> 45 mm Hg) in arterial blood and a blood pH of < 7.35

**Causes of:**

- 1) Inadequate exhalation of CO<sub>2</sub> which ↓ blood pH
- 2) Hypoventilation from emphysema, bronchitis (shallow breathing)
- 3) Obstruction of airways, eg. choking.

\*\* Any condition that reduces the movement of CO<sub>2</sub> from the blood to the lungs → to atmosphere, ie. exhalation



**Byproduct**

**Le Chatlier’s Principle - the equation must be balanced. When the system is in equilibrium and if the equilibrium is disrupted - it will counteract & establish a new equilibrium.**

Two examples using the above system:

1) Hypoventilation - [ $\uparrow$   $\text{CO}_2$ ] ; [ $\uparrow$   $\text{H}^+$ ] ;  $\downarrow$  pH of blood

\* With an increase in  $\text{CO}_2$  due to hypoventilating, the rxn is driven to the right, thus producing excess  $\text{H}_2\text{CO}_3$  (according to Le Chatlier). The  $\text{H}_2\text{CO}_3$  dissociates and  $\text{H}^+$  is made driving the pH down (acidic). This causes respiratory acidosis. Homeostatic pH is disrupted.

Question?

What is one compensatory mechanism that can respond to acidosis?  
→ YES, that's right BUFFER SYSTEMS

\* With an [ $\uparrow$   $\text{H}^+$ ] the rxn. is driven back to the left to establish a new equilibrium. The blood pH  $\uparrow$  back to normal because the  $\text{H}^+$  are bound (tied up) in the  $\text{H}_2\text{CO}_3$  (carbonic acid).

NOTE: the carbonic acid is much less acidic with respect to  $\text{H}^+$   
(See Figure 27.7, page 1048)

\*\* Other Compensatory Mechanism for Respiratory Acidosis -

A) an increased excretion of  $\text{H}^+$  in the urine

B) an increased reabsorption (retention) of  $\text{HCO}_3^-$  in the kidneys

C) increased respiratory rate; ventilation becomes rapid, so  $\text{CO}_2$  is removed quickly, thus a [ $\downarrow$   $\text{CO}_2$ ] ; [ $\downarrow$   $\text{H}^+$ ] ;  $\uparrow$  pH of blood

## **Sample condition #2: Respiratory Alkalosis**

2) **Hyperventilation** - [ $\downarrow$   $\text{CO}_2$ ] ; [ $\downarrow$   $\text{H}^+$ ] ;  $\uparrow$  pH of blood  
ie. the reaction is driven to the left in this case.

**Respiratory Alkalosis:** results from a depressed  $\text{ppCO}_2$  (  $< 35$  mm Hg) in arterial blood and a blood pH of  $> 7.45$

### **Causes of Respiratory Alkalosis:**

- \* High altitudes
- \* Pulmonary disease, egs. Asthma, pneumonia, stroke
- \* Anxiety
- \* Hyperventilation due to any of the above causes, or voluntarily hyperventilating- swimmers were once encouraged to do this in order to hold their breath longer; see C below!)

\*\* Other Compensatory Mechanism for Respiratory Alkalosis -

A) a **decreased excretion** of  $\text{H}^+$  in the urine

B) a **decreased reabsorption** of  $\text{HCO}_3^-$  in the kidneys.

C) decreased respiratory rate; ventilation becomes slow, so  $\text{CO}_2$  accumulates, thus [ $\uparrow$   $\text{CO}_2$ ] ; [ $\uparrow$   $\text{H}^+$ ] ;  $\downarrow$  pH of blood

\* Also, have the subject breath into a bag and inhale the  $\text{CO}_2$

## **III. Metabolic Acidosis and Alkalosis:**

\* Any pH imbalance of ICF/ECF **caused by anything other than too much or too little  $\text{CO}_2$**  in the blood, ie. otherwise it would be referred to as respiratory acidosis/alkalosis! (see above)

\* Bicarbonate ion conc. [ $\text{HCO}_3^-$ ] in the blood above or below the normal range of 22 to 26 mEq/L is indicative of a metabolic acid/base imbalance.

Two sample metabolic conditions using the above equation:

1) Metabolic Acidosis:

[ $\text{HCO}_3^-$ ] is  $< 22$  mEq/L; blood pH is  $< 7.35$



### Causes of:

1. Severe diarrhea causes an excessive loss of  $\text{HCO}_3^-$
2. Kidney disease; lack of  $\text{H}^+$  excretion in urine
3. Starvation; body breaks down protein & fats which produces acidic byproducts (ketones & fatty acids)
4. Excessive alcohol consumption; excess acids in the blood
5. Lactic acid accumulation by muscle cells; anaerobic MET.

### Sample condition #2:

#### 2) Metabolic Alkalosis:

[  $\text{HCO}_3^-$  ] is  $> 26$  mEq/L; blood pH is  $> 7.45$

### Causes of:

1. Vomiting; loss of stomach HCl
2. Excessive intake of sodium bicarbonate or antacids (a base)
3. Constipation; results in increased amounts of  $\text{HCO}_3^-$  being reabsorbed.

**Note: Remember, other compensatory mechanisms are *operating simultaneously* to maintain pH, ie. lungs and kidneys.**

### Extreme cases of acid-base imbalance:

1. Acidosis: nervous system becomes depressed → coma → death!
2. Alkalosis: nervous system becomes overexcited → muscle tetany (convulsions) → death from respiratory arrest!