

LAB 9: ACID BASE BALANCE

Introduction:

Acids and Bases

Acids: compounds that donate hydrogen ions (H^+) (also called proton donors) when dissolved in water. Acidic solutions have a pH less than 7.

- **Strong acids**, like hydrochloric acid (HCl), donate more protons (H^+) (compared to weak acids). They have *greater effect* on pH change.
- **Weak acids**, like carbonic acid (H_2CO_3), donate less protons (H^+) (compared to strong acids). They have a *lesser effect* on pH change.

Bases: compounds that bind protons. Basic or alkaline solutions have a pH above 7.

- **Strong bases**, like sodium hydroxide (NaOH), bind more protons (H^+) (compared to weak bases); have *greater effect* on pH change.
- **Weak bases**, like sodium bicarbonate (NaHCO_3) bind less protons (H^+) (compared to strong bases), they have *lesser effect* on pH change.

The pH scale (written **pH**, not Ph or ph or PH)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
acids (H^+)						neutral		bases (OH^-)						

- Why is the number **7** significant on the pH scale? Chemicals at a pH of 7 release equal amounts of hydrogen and hydroxyl ions.
- A shift of one pH unit represents a **10-fold** change in acidity or alkalinity.
 - **Example:** Coffee (pH 5) is 10 times more acidic than urine (pH 6) and 100 times more acidic than distilled water (pH 7).
 - **Example:** Clorox (pH 12) is ____ times more _____ than sea water (pH 8)

Normal human blood pH range is **7.35 – 7.45**. Thus, blood is slightly basic or alkaline.

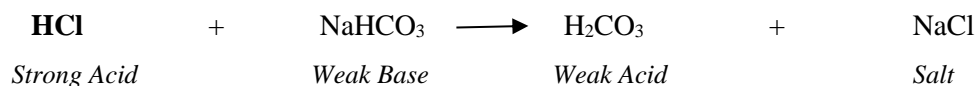
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pH control mechanisms:

1. **Buffers** prevent drastic changes in the pH of body fluids by acting as proton (H^+) acceptors or proton (H^+) donors. Strong acids lower the pH more than weak ones because they give off more H^+ . Strong bases raise the pH more than weak ones because they accept more H^+ . Therefore, buffers help prevent strong acids and strong bases from making as large of an impact on the pH of the blood.

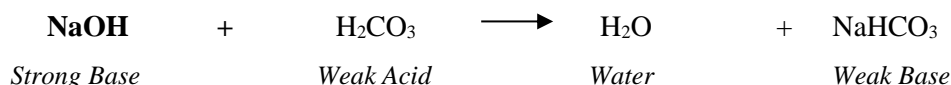
- **Bicarbonate buffer system of the blood** is the most important buffer system. The weak acid is carbonic acid (H_2CO_3) and it acts as a proton acceptor (H^+ ions). The weak base is sodium bicarbonate ($NaHCO_3$) and it acts as a proton donor.

ADD A STRONG ACID TO THE BLOOD



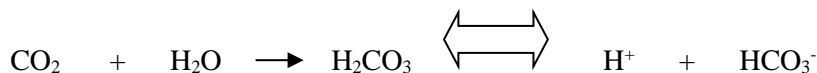
$NaHCO_3$ acted as a buffer and accepted hydrogen ions from the strong acid, HCl.

ADD A STRONG BASE TO THE BLOOD



H_2CO_3 acted as a buffer and released hydrogen ions.

2. **Respiratory system** is responsible for removing carbon dioxide from the blood stream. Recall that carbon dioxide dissolves in the blood plasma with water to form **carbonic acid, H_2CO_3** . Carbonic acid dissociates into the bicarbonate ion, HCO_3^- and releases hydrogen ions. How do those hydrogen ions impact blood pH?



- How would an increase in carbon dioxide in the blood affect levels of carbonic acid? _____
- How would blood pH change in response to more carbonic acid and more hydrogen ions? _____
- How would a decrease in carbon dioxide in the blood affect levels of carbonic acid and pH? _____

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2. Respiratory system (continued):

Respiratory Center (RC) in the medulla monitors the concentration of H^+ ions in the blood. The pH of body fluids may be changed by adjusting the rate and depth of **breathing**.

- Is the RC *stimulated* or *inhibited* by an increase in H^+ ions in the blood? _____
- How is an increase in H^+ ions linked to the process of respiration? _____
- How could a person adjust the respiration rate to release *more* carbon dioxide? _____
- If a person hyperventilates, and releases more carbon dioxide, how is blood pH affected? _____
- The RC is inhibited by a decrease in H^+ ions in the blood. How does that affect respiration rates? _____
- How would hypoventilation affect carbon dioxide levels? _____
- And, how would hypoventilation affect blood pH? _____

3. Urinary system

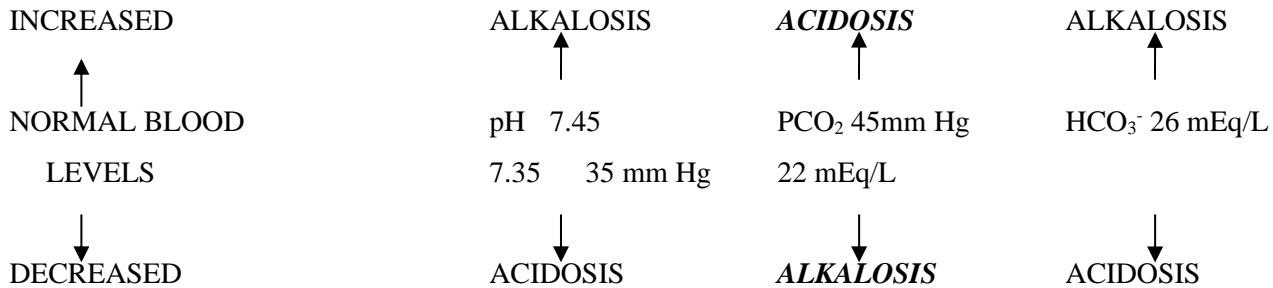
In response to changes in blood pH, the kidneys secrete or reabsorb ions in order to maintain proper blood pH. In the tubule of the nephron, the kidneys will both secrete and reabsorb ions in order to maintain blood pH:

- Increase or decrease secretion of H^+ ions
- Increase or decrease reabsorption of HCO_3^- ions
- If more H^+ ions are secreted into the urine, how is blood pH affected? _____
- If more HCO_3^- ions are reabsorbed, how is blood pH affected? _____
- How would the kidneys respond to blood that is too acidic? _____
- How would the kidneys respond to blood pH of 7.5? _____

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Determining if an imbalance is present:

By analyzing arterial blood, it is possible to determine if a person is in an acid/base imbalance and to determine if the acidosis or alkalosis is due to a respiratory or metabolic disorder. The following chart demonstrates these relationships. Notice that when the CO_2 changes, it causes the opposite pH change...more CO_2 leads to a lower pH. Likewise, when the bicarbonate levels change, it causes the same pH change...more bicarbonate leads to a higher pH.

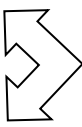


pH Diagnosis of an ABG (arterial blood gas)

How to determine the imbalance (and compensation, if any):

1. Look at the pH
2. Convert the CO_2 and HCO_3^- values to pH
3. Match the pH conversions to the patient's pH-whichever pH is matching is the cause of the problem (imbalance). If the acid/base imbalance is the result of a change in the PCO_2 values, then the imbalance is **respiratory**. If the acid/base imbalance is the result of a change in the HCO_3^- , then the imbalance is **metabolic**.
4. Look at the other pH conversion to see if it's the opposite
 - if it's opposite = with compensation
 - if it's not opposite = without compensation

Completed Example: Given the following list of blood values, determine the imbalance:

Blood Values	Convert Values to pH	
pH of 7.5	→ Alkaline (Basic)	
PCO ₂ of 55 mm Hg	→ Acid	
HCO ₃ ⁻ 32 mEq/L	→ Alkaline (Basic)	

Since these match, the imbalance is **alkalosis**.

- Imbalance is **metabolic alkalosis** because the HCO_3^- has changed.
- The body is compensating--**respiratory acidosis**. Carbon dioxide levels are acidic. If the carbon dioxide levels had been within the normal range of values, there would have been no compensation (perhaps yet) from the respiratory system.

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INCREASED	↑ Alkalosis	↑ Acidosis	↑ Alkalosis
NORMAL LEVELS	pH 7.35 to 7.45	pCO₂ 35 - 45 mm Hg	HCO₃⁻ 22-26 mEq/L
DECREASED	↓ Acidosis	↓ Alkalosis	↓ Acidosis

If the problem is:	Which could be caused by:	pH	pCO ₂ Respiratory	HCO ₃ ⁻ Metabolic	Then the compensation is:
Respiratory Acidosis	Hypoventilation: COPD, pulmonary edema, airway obstruction, damage to respiratory center in medulla	less than 7.35	more than 45	more than 26	Metabolic Alkalosis Increased reabsorption of HCO ₃ ⁻ and Increased secretion of H ⁺ ... causing pH to rise
Respiratory Alkalosis	Hyperventilation: anxiety, high altitudes	more than 7.45	less than 35	less than 22	Metabolic Acidosis Decreased reabsorption of HCO ₃ ⁻ and decreased secretion of H ⁺ ... causing pH to fall
Metabolic Acidosis	Diabetes mellitus, starvation, renal failure, diarrhea	less than 7.35	less than 35	less than 22	Respiratory Alkalosis Hyperventilation to decrease amount of CO ₂ in the blood ... causing pH to rise
Metabolic Alkalosis	Vomiting, too many Rolaids	more than 7.45	more than 45	more than 26	Respiratory Acidosis Hypoventilation to increase amount of CO ₂ in blood ... causing the pH to fall

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ACTIVITY 19: ACID-BASE BALANCE PROBLEMS

IMBALANCE

In the lab, your instructor will demonstrate how to solve the following pH problems. For each problem, denote if the acid/base imbalance is respiratory acidosis/alkalosis or metabolic acidosis/alkalosis.

pH	pCO ₂	HCO ₃ ⁻	Imbalance
1. 7.42	40	25	_____
2. 7.50	30	26	_____
3. 7.30	48	24	_____
4. 7.18	40	17	_____
5. 7.75	40	36	_____

COMPENSATION

Compensation is the body's attempt to correct an acid/base imbalance. If the imbalance is respiratory, the compensating mechanism is changing HCO₃⁻ (called reabsorption). If the imbalance is metabolic, the compensating mechanism is changing CO₂ (called ventilation). **Note: If an organ system is failing, the body may not be able to properly compensate for the original imbalance.** In each case listed below, denote whether the acid/base imbalance is a respiratory acidosis or alkalosis or a metabolic acidosis or alkalosis. Then state how the body is specifically trying to compensate for the imbalance.

Example:

Problem (imbalance) = respiratory alkalosis

General compensation = metabolic acidosis

Organ system that compensates = renal (urinary system)

Specific compensation = decrease HCO₃⁻ reabsorption *and* decrease H⁺ secretion).

Example:

Problem (imbalance) = metabolic alkalosis

General compensation = respiratory acidosis

Organ system that compensates = respiratory system

Specific compensation = hypoventilation

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ACTIVITY 19: ACID-BASE BALANCE PROBLEMS

Blood Chemistry Values			Imbalance		Compensation			
pH	pCO ₂ mm Hg	HCO ₃ ⁻ mEq/L	Imbalance	Cause of Imbalance	General Compensation	Which organ system compensates?	Specific Compensation	
7.52	49	36						
7.15	24	8						
7.52	24	20						
7.15	60	32						
7.48	47	30						
7.05	50	30						
7.48	28	19						