Blood Buffers

Module H

Malley pages 120-126

Objectives

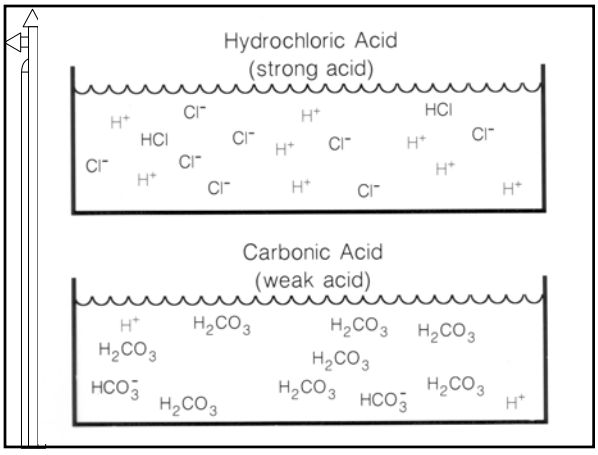
- Define a buffer system and differentiate between the buffering systems present in the body.
- Given an arterial blood-gas result, determine the degree of pH change that would result from an acute change in P_{aCO_2}.
- State two origins of fixed acids.
- Differentiate between a strong and weak acid and a strong and weak base.
- List the three extracellular fluid buffers.
- List the five intracellular fluid buffers.
- Using chemical notation, describe the Henderson-Hasselbalch equation.
- Describe Standard Bicarbonate, Buffer Base, and Base Excess.

Definitions

- Buffer: A buffer is defined as a solution of two or more chemical compounds that prevent marked changes in H^+ ion concentration when either an acid or base is added to solution.
  - A sponge
- Acid: Proton donor.
- Base: Proton acceptor.

Strong/Weak Acids

- Acids are proton donors.
- A strong acid is one where complete dissociation of the compound occurs.
  - Hydrochloric acid and sulfuric acid are strong acids.
- A weak acid is one where incomplete dissociation of the compound occurs.
  - Carbonic acid and acetic acid are weak acids.



Fixed (Non-Volatile) Acids

- Produced through body metabolism or ingested.
- Cannot be excreted as a gas through the lungs.
- Must be excreted in a liquid form through the kidney.
- Catabolism of Protein
  - Amino acids
  - Uric acid
  - Sulfuric acid
  - Phosphoric acid
- Catabolism of Carbohydrates
  - Pyruvic acid
  - Succinic acid
  - Lactic Acid (if no oxygen is present)
- Catabolism of Lipids
  - Fatty acids
  - Ketoacids (if no insulin is present)
    - Acetoacetic acid
    - Beta-hydroxybutyric acid

Volatile Acids

- The only volatile acid is carbonic acid (H_2CO_3).
- This acid is in equilibrium with its dissolved gaseous component ($PaCO_2$).

Acid Excretion

- Lungs -– excretes a volatile acid (H_2CO_3)
  - Major source of acid excretion
  - 13,000 mEq/day of carbonic acid
- Kidneys – excrete fixed acids
  - 40 – 80 mEq/day
  - Fixed acids may increase to 2,000 mEq/day
    - IV infusions
    - Ingestion of poisons
  - If production of fixed acids is high, the kidney may not be able to excrete the acid and metabolic acidosis occurs.

Base Excretion

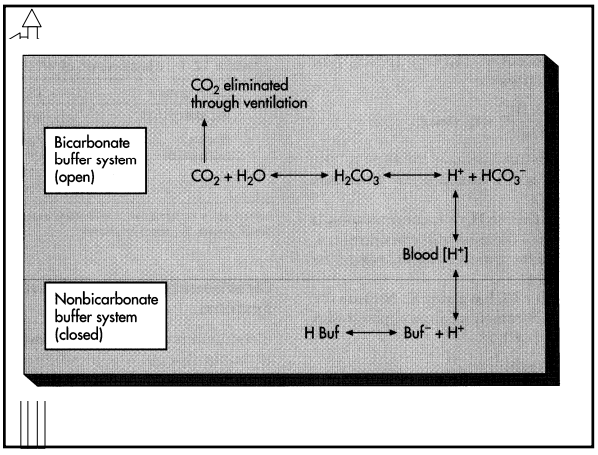
- Only regulated by the kidney.
- Primary base in the body is HCO_3^-.
- The kidney can retain or excrete HCO_3^- as needed.

Buffer Systems

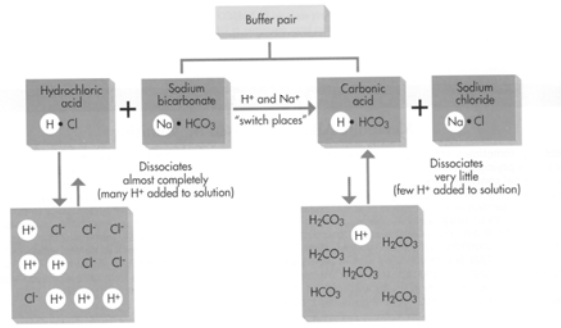
- Buffer systems do not prevent pH change but rather minimize the pH change.
- Buffer systems
  - Plasma
  - RBC
  - Urine

Plasma Buffer Systems

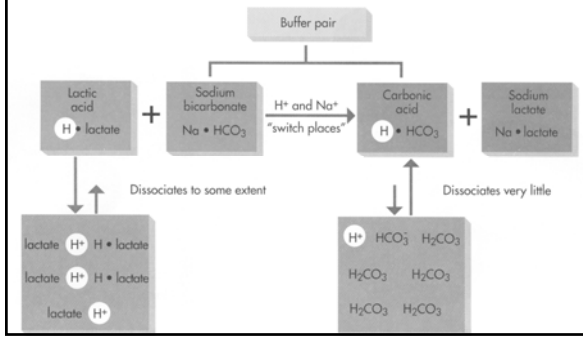
- Carbonic Acid/Sodium Bicarbonate
  - Open Buffer System
- Sodium Acid phosphate/Sodium alkaline phosphate
- Acid proteinate/Sodium proteinate



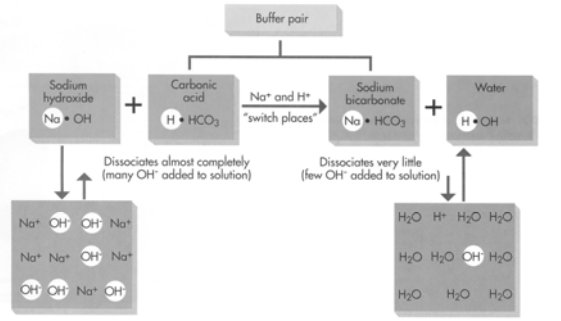
Buffering of a Strong Acid



Buffering of a Weaker Acid



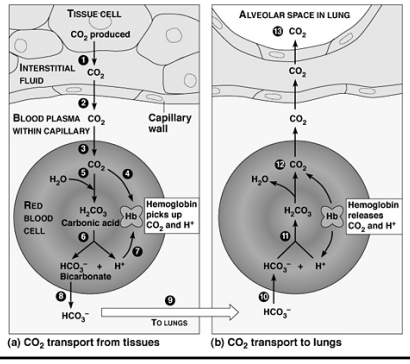
Buffering of a Strong Base



RBC Buffer Systems

- Acid Hemoglobin/Potassium Hemoglobin
- Potassium acid phosphate/Potassium alkaline phosphate
  - K^+ is main cation in the RBC

Hemoglobin as a Buffer



Urine Buffer Systems

- Carbonic Acid/Bicarbonate
- Ammonia Buffer System
  - NH_4^+/NH_3
- Phosphate Buffer System

pH Regulation

- When pH deviates from normal, the following systems kick in to minimize pH change:
  - Buffer system responds within seconds.
  - Respiratory system responds within minutes.
  - Kidneys will respond within hours/days.

Metabolic Indices

- Standard Bicarbonate
- Buffer Base
- Base Excess

Standard HCO_3

- Definition: The plasma HCO_3^- concentration that would be present if the $PaCO_2$ were 40 mm Hg.
- Eliminates the respiratory influence on plasma HCO_3^-.
- Allows evaluation of pure metabolic component.

Example of Standard HCO_3

- pH 7.20, $PaCO_2$ 90 torr, HCO_3^- 36 mEq/L
- The lab will place the blood sample in a **tonometer** and expose the sample to a known sample of $PaCO_2$ at 40 mm Hg.
- CO_2 will diffuse out of the sample until the $PaCO_2$ is 40 mm Hg. This eliminates the hydrolysis effect.
- Re-measure the HCO_3^- level and report it as standard HCO_3^- ($PaCO_2$ 40, Std HCO_3^- 31)

pH 7.25, $PaCO_2$ 60, HCO_3^- 22

- Appears to be an acute respiratory acidosis with no compensation.
- After CO_2 is equilibrated to a $PaCO_2$ of 40 mm Hg, standard HCO_3^- level is 20 mEq/L.
- In actuality, this is a mixed respiratory and metabolic acidosis!

Buffer Base

- The bicarbonate buffer base is only one of the buffer systems in the blood.
- The whole "Buffer Base" (BB) is the sum of all the buffer bases present in 1 liter of blood.
  - This includes HCO_3^-, Hemoglobin, plasma proteins, and phosphates.
- BB decreases in the presence of increased fixed acids or loss of base (metabolic acidosis).
- BB increases in the presence of increased base or loss of acid (metabolic alkalosis).
- Normal value is 48 mEq/L.
  - The normal value changes with Hb levels.

Base Excess

- In an ABG report, Base Excess is usually reported.
- Base Excess = Observed BB – Normal BB.
- Normal BE is 0 ± 2 mEq/L.

Examples of Base Excess

- If the observed buffer base is 58 mEq/L and the normal buffer base is 48 mEq/L then:
- BE = 58 - 48
  = +10 mEq/L
- This means you are either gaining base or losing acid.

Example of Base Excess

- If the observed BB is 40 mEq/L and the normal BB is 48 mEq/L then:
- BE = 40 - 48
  = -8 mEq/L
- This means you are either losing base or gaining acid.
- This technically would be a **base deficit**.