ACID BASE BALANCE

Homeostasis

- The Ideal Environment Cells Function Best in.
- It includes:
  - Temperature
  - Humidity
  - Oxygenation
  - Nutrition
  - Acidity

Acidity And Alkalinity

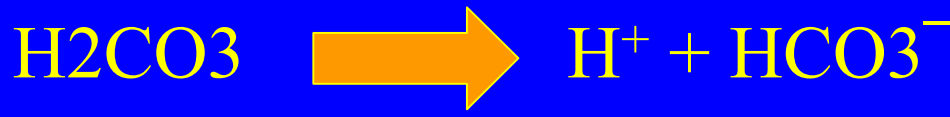
- Ideal Acidity for human cells to have the chemical reactions needed for their function and survival is a PH of 7.40 (7.35 - 7.45).

How Does the Body Maintain a Steady PH?

- Remember the followings:
- Carbon Dioxide (CO_2) in the blood is dissolved.
- It combines with water (H_2O) to form H_2CO_3 which is an acid.
- $H_2O + CO_2 \rightarrow H_2CO_3$

How Does the Body Maintain a Steady PH?

- H_2CO_3 dissociates into H^+ and HCO_3^-



Facts

- $NaHCO_3^-$ (Sodium Bicarbonate) is a base. In the body, it acts as a buffer.
- H_2O (Water) is neutral
- H_2CO_3 (CO_2+H_2O) is an acid

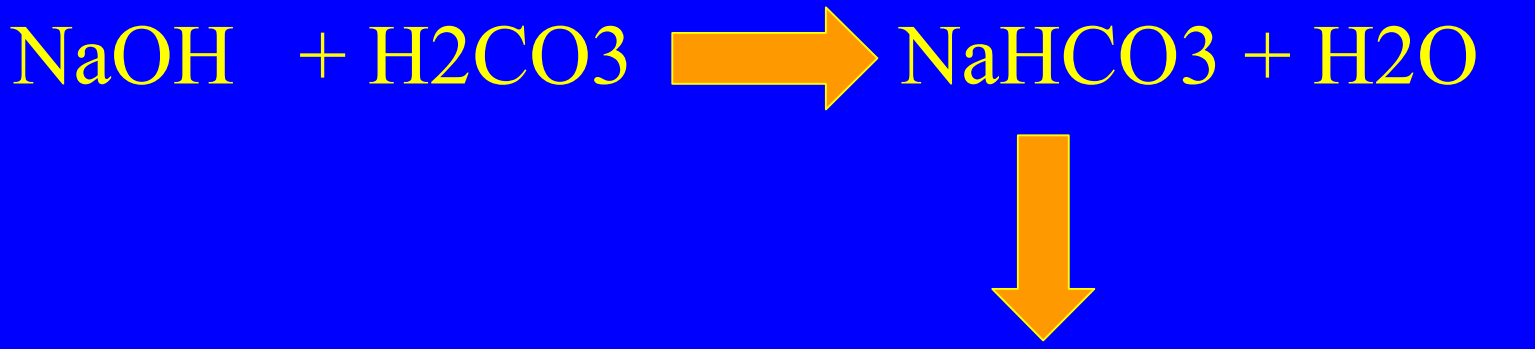
Facts

- PH Less than 7.35 is acidic
- Acidemia (acid-blood): Term used if it is measured in the blood by analysis of sample (Ex. ABG's)
- Acidosis is a state. Acidosis can exist with a normal PH if it is compensated by alkalosis

Facts

- PH more than 7.45 is alkali
- Alkalemia (alkali-blood): Term used if it is measured directly in the blood (Ex. ABG's)
- Alkalosis is a state. It may exist even if the PH is normal when compensated by acidosis)

If a Base Is Added to the Blood



If an organic acid (H R) is added to the blood

H R + NaHCO3

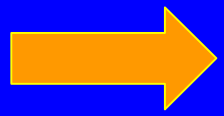
$Na^{+} R^{-}$ (Salt) + H2CO3

H2O + CO2

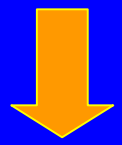
Exhaled by the lungs

(Respiratory)

Question: What Happens If We Inject HCL (Inorganic Acid)?

- HCL + NaHCO3 

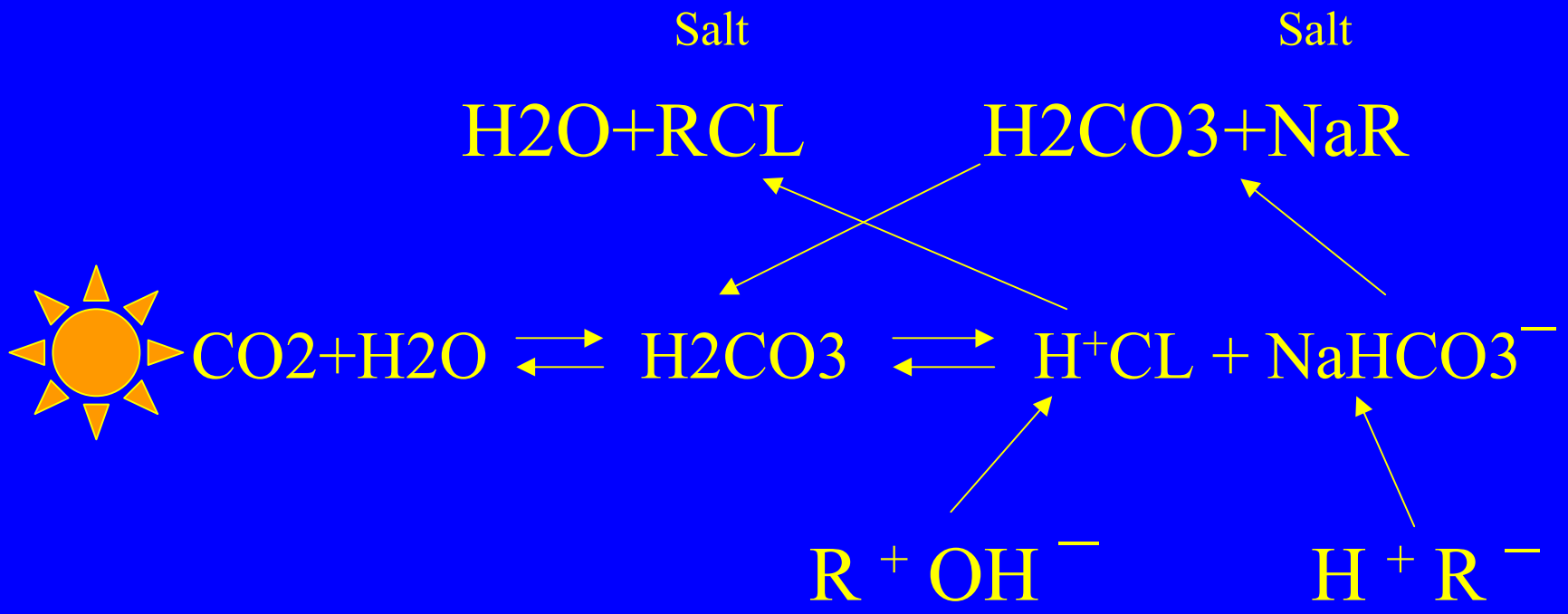
NaCl + H2CO3



CO2+ H2O

Exhaled by the lungs

Summary



Arterial Blood Gases (ABG's)

- ABG's is the analysis of an arterial blood sample for:
- PH
- PCO2 (Partial pressure of carbon dioxide in blood which corresponds to its concentration)
- PO2 (Partial pressure of oxygen in blood which corresponds to its concentration)
- HCO3 (Bicarbonate concentration)

Anion Gap

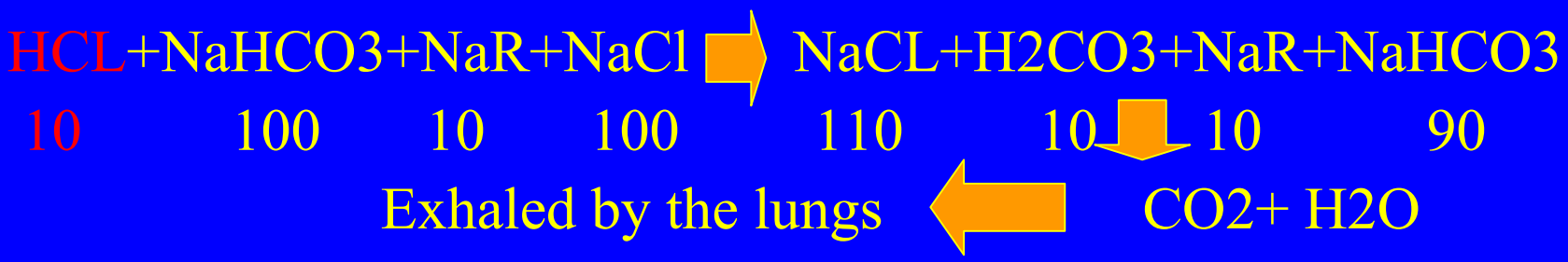
- Major Ions in body are NaCl → Na^+ Cl^- and NaHCO3 → Na^+ $HCO3^-$
- Anions are Cl^- & $HCO3^-$
- Cations are Na^+ & K^+
- AG = $[Na^+]$ - $[Cl^- + HCO3^-]$
- AG represents unaccounted for anions (R^-)
- Normal anion gap = 10

- Let's Assume we have :
- NaCl NaHCO3 NaR
  100 100 10
- Total [Na] = 100+100+10 = 210
- Total [Cl] = 100 .
- Total [HCO3] = 100 .
- Total [R] = 10 .

- AG= 210 –100 – 100 = 10 .

- **Notice that [R] did not affect AG**

Question: What Happens To AG If We Inject 10 meq of HCL (Inorganic Acid)?



AG before HCL = 210 – 100 -100 = 10

AG after HCL = 110 +10 +90 – 110 – 90 = 10

So AG is not affected by addition of inorganic acids

Question: What Happens To AG If We Inject 10 meq of HR (Organic Acid)?

AG before HR = 210 – 100 -100 = 10

AG after HCL = 110 +90+20 – 110 – 90 = 20

- So AG is affected by addition of inorganic acids.
- The increase in AG is equal to the number of meq of organic acids added.

Organic Acids

- Lactic Acid formed when glucose is burned in the body in the absence of adequate oxygen supply (ex. Ischemia)
- Ketones formed when fatty acids are broken down to produce energy when glucose is either absent (ex. starvation) or can not be metabolized (ex. Absence of insulin in diabetics)
- Other less important ones

Non Anion Gap Acidosis

- GI HCO3 Loss
- Renal NaHCO3 Loss
  - Renal Tubular Acidosis
  - Early Renal Failure
  - Carbonic Anhydrase Inhibitors
  - Aldosterone Inhibitors
- HCL infusion
- Post-hypocapnea

Anion Gap Acidosis

M.U.D.P.I.L.E.S

- Diabetic Ketoacidosis (Ketones are like organic acids)
- Alcoholic Ketoacidosis
- Renal Failure GFR<20 (Can not excrete acids)
- Sepsis/ infection
- Lactic Acidosis
- Rhabdomyolysis : Broken muscles
- Toxins (Methanol, Ethanol, ethylene Glycol, paraldehyde, ASA)

Rules For Analyzing The ABG's

- Look at PH and decide if it is ACIDOTIC or ALKALOTIC
- Look at PCO2 . If more than 45, it's respiratory acidosis. If less than 35, it's respiratory alkalosis.
- Look at HCO3. If more than 26, it's metabolic alkalosis. If less than 22, it's metabolic acidosis.

- PH PCO2 HCO3 GAP
  7.50 29 22
- RESPIRATORY ALKALOSIS
- Scenario ?
- Hyperventilation

- PH PCO2 HCO3 GAP
  7.25 60 26
- RESPIRATORY ACIDOSIS
- Scenario ?
- Acute Ventilatory Failure

PH	PCO2	HCO3	GAP
7.34	60	31	

- **RESPIRATORY ACIDOSIS**

- **& METABOLIC ALKALOSIS**
- **Scenario?**
- **COPD**

- PH PCO2 HCO3 GAP
  7.50 48 36

- METABOLIC ALKALOSIS
& RESPIRATORY ACIDOSIS
- Scenario?
- COPD with Dehydration

- PH PCO2 HCO3 GAP
  7.20 21 8

- METABOLIC ACIDOSIS
- & RESPIRATORY ALKALOSIS
- Scenario?
- Sepsis with Compensatory Hyperventilation

More Rules For Analyzing The ABG's

- Look at the anion gap.
  - If elevated and metabolic acidosis is present, it's anion gap metabolic acidosis. If not elevated, it's non-anion gap metabolic acidosis.
  - If more than 20, there is definitely anion gap acidosis even if the PH and the HCO3 are normal.

CHANGE IN ANION GAP

? ?

? ?

- If anion gap has increased (by 10 for example), it means that HCO3 has dropped by the same amount (10). This is because it had to react with the 10 of the added organic acid.
- We can then say that if the HCO3 is now, let's say 24, then we must have started with HCO3 of 24+10=34 (alk) before the new problem started.
- Wouldn't it be interesting to know if we had acidosis or alkalosis to start with?

More Rules For Analyzing The ABG's

- Look at the change in anion gap. (? AG)
  - Add the change to the HCO3 in the ABG's
  - Look at the total HCO3 + ? AG
  - If the total is more than 28, then there was a metabolic alkalosis to start with before the acute problem started.
  - If the total is less than 20, then there was a non-anion gap acidosis before the acute problem started

PH	PCO2	HCO3	GAP
7.50	20	15	22

- RESPIRATORY ALKALOSIS
- & METABOLIC ACIDOSIS
- WITH ANION GAP
- Scenario ?
- Sepsis with Compensatory Hyperventilation

PH	PCO2	HCO3	GAP
7.40	40	24	21

- METABOLIC ACIDOSIS WITH ANION GAP
- & METABOLIC ALKALOSIS
- Scenario?
- Dehydration Leading to Ischemic Bowels

PH	PCO2	HCO3	GAP
7.50	20	15	30

- RESPIRATORY ALKALOSIS
- ANION GAP METABOLIC ACIDOSIS
- & METABOLIC ALKALOSIS
- Scenario?
- Dehydration leading to Ischemic Bowels then Hyperventilation due to pain or fever

PH	PCO2	HCO3	GAP
7.10	50	15	30

- RESPIRATORY ACIDOSIS
- METABOLIC ACIDOSIS WITH ANION GAP
- & METABOLIC ALKALOSIS
- Scenario?
- Dehydration leading to Ischemic Bowels but now developing Ventilatory Failure

PH	PCO2	HCO3	GAP
7.15	15	5	25

- RESPIRATORY ALKALOSIS
- METABOLIC ACIDOSIS WITH ANION GAP
- & METABOLIC ACIDOSIS NON ANION GAP

SUGGESTED REFERENCE:
WESTERN JOURNAL OF MEDICINE 155(2):146-51, 1991 AUGUST