

Quantitative Analysis of Acid Base Disorder

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Objectives



- Idea about history of interpretation (Boston And Copenhagen)
- Understanding Mathematical Concept of Stewart approach
- Quantitative Interpretation of Acid Base disturbances
- Clinical Application of Stewart approach

Story started from HH

- Aim: Maintain pH of solution
- Method : You should have *Buffer*

Method

Classical buffer contains solution of weak acid and conjugate base.
Small amounts of acids or bases added are absorbed by buffer and the pH changes only slightly...

Bicarbonate Buffer System

$$[H^+] = K_a \frac{HA}{A^-}$$

HH Equation

$$pH = pK_a + \log_{10} \left[\frac{HCO_3^-}{0.03 * PaCO_2} \right]$$

So...

Simply

$$pH \propto \left[\frac{HCO_3^-}{PaCO_2} \right]$$

For disturbing H⁺ Concentration:

- HCO₃⁻ Increase or Decrease
- PaCO₂ Increase Or Decrease

Controllers :Lungs, Kidney, Liver

Compensation

$$pH \propto \left[\frac{HCO_3^- \uparrow \downarrow}{PaCO_2 \uparrow \downarrow} \right]$$

- CO_2 = Respiratory = Lung
- HCO_3^- = Metabolic = Kidney

6 types of Disorder

- Acute Respiratory Acidosis
- Chronic Respiratory Acidosis
- Acute Respiratory Alkalosis
- Chronic Respiratory Alkalosis
- Metabolic Acidosis
- Metabolic Alkalosis



Winter Rules

- The rules describe the normal physiological reactions of the human body to one isolated acid-base Disorder
- The clinical question the rules are designed to answer in this situation is, whether the patient's respiratory compensation is within the range to be expected or whether there is an additional component of respiratory disturbance
- Example :: DKA with Respiratory Compensation

Winter rules

NCBI Resources How To My NCBI S

PubMed.gov
U.S. National Library of Medicine
National Institutes of Health

Search: PubMed Limits Advanced search Help

Display Settings: Abstract Send to:

Ann Intern Med. 1967 Feb;66(2):312-22.

Quantitative displacement of acid-base equilibrium in metabolic acidosis.

Albert MS, Dell RB, Winters RW.

PMID: 6016545 [PubMed - Indexed for MEDLINE]

MeSH Terms, Substances

LinkOut - more resources

Related citations

[Quality control of base excess (BE, mmol/L)]
[Anesthesiol Intensivmed Notfallmed Schmerzther]

[Quantitative studies in metabolic acidosis in clinical practice] [Pediatr (Bucur)]

Effects of maternal metabolic acidosis on the human fetus and neonate [Am J Obstet Gynecol]

Review Arterial blood gases. [Emerg Med Clin North Am]

Review [Acid-base equilibrium in preterm and newborn infants] [Pediatrics]

See rev

Cited by 2 PubMed Central articles

Assessing acid-base disorders, Kidney International ..copied from acidbase.org

The formulae used in our scripts are based on the version propagated by Horacio J. Adrogué.
(Assessing acid-base disorders, Kidney International advance online publication, 7 October 2009; doi:10.1038/ki.2009.359)
(the prefix "delta" indicates that the variable represents the amount the value in question deviates from its normal value.)

1- metabolic acidosis as the primary disturbance, PCO₂ (in mmHg) in relation to [HCO₃⁻]
delta_PaCO₂/delta_[HCO₃⁻]= 1.2mmHg per mEq/l

2- metabolic alkalosis as the primary disturbance, PCO₂ (in mmHg) in relation to [HCO₃⁻]
delta_PaCO₂/delta_[HCO₃⁻]= 0.7mmHg per mEq/l

3- respiratory acidosis as the primary disturbance, [HCO₃⁻] in relation to PCO₂ (in mmHg)
3a- acute compensation:
delta_[HCO₃⁻]/delta_PaCO₂= 0.1mEq/l per mmHg
3b- chronic compensation:
delta_[HCO₃⁻]/delta_PaCO₂= 0.3mEq/l per mmHg

4- respiratory alkalosis as the primary disturbance, [HCO₃⁻] in relation to PCO₂ (in mmHg)
4a- acute compensation:
delta_[HCO₃⁻]/delta_PaCO₂= 0.2mEq/l per mmHg
4b- chronic compensation:
delta_[HCO₃⁻]/delta_PaCO₂= 0.4mEq/l per mmHg

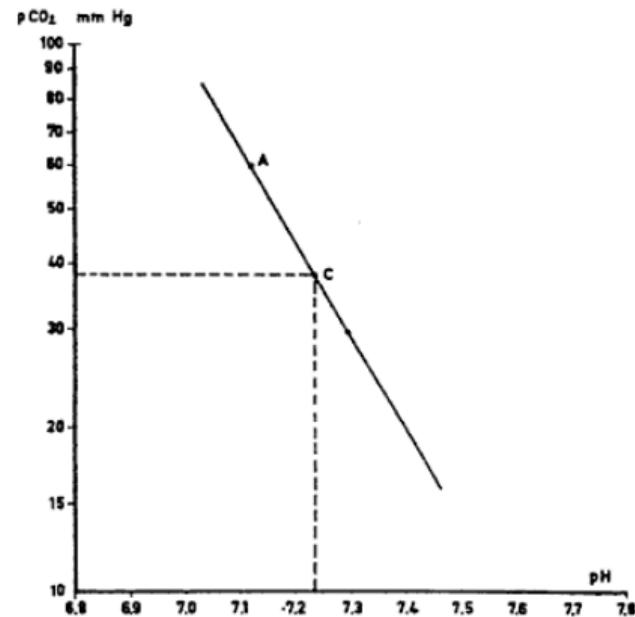
- **In Metabolic Acidosis**

Anion Gap should be Checked :: High Or Normal ::

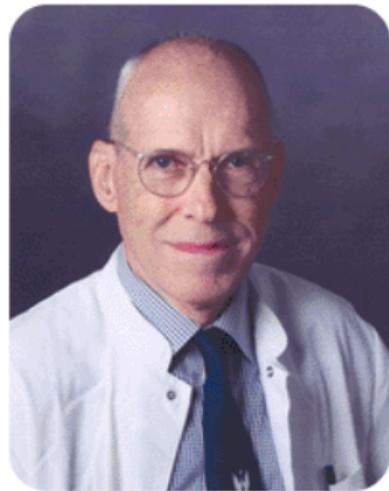
- **In Metabolic Alkalosis**

Type should Be known :: Cl Responsive or Resistant ::

Henderson and Van Slayk



Siggaard Andersen..The Complete Picture



1960, Ole Seggard Anderson 25 year old, rotating intern, helped to produce an alignment nomogram relating PCO₂ and pH to base Excess

More Buffers..

AN IMPROVED CLINICAL METHOD FOR THE ESTIMATION OF DISTURBANCES OF THE ACID-BASE BALANCE OF HUMAN BLOOD

RICHARD B. SINGER¹ AND A. BAIRD HASTINGS

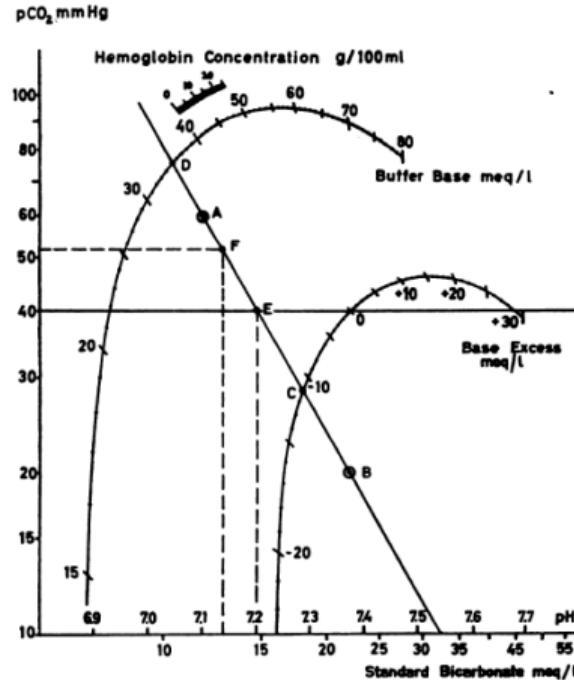
Department of Biological Chemistry, School of Medicine, Harvard University, Boston

INTRODUCTION

The clinical conditions that are associated with disturbances of the acid-base balance of the blood are familiar to many physicians. Some of these, such as diabetic coma and nephritis, are of concern to the internist; while cases of intestinal obstruction with vomiting and of draining gastro-intestinal fistulas must

*Singer and Hastings proposed **buffer base** as sum of all blood buffers (anions) including bicarbonate, proteins, and hemoglobin in one liter of blood*

Seggard Anderson nomogram



- Point A : measured pH at high PaCO_2
- Point B : measured pH at low PaCO_2
- Point C : the BE "Base Excess"
- Point D : the Buffer Base

So we Can Define

Base Excess:

The **miliequivalents of strong acid or bases** that is needed to titrate one liters (in vitro) of blood or plasma that has been equilibrated to $pCO_2 = 40$ mmhg and to physiological pH of 7.4, at temperature 37 c and full O₂ saturation

Buffer Base:

Is the sum of all buffering agents in the blood including **bicarbonate, proteins, and hemoglobin** in one liter of blood

BE calculation And SBE

Van Slayk equation

$$\text{BE} = (\text{HCO}_3 - 24.4 + [2.3 * \text{Hb} + 7.7] * [\text{pH} - 7.4]) * (1 - 0.023 * \text{Hb})$$



BE calculation And SBE

Van Slayk equation

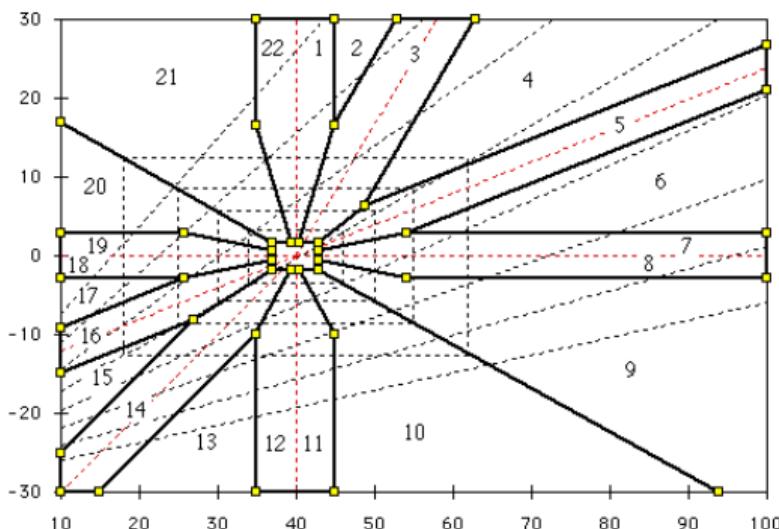
$$\text{BE} = (\text{HCO}_3^- - 24.4 + [2.3 \times \text{Hb} + 7.7] \times [\text{pH} - 7.4]) \times (1 - 0.023 \times \text{Hb})$$

Standard Base Excess

$$\text{SBE} = 0.9287 \times (\text{HCO}_3^- - 24.4 + 14.83 \times [\text{pH} - 7.4])$$

BE Computing Method

Alan W. Grogono, created java applet for interpretation of acid base disorder using pH, PCO₂ and SBE



Typical Zones:

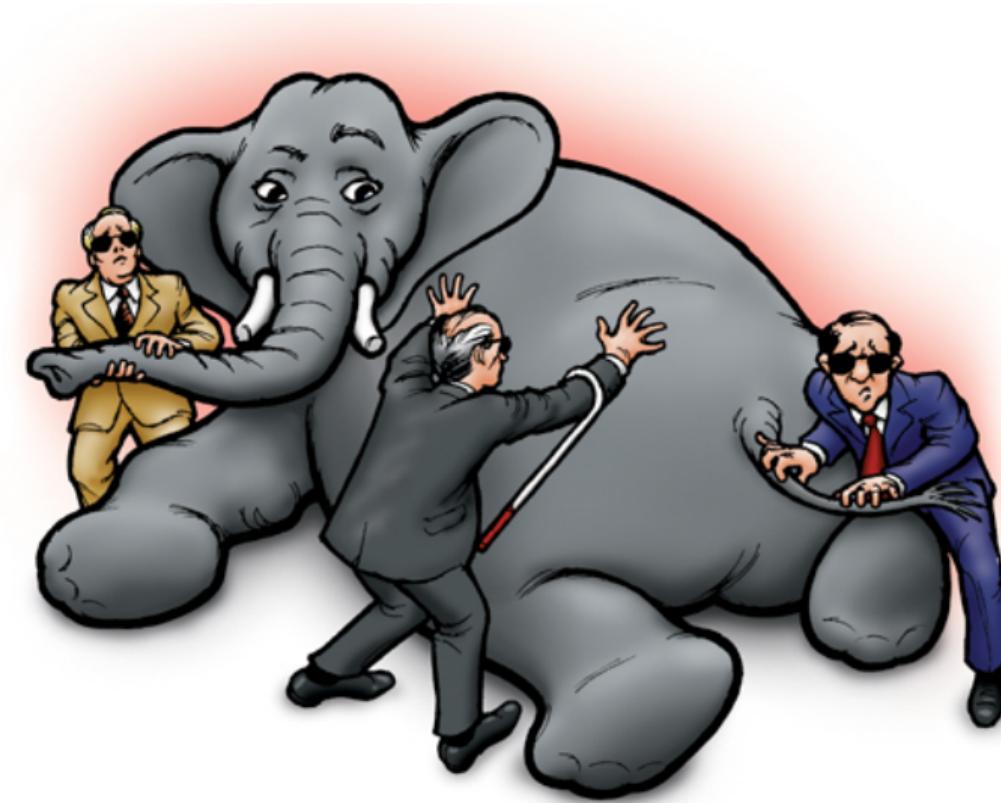
- Acute Respiratory Acidosis (7 and 8)
- Chronic Respiratory Acidosis (5)
- Metabolic Alkalosis (3)
- Acute Respiratory Alkalosis (18 and 19)
- Chronic Respiratory Alkalosis (16)
- Metabolic Acidosis (14)

Clinical Example

Running Java Application using AppViewer

Stewart Approach...

Elephant Idea from acidbase.org



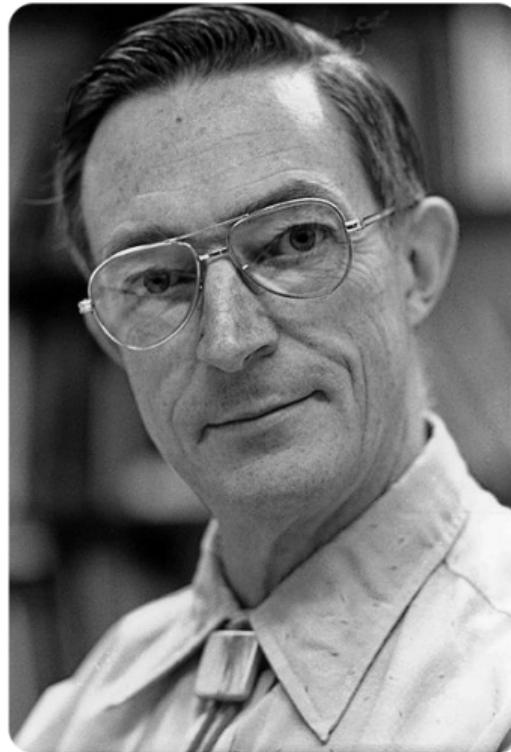
Stewart Approach.. Simply

What is the role of bicarbonate
 (HCO_3^-)
in
acid-base balance?

The answer is simply:

None!

Peter Stewart (1921-1993)



Do we need other approach

Ok ...look to the following Case -Fencle Case 18-, what is your interpretation...

18	
Measured quantities	
Na ⁺ , mEq/L	140
K ⁺ , mEq/L	4.8
Ca ²⁺ , mEq/L	3.4
Mg ²⁺ , mEq/L	1.6
Cl ⁻ , mEq/L	103
Pi, mmol/L	0.9
Albumin, g/L	15
pH	7.45
Pco ₂ , mm Hg	48
Derived quantities	

Chronic obstructive pulmonary disease [COPD], bronchopneumonia, congestive heart failure)

You may think that the solution my be

Post-Hypercarbic Metabolic Alkalosis

Terminologies: Let Us Set New Rules...

- **Neutral Solution** :Solution that its hydrogen ion concentration is equal to hydroxyl ion concentration.

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- **Acidic Solution** :Solution that its hydrogen ion Concentration is greater than hydroxyl ion concentration.

Terminologies: Let Us Set New Rules...

- **Neutral Solution** :Solution that its hydrogen ion concentration is equal to hydroxyl ion concentration.
- **Acidic Solution** :Solution that its hydrogen ion Concentration is greater than hydroxyl ion concentration.
- **Alkaline Solution** : Solution that its hydroxyl ion concentration is greater than its hydrogen ion concentration .

Terminologies..Cont.

Acidic Substance :

- Substance, if added to solution, it brings about an increase in hydrogen ion concentration of solution

Terminologies..Cont.

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- All other independent variables in solution remains constant

Terminologies..Cont.

Acidic Substance :

- Substance, if added to solution, it brings about an increase in hydrogen ion concentration of solution
- All other independent variables in solution remains constant
- Acids achieve their effect either by dissociating in solution yielding an anion plus Hydrogen ion

Terminologies..Cont.

Base Substance :

- Substance, if added to solution, it brings about a decrease in hydrogen ion concentration of solution

Terminologies..Cont.

Base Substance :

- Substance, if added to solution, it brings about a decrease in hydrogen ion concentration of solution
- All other independent variables in solution remains constant.

Terminologies..Cont.

Base Substance :

- Substance, if added to solution, it brings about a decrease in hydrogen ion concentration of solution
- All other independent variables in solution remains constant.
- Bases achieve their effect either by dissociation to form cation plus hydroxyl group

Electrolytes, Non Electrolytes, Strong And Weak Electrolytes

- **Non-electrolytes** :Substance that does not dissociate are called non-electrolytes..

Electrolytes, Non Electrolytes, Strong And Weak Electrolytes

- **Non-electrolytes** :Substance that does not dissociate are called non-electrolytes..
- **Strong electrolytes** :electrolytes which are completely dissociated in solution,i.e parent substance disappears when dissolved in water

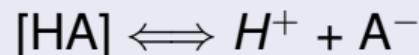
Example

NaCl if dissolved in water, solution will contain Na^+ , Cl^- , H^+ , OH^- , water and no NaCl molecules

Weak Electrolytes:

- Substance that partially dissociate when dissolved in water
- The molecules of parent substance as well as the product of dissociation will exist

HA ??



For achieving equilibrium,

"The rate of dissociation should equal rate of recombination"

$$[\text{H}^+] \times [\text{A}^-] = K_A \times [\text{HA}]$$

Dependant and Intendant Variables

- **Independent Variables:**the variables being manipulated or changed by external maneuvers
- **Dependent variables :** observed result of the independent variable being manipulated

Conversion of mass

The mount of each component substance in any aqueous solution remains constant unless

- Condition 1 : substance is Added Or Removed from solution
- Condition 2 : substance that is Generated Or Destroyed by chemical reaction within the solution .

The Simplest Acid-Base System : Pure water

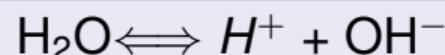


The Simplest Acid-Base System : Pure water

- Water dissociates into hydrogen and hydroxyl ions. At 37 C
- The dissociation constant is 4.3×10^{-16} Eq/Liters.

K_w is highly temperature dependent and very small

So...



$$[\text{H}^+] \times [\text{OH}^-] = K_w \times [\text{H}_2\text{O}]$$

$$K'_w = K_w \times [\text{H}_2\text{O}]$$

$$[\text{H}] \times [\text{OH}] = K'_w$$

The Simplest Acid-Base System : pure water..Cont

Cont.

Since water contains Hydrogen and Hydroxyl only

$$\text{H}^+ = \text{OH}^-$$
$$[\text{H}^+] \times [\text{H}^+] = K'_{\text{W}}$$

So..

$$\text{H}^+ = \sqrt{K'_{\text{W}}}$$

$$\text{OH}^- = \sqrt{K'_{\text{W}}}$$

New Definition for acidic and alkaline solution

- Solution is acid-base neutral if the hydrogen ion concentration is equal to the square root of the $K'w$.
- A solution is acidic if $[H^+] > \sqrt{(K'w)}$
- A solution is basic if $[H^+] < \sqrt{(K'w)}$

Adding strong ions in water

Adding specified amount of NaCl to Water [H₂O], so solution will only contain Na, Cl, H And OH

By application of electrical neutrality

$$Na^+ - Cl^- + H^+ - OH^- = 0$$

$$[H^+] \times [OH^-] = K'_W$$

By substitution of OH⁻ by [K'W]/[H⁺]

$$H^+ - (K'_W/H^+) + Na^+ - Cl^- = 0$$

$$[H^+]^2 + [H^+]([Na^+] - [Cl^-]) - K'_W = 0$$



Some Math

the quadratic equation can be solved as

$$[H^+]^2 + [H^+]([Na^+] - [Cl^-]) - K'_W = 0$$

$$[H^+] = -(Na^+ - Cl^-)/2 + \sqrt{((Na^+ - Cl^-)^2/4 + K'_W)}$$

- By replacing Na^+ and Cl^- by any strong ions, H^+ can be obtained
- Difference between **Strong Ions** can be expressed as -Strong Ion Difference- [SID]

SID

$$[\text{H}^+] = \sqrt{(\text{K}'_W + \text{SID2}/4) - \text{SID}/2}$$

$$[\text{OH}^-] = \sqrt{(\text{K}'_W + \text{SID2}/4) + \text{SID}/2}$$

Strong Ion Difference

Strong Ion difference

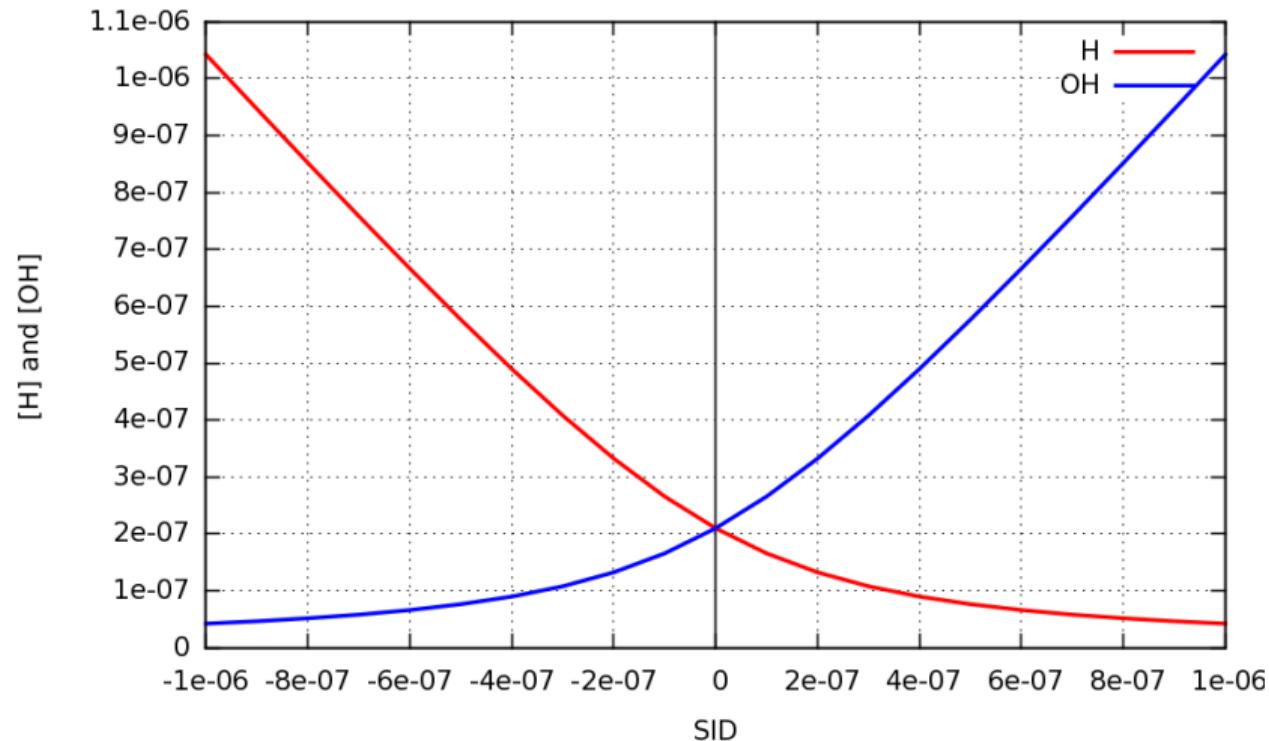
The sum of all strong base cation concentration minus the sum of all strong anion concentration, all expressed in equivalents per Liter

$$SID = \sum StrongBaseCations - \sum StrongAcidAnions$$

In biological solution, SID is almost positive

it is on the order of +40 mEq/Liter. In extra cellular fluids, Na^+ and Cl^- is the main Strong Ions , the SID is closely to $(\text{Na}^+ - \text{Cl}^-)$

SID Graphical Presentation..let the computer plays the game



Explanation of some body processes and chemical reactions

- **Adding HCl to Water :**

Using traditional approach

Adding H^+ will cause increase of H^+ that mean acidosis

Using Stewart approach

- You are adding a strong anion (Cl^-) without adding a strong cation. The SID decreases. This is a net negative change in charge due to SID.
- To maintain electrical neutrality the solution must liberate H^+ , leading to acidosis

Explanation of some body processes and chemical reactions

- **Production of stomach acid:**

Using traditional approach

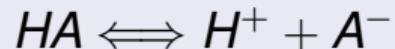
Parietal cells secrete HCl into the stomach fluid, increasing its acidity.

Using Stewart approach

- Parietal cells transport a strong anion (Cl^-) from the plasma into the stomach fluid without transporting a strong cation. This decreases the SID in the stomach fluid, which causes it to be more acidic.
- To maintain electrical neutrality, either a positive charge must move with the Cl^- or a negative charge must move opposite it

Adding weak electrolytes

Some Math.. BE Patient Plz

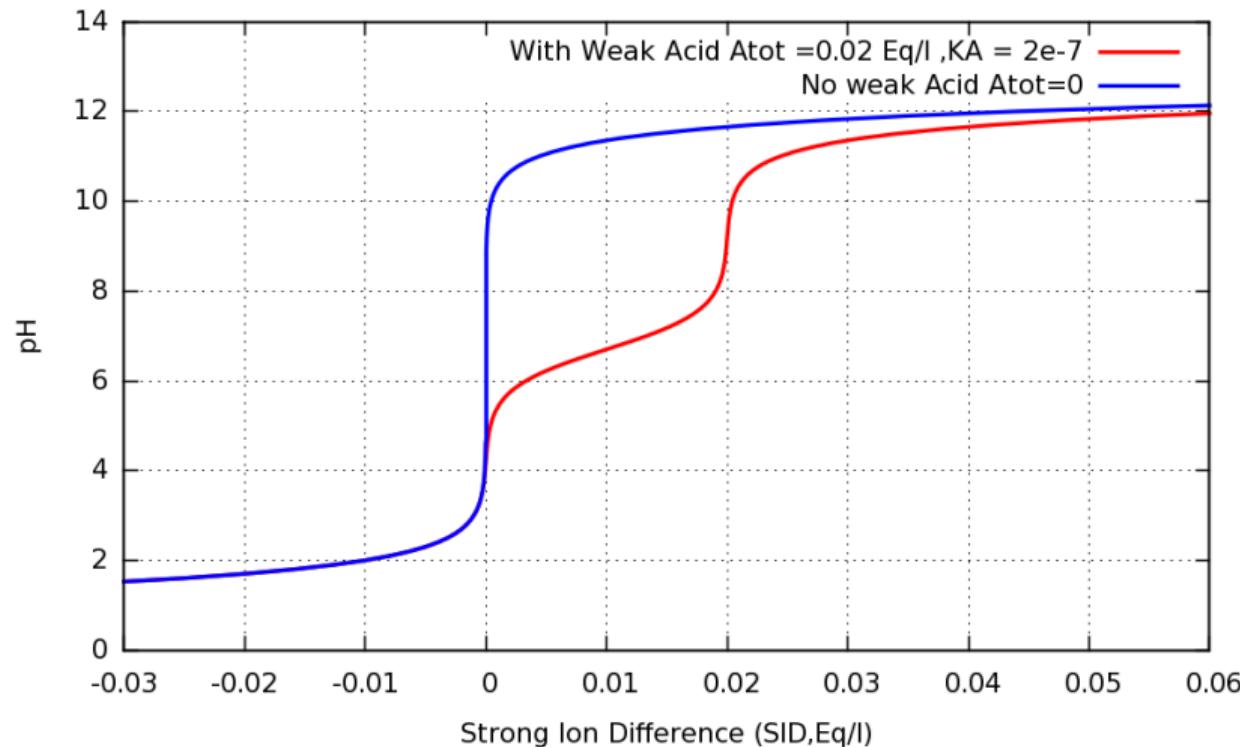


$$[H^+] + [OH^-] + [SID] + [A^-] = 0$$

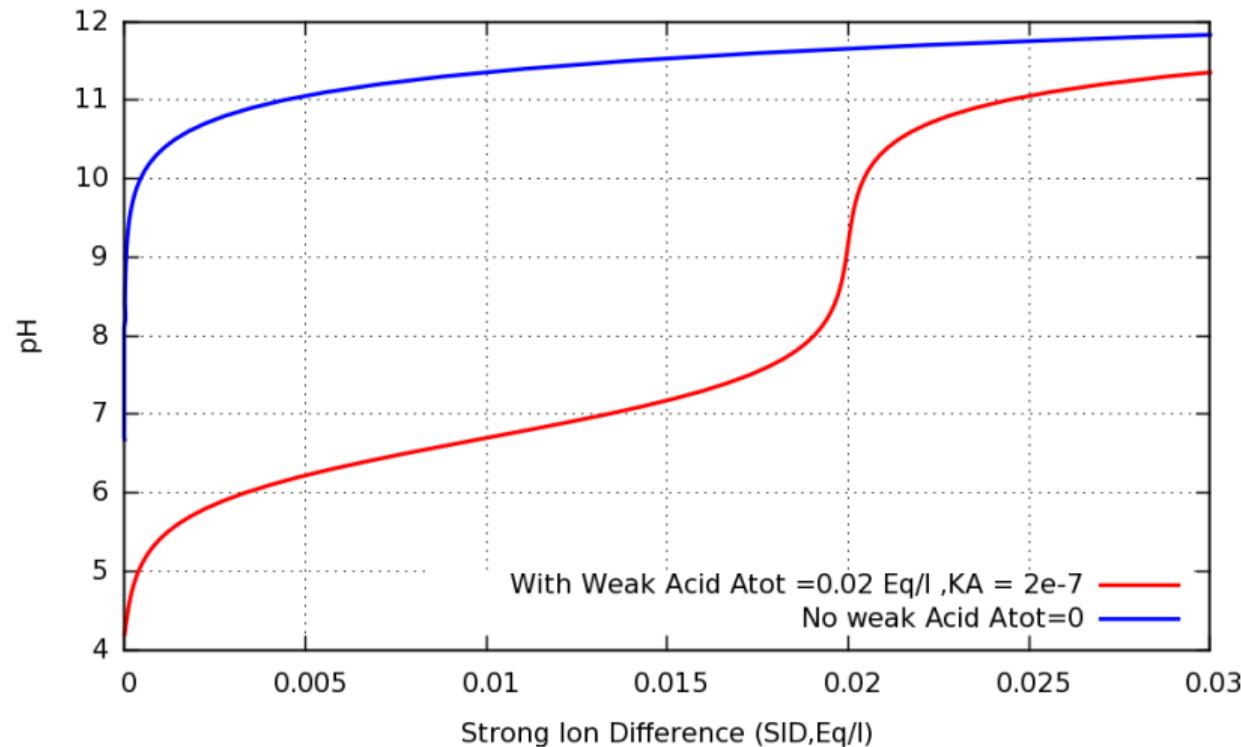
$$[H^+]^3 + KA + [SID] * [H^+]^2 + K_A * ([SID] - [A_{TOT}]) - K'_W * [H^+] - K_A * K'_W = 0$$

- By using computer programming languages H^+ value could be obtained from the previous equation.

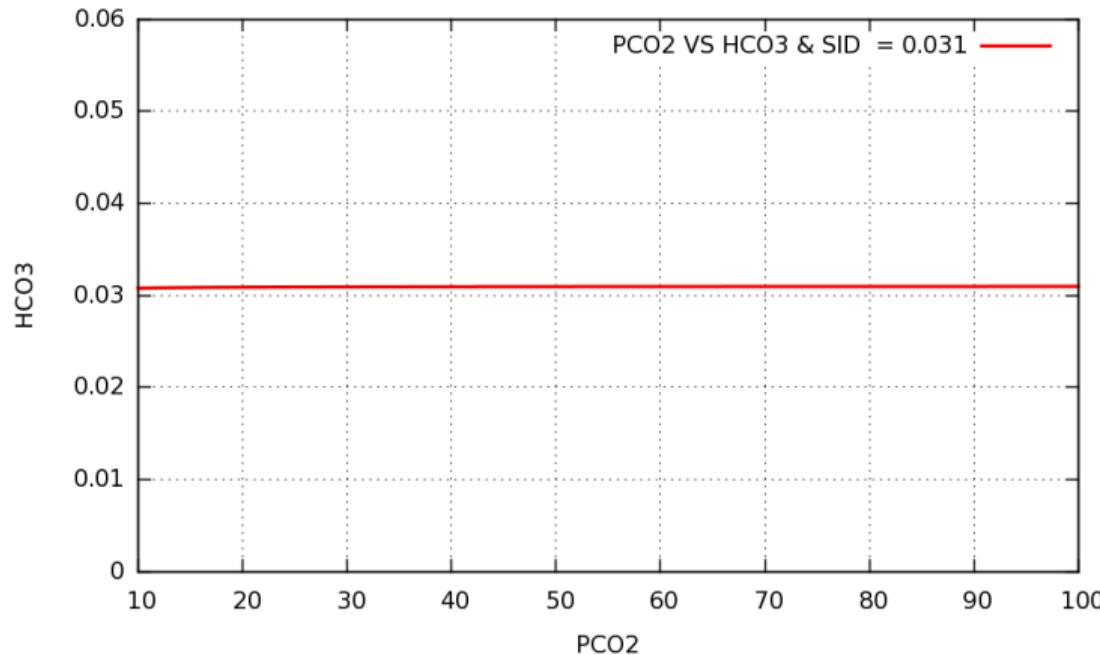
A_{TOT}



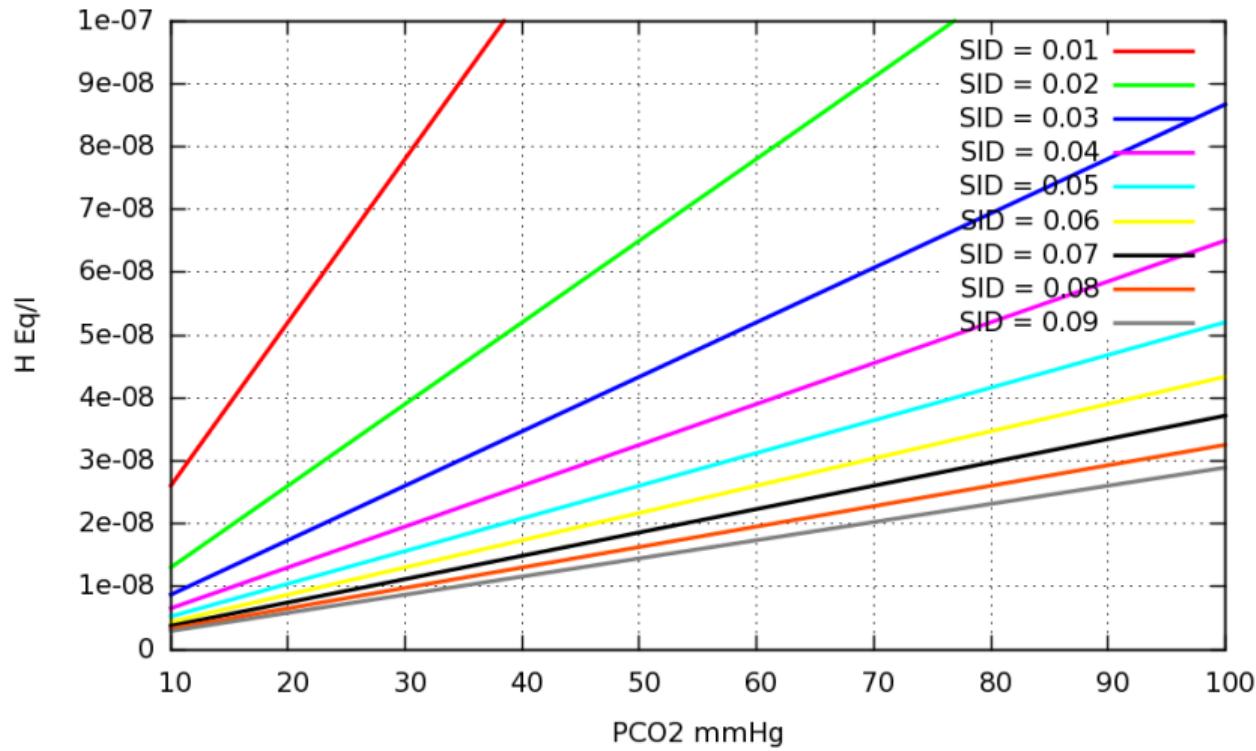
$A_{TOT}Zoom$



Adding CO₂



H₂CO2 And SIDs



H, CO_2 And SIDs

After plotting of H and CO_2 relationship with known SID

- SID could be evaluated by known H (using pH meter) and known $PaCO_2$, after that, the value of OH^- , CO_3^{--} and HCO_3^- could be calculated if needed

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- SID could be evaluated by known H (using pH meter) and known $PaCO_2$, after that, the value of OH^- , CO_3^{--} and HCO_3^- could be calculated if needed
- H^+ depends only on SID and $PaCO_2$ only

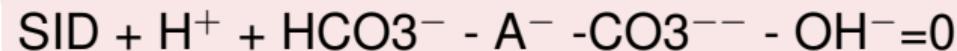
H, CO_2 And SIDs

After plotting of H and CO_2 relationship with known SID

- SID could be evaluated by known H (using pH meter) and known $PaCO_2$, after that, the value of OH^- , CO_3^{--} and HCO_3^- could be calculated if needed
- H^+ depends only on SID and $PaCO_2$ only
- H^+ does not depend on HCO_3^- , HCO_3^- was important historically as it could be calculated from known value of CO_2 and H^+

The Complete Picture

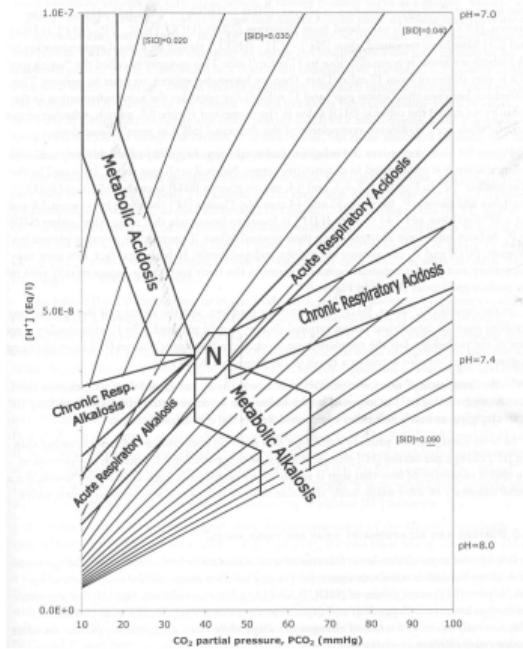
All Dependant Variables



Simple... :)

$$H^4 + KA + SID * H^3 + KA * (SID) - ATOT - (KC * PC + K'W) * H^2 - KA * (KC * PC + K'W + K3 * KC * PC * H - KA * K3 * KC * PC) = 0$$

The Complete Picture... Cont.



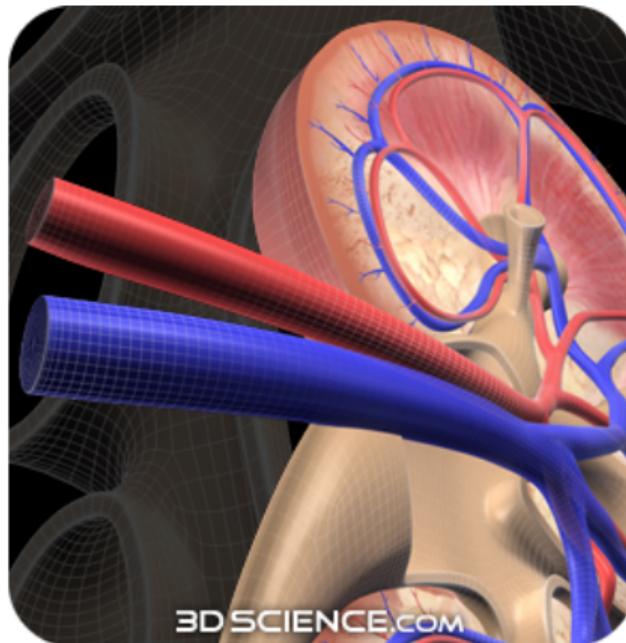
Acid-base Balance

Set of mechanisms by which parts of the body, notably **lungs**, **kidneys**, and **gastrointestinal** track control the composition of circulating blood plasma, so its H^+ generally within range from 2×10^{-7} to 1×10^{-7} Eq/L or pH 7.7 to 7.0

Lungs.. CO_2 regulator



Kidney...



3D SCIENCE.com

Lung And Kidney

- **Acute Respiratory Acidosis** = PCO_2 up briefly, so plasma H^+ is up
- **Acute Respiratory Alkalosis** = PCO_2 down briefly, so plasma H^+ is down
- **Chronic Respiratory Acidosis** = PCO_2 up -sustained-, SID up , H^+ up slightly
- **Chronic Respiratory Alkalosis** = PCO_2 down -sustained-, SID down, H^+ down slightly

- **Prolonged Vomiting**

Stomach Rule as Example for regulation and disturbances

- Lowered plasma Cl^- level "Hypochloremia"
- Elevated SID = Metabolic Alkalosis
- Above normal PCO_2 = Respiratory acidosis
- Moderately lowered H^+ = Elevated pH

Some Questions



- How can we Calculate SID.
- How could we Calculate A_{TOT}
- pH affection by each variables

The screenshot shows a Linux desktop environment with a window titled "2246.pdf - Adobe Reader". The main content is an article from a medical journal. The title of the article is "Diagnosis of Metabolic Acid-Base Disturbances in Critically Ill Patients" by VLADIMIR FENCL, ANTONÍN JABOR, ANTONÍN KAZDA, and JAMES FIGGE. The article discusses the comparison of three diagnostic approaches for metabolic acid-base disturbances in critically ill patients, using arterial blood samples from 152 patients and nine normal subjects. The abstract notes that 96% of patients had serum albumin concentrations below the mean of control subjects, which can affect the interpretation of acid-base parameters.

We compare two commonly used diagnostic approaches, one relying on plasma bicarbonate concentration and "anion gap," the other on "base excess," with a third method based on physicochemical principles, for their value in detecting complex metabolic acid-base disturbances. We analyzed arterial blood samples from 152 patients and nine normal subjects for pH, PCO_2 , and concentrations of plasma electrolytes and proteins. Ninety-six percent of the patients had serum albumin concentration $\leq 3 \text{ SD}$ below the mean of the control subjects. In about one-sixth of the patients, base excess and plasma bicarbonate were normal. In a great majority of

acid in plasma's chemical equilibria. Normal serum globulins do not carry a significant net electric charge at pH values prevailing in plasma (6, 7).

Hypoalbuminemia is a common finding in critically ill patients (8); it may confound the customary interpretation of acid-base data, owing to the contribution of albumin to plasma's acid-base equilibria. In particular, in the diagnostic system relying on plasma $[\text{HCO}_3^-]$, hypoalbuminemia is known to cause uncertainty in the interpretation of the AG (2, 9–11); if AG is adjusted for abnormal albumin concentration (12, 13),

Definition

$$SID = \sum StrongBaseCations - \sum StrongAcidAnions$$

- Na^+ , K^+ , Mg^+ and Ca^+ is strong cations
- Cl^- And XA^- -Unknown Anions- is Strong Anions

How Can We Get XA^- ??

Solution :: You Have two SIDs

Presentation of SID

d equally; this increases or reduces the SID by the same degree. $a \times C - a \times A = a \times D$; concentrational alkalosis and dilutional alkalosis are not to be confused with "contraction alkalosis" and "dilutional alkalosis". The latter terms have been used in reference to supposed acid-base changes due to increase in extracellular fluid volume, respectively. However, neither of these changes by themselves, change any of the variables that determine SID. The extracellular volume is expanded by infusion of NaCl saline, but the SID does not change (20, 21).

is and hypochloremic alkalosis.

(lactate, keto acids in "metabolic acidosis" *sensu strictiori*; formic acid, and sulfate and other anions in chronic renal failure). Non-volatile organic acids are at least three orders of magnitude lower in concentration than volatile acids; therefore, they are always $> 99.9\%$ dissociated. These non-volatile anions can be included in the definition of the SID; unlike the volatile acids, they do not include inorganic phosphate (which here is evaluated separately from the nonvolatile weak acids).

In severe extracellular volume loss, such as in cholera (22), the SID is clinically insignificant: the normal value of [Pi] (~ 1 mmol/L) is too low to have an appreciable acid-base effect.

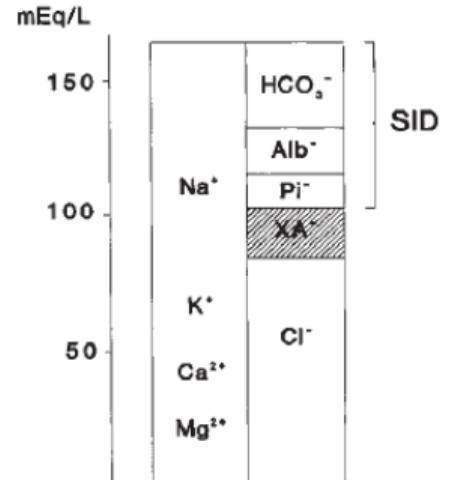


Figure 1. Electroneutrality in blood plasma: sum of positive charges equals the sum of negative charges, as indicated by equal heights of the columns representing cations and anions. Omitted (as insignificant on the scale shown) are ions having micromolar or nanomolar concentrations in plasma (OH^- , CO_3^{2-} , and H^+). Alb⁻ and Pi⁻ are negative electric charges displayed by serum albumin and inorganic phosphate, respectively. XA⁻ = unidentified strong anions; SID = strong ion difference.

SIDE.. Introduction

$$SID = [HCO_3^-] + [A_{TOT}]$$

$$SID = [HCO_3^-] + [Alb] + [Pi]$$

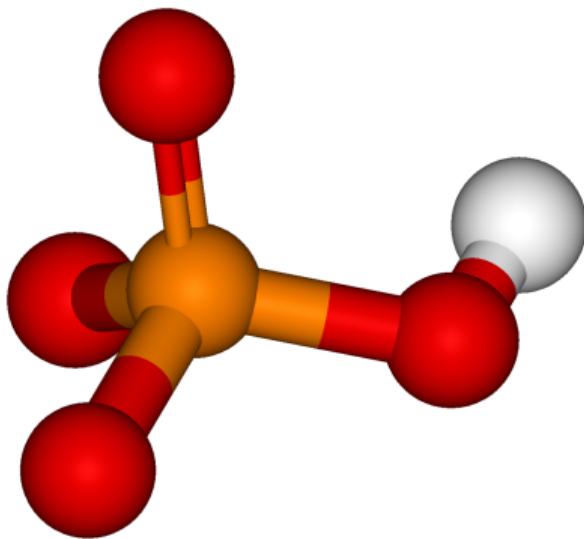


Albumin Effect

$$[Alb] = [Alb] \times (0.123 \times pH - 0.631)$$

$$Alb = 2.8 * \times Alb \text{ g/dl}$$

Inorganic Phosphate



Phosphorus

$$[Pi] = [Pi] \times (0.309 \times pH - 0.469)$$



Effective Strong Ion Difference

SIDE

$$SIDE = HCO_3^- + 2.8 \times alb + Pi$$

$$SIDE = HCO_3^- + 2.8 \times alb + 2$$

Apparent Strong Ion Difference

SIDA

$$SIDa = [Na^+ + K^+ + Mg^{++} + Ca^{++}] - [Cl^-]$$

Presentation of SID

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Lactate, keto acids in "metabolic acidosis" *sensu strictiori*; formic acid, and sulfate and other anions in chronic renal failure and organic acids are at least three orders of magnitude lower than those of the volatile acids; therefore, they are always > 99.9% dissociated and can be included in the definition of the SID; unlike the anions, however, inorganic phosphate (which here is evaluated separately) and the nonvolatile weak acids).

In severe extracellular volume loss, such as in cholera (22), the SID is clinically insignificant: the normal value of [Pi] (< 1 mmol/L) does not have an appreciable acid-base effect.

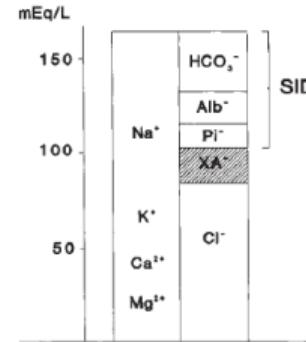


Figure 1. Electroneutrality in blood plasma: sum of positive charges equals the sum of negative charges, as indicated by equal heights of the columns representing cations and anions. Omitted (as insignificant on the scale shown) are ions having micromolar or nanomolar concentrations in plasma (OH^- , CO_3^{2-} , and H^+). Alb^- and Pi^- are negative electric charges displayed by serum albumin and inorganic phosphate, respectively. XA^- = unidentified strong anions; SID = strong ion difference.

$$\text{XA}^- = \text{SID}_a - \text{SID}_e = \text{SIG}$$

$$[\text{XA}^-] = ([\text{Na}^+] + [\text{K}^+] + [\text{Ca}^{++}] + [\text{Mg}^{++}]) - [\text{Cl}^-] - \text{SID}$$

Respiratory.... Non Respiratory

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TABLE 1
CLASSIFICATION OF PRIMARY ACID-BASE DISTURBANCES

	Acidosis	Alkalosis
I. Respiratory	↑ Pco_2	↓ Pco_2
II. Nonrespiratory (metabolic)		
1. Abnormal SID		
a. Water excess/deficit*	↓ SID, ↓ $[\text{Na}^+]$	↑ SID, ↑ $[\text{Na}^+]$
b. Imbalance of strong anions		
i. Chloride excess/ deficit†	↓ SID, ↑ $[\text{Cl}^-]$	↑ SID, ↓ $[\text{Cl}^-]$
ii. Unidentified anion excess‡	↓ SID, ↑ $[\text{XA}^-]$	—
2. Nonvolatile weak acids		
a. Serum albumin	↑ $[\text{Alb}]^\S$	↓ $[\text{Alb}]$
b. Inorganic phosphate	↑ $[\text{Pi}]^\parallel$	↓ $[\text{Pi}]^\parallel$

mohamad... Inorganic-... [Inbox - M... imgs - Fil... [essey_m... acid_base... acid_base... [all.png] 9904099 [manensa...]

other than CO_2 in certain disorders. Total $[\text{XA}^-]$ that they can

$$[\text{XA}^-] =$$

Water excess appreciated as a fall of plasma water for the resulting the observed

$$[\text{Cl}^-]_{\text{corrected}}$$

and chloride $[\text{Cl}^-]_{\text{corrected}} =$
If $[\text{Alb}], [\text{Pi}]$

Factor affecting H ion Concentration.

Independent Variable

- PaCO_2
- A_{TOT} presented by Albumin And Pi
- **SID** which is affected by water deficit/excess Cl deficit or excess
- XA^-

SID in clinical practice

The Stewart approach to acid-base - Mozilla Firefox

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electroneutrality. This increased $[H^+]$ we call 'acidosis'. Because of the inverse relationship between H^+ and OH^- , it is sometimes easier to assess pH changes through changes in the basic OH^- . Increased OH^- leads to alkalosis, decreased OH^- results in acidosis. For example, the problem of hyperchloraemia can be looked at in another way using OH^- . The increased Cl^- will decrease the SID. The SID is normally positively charged so that the decreased SID would result in fewer OH^- . Fewer of the basic OH^- results in acidosis. The following picture is a simplified rendering of normal acid-base status in plasma. We will explore changes in acid-base balance using this illustration:

Normal acid-base status

Na^+ = 140 mEq/L
Cl^- = 110 mEq/L
<hr/>
SID = 30 mEq/L
OH^- = 30 mEq/L

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SID In Clinical practice

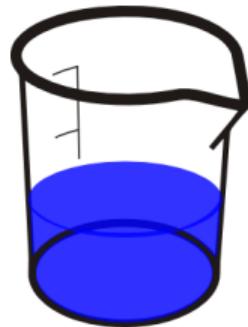
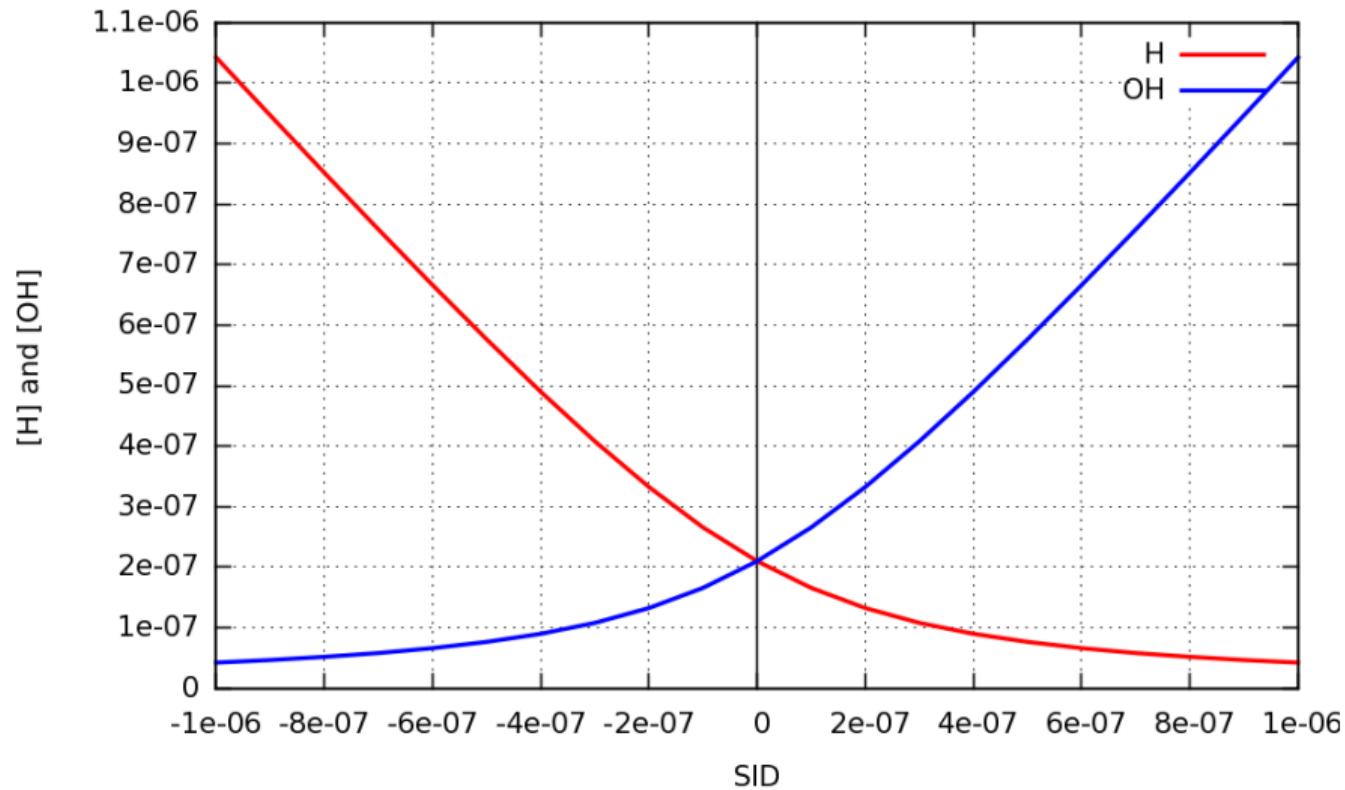


Figure: Beaker Model For simulation of body fluid content

- Na^+ : 140 mEq/L
- Cl^- : 110 mEq/L
- SID = 30

Relation between H^+ and SID



SID Change

Three mechanisms by which SID will change :

- Change in water content of plasma
- Change in Chloride concentration
- Increase concentration of unknown anions (XA^-)

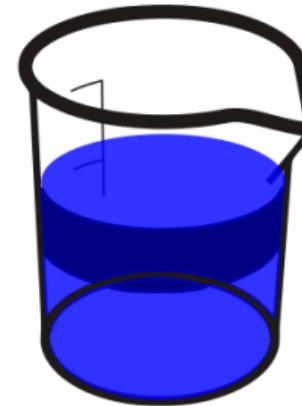
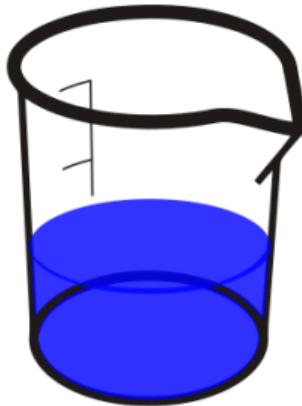
Change in water content of plasma

Concept:

Adding or removing the free water concentrations will cause change of electrolytes concentration which will cause:

- Dilutional Acidosis
- Concentrational Alkalosis

Adding Free Water



- $\text{Na}^+ : 140 \text{ mEq/L}$
- $\text{Cl}^- : 110 \text{ mEq/L}$
- $\text{SID} = 30$

- $\text{Na}^+ : 140/2 = 70$
- $\text{Cl}^- : 110/2 = 55$
- $\text{SID}^- : 30/2=15$

Clinical Application : TURP Syndrome :

- Management of hyponatremia of TRRP syndrome focused on treating using normal or hypertonic saline .
- Analysis of this treatment reveals that this may not be the best method of managing this problem

Clinical Application : TURP Syndrome :

Taking 1 liter from the previous resultant example

- Na^+ : 70 meq/l
- Cl^- : 55 meq/l
- SID : 15

Normal Saline electrolyte concentration :

- Na^+ : 154 mEq/l
- Cl^- : 154 mEq/l
- SID : 0

Resultant solution

$$\text{Na}^+ : (150+70)/2 := 112$$

$$\text{Cl}^- : (55+154)/2 : 105$$

$$\text{SID}=112-105=7$$

The result will be :

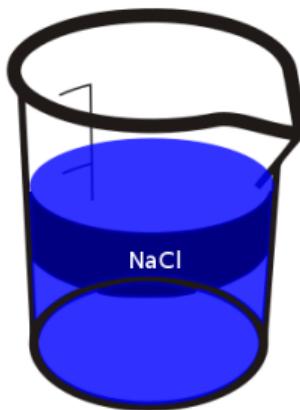
- Correction of hyponatremia
- Decrease in SID which will cause further acidosis

So

- A more appropriate treatment might be with sodium bicarbonate . Here, sodium ions are administered with HCO_3^- .
- The bicarbonate is conveniently expired through the lungs leaving the Na^+ to increase the SID.

HyperCholermic Metabolic Acidosis

- Adding one liter of normal Saline to normal one Liter of Plasma:



Normal Saline Na⁺, Chloride and SID

- Na⁺ : 154 mEq/l
- Cl⁻ : 154 mEq/l
- SID : 0

Final Solution

- Na⁺ : $(140+154)/2 = 147$
- Cl⁻ : $(110+154)/2 = 132$
- SID = 147 - 132 = 15

HyperCholermic (Metabolic) Acidosis

So

- SID is decreased so acidosis is developed.
- More appropriate Fluid for maintenance of SID: Lactated Ringer

Lactated Ringer SID:

Cations: 137 meq/l **Cl⁻** : 109 meq/l

Final Solution SID

Cations: $(140+137)/2$ 139 **Cl⁻:** $(110+109)/2$ 110 **SID**=139-110=29

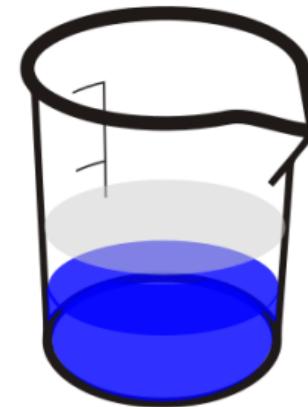
Contractional Alkalosis

- In case of volume restriction or diuretic therapy

The resultant Solution

- $\text{Na}^+ : 140 \times 2 \text{ mEq/L} = 280$
- $\text{Cl}^- : 110 \times 2 \text{ mEq/L} = 220$
- $\text{SID} = 280 - 220 = 60$

Correction of contraction alkalosis could be done using free water administration in the form of **hypotonic saline**



In case of volume depletion, with consideration of half volume depletion

Hypochloremia and Metabolic Alkalosis

Gastrointestinal abnormality, in case of vomiting or naso gastric tube suction

Cl Loss

- $\text{Na}^+ : 140 \text{ mEq/l}$
- $\text{Cl}^- : 95 \text{ mEq/l}$
- SID = 45

Treatment Using normal Saline

- $\text{Na}^+ : (140+154)/2 = 147 \text{ mEq/l}$
- $\text{Cl}^- : (95+154)/2 = 125 \text{ mEq/l}$
- SID = 147 - 125 = 22

Problem With Volume...



K^+, Mg^{++}

If volume expansion will be problematic ; then potassium, calcium or magnesium chloride can be administered, Alternative Solution, Cl^- Administration could be done using HCL

XA and SID

- SID can also be affected by the presence of organic acids such as lactate or ketoacids, because these negatively charged molecules , it will decrease SID, they result in an acidosis.
- Treatment is usually focused on stopping the production of acid. Resolution of the abnormal H^+ can also be achieved by increasing the SID using $NaHCO_3$

Intraoperative Fluid Management

Crystalloids And Colloids

- Saline
- Lactated Ringer
- Albumin
- hetastarch



Just think of **SID** and **ATOT**

Intraoperative Fluid Management

Critical Care April 2005 Vol 9 No 2 Morgan

Review

Clinical review: The meaning of acid-base abnormalities in the intensive care unit - effects of fluid administration

Thomas J Morgan



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Published online: 2 September 2004

Critical Care 2005, 9:204-214 (DOI 10.1186/cc3946)



BE again

Simply

- For Non-Respiratory Component, each Independent Variable -SID And A_{TOT^-} Deviation will be reflected to BE
- New BE = SBEC = Corrected Base excess = Buffer Base = complete version of the -van Slyke equation-

$$SBEC = [HCO_3^-] - 24.4 + 8.3 \times Alb \times 0.15 + 0.29 \times Phos \times 0.32 * (pH - 7.4)$$

Quantitative Analysis Of Acid Base

- History,Anticipate,Proceed
- Check pH against 7.4 value
- global deviation can be concluded from deviation of BE and CO₂ from Normal
- Respiratory Component -**CO₂ analysis** -Acidosis Or Alkalosis-
- Non-Respiratory Component -**SID And A_{TOT}**.
- Na⁺, Cl⁻ deviation calculation
- SID, SIDe, SIDa, SIG
- Albumin
- Winter Rules

History

Step 1

- Very important
- Get Idea about possible deviation of acid base
- Always remember you are treating patient not the ABG paper :)

Step 2

- pH less than 7.4 = Acidosis irrespective to its origin -
- pH more than or equals = Alkalosis irrespective to its origin -

Step 3

- Normal Range : 35:45 mmHg
- More than 45mmHg = respiratory Acidosis -may be primary or compensatory -
- Less than 35mmHg = respiratory Alkalosis -may be primary or compensatory -

Non Respiratory elements

Step 4

- SBEc will give you idea about total Metabolic elements deviation
- SID And A_{TOT}
- SID = $\text{Na}^+ - \text{Cl}^-$ effect And XA effect
- A_{TOT} = for simplicity : Albumin effect

Step 5

- How much Na^+ deviate from normal range "140 mEq/l".
- Amount of deviation to Cl^- value "105 mEq/L as mean".

SID And A_{TOT}

Step 6

- $SIDe = \text{Albumin gm/dl} \times 2.8 + HCO_3^- + 2$
- $SIDA = Na^+ + K^+ + 6 - Cl^-$
- $XA^- = SIDa - SIDe$ - Normal Value in Critically ill patient 2-8 mEq
- Albumin Effect = $2.8 \times \text{Albumin gm/dL}$

Deviations

Step 6 Cont.

- Na^+ , Cl^- , Albumin, XA^- from its normal range indicates deviation SBEc from its normal Range
- Example : Na^+ deviation , HyperChloremic Acidosis , Unknown Anion Acidosis , Hypoalbuinemic Alkalosis ,.....

Step 7

- For Assessment of Compensation

Quantitative analysis Computing Method

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Welcome!

This site is devoted to the Stewart approach to acid-base. This quantitative method greatly demystifies patient acid-base problems and may therefore improve outcome. Our aim is to make it available for everyone!

You can do a number of things here:

- Buy the 2009 edition of **Stewart's Textbook of Acid-Base** (you won't be disappointed!). More info on the right.
- Read Stewart's [original publication](#) online free of charge
- Use our [analysis module](#) to help understand your patient's acid base data

Notify a friend or colleague!

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Available now: **Stewart's Textbook of Acid-Base**

If you have ever been confused by traditional acid-base teaching and/or want a deeper and practical understanding of the subject, this is the book for you! You will be rewarded!

What is the role of bicarbonate (HCO_3^-) in acid-base balance? The answer is simply: none!

What then determines pH or $[H^+]$ in body fluids? Understanding acid-base balance means having clear answers to this question, and the quantitative analysis in this book supplies them. They are astonishingly simple! - Peter A Stewart

Stewart's Textbook of Acid-Base

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- Chapter 10
- Chapter 19
- Chapter 25
- Chapter 29
- Afterword by Prof. Story

Almost 30 years ago, Peter A Stewart published his classic work introducing the quantitative approach to acid-base. Treasured by many, despised by some, his approach has now become the method of choice in the latest editions of classic medical treatises.

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required data

		mEq/l	required for cross-checking purposes			
pH				lithium	mmol/l	
BE (base excess) read more!				Mg	mmol/l	
Na read more! about the influence of serum Na^+ on its ionic activity		mmol/l		(total, not ionised) Ca	mmol/l	
K		mmol/l		phosphate	mmol/l	
Cl		mmol/l	may you make an educated guess about chloride? NO - why???: read more!	lactate	mmol/l	strongly recommended!
PCO ₂		kPa	be careful choosing the unit! (mmHg or kPa - this is essential!!)	osmolality (freezepoint method)	mosmol/l	only required if you want to calculate the osmotic gap, strongly recommended in cases of intoxication or ketoacidosis
albumin the most prominent of the weak acids read more!		g/l	may you make an educated guess about albumin? yes - BUT: read more!	glucose	mmol/l	
				urea	mmol/l	
				ethanol or other osmotically active substances (1 % ethanol is 21 mosmol/l)	mosmol/l	do not register anionic substances like hydroxybutyrate (because their osmotic effect is already accounted for by the corresponding cation)
				did you "buffer" with trometamol (THAM), e.g. as tribionate?	mmol/l	
				yes? <input type="checkbox"/>		

Done

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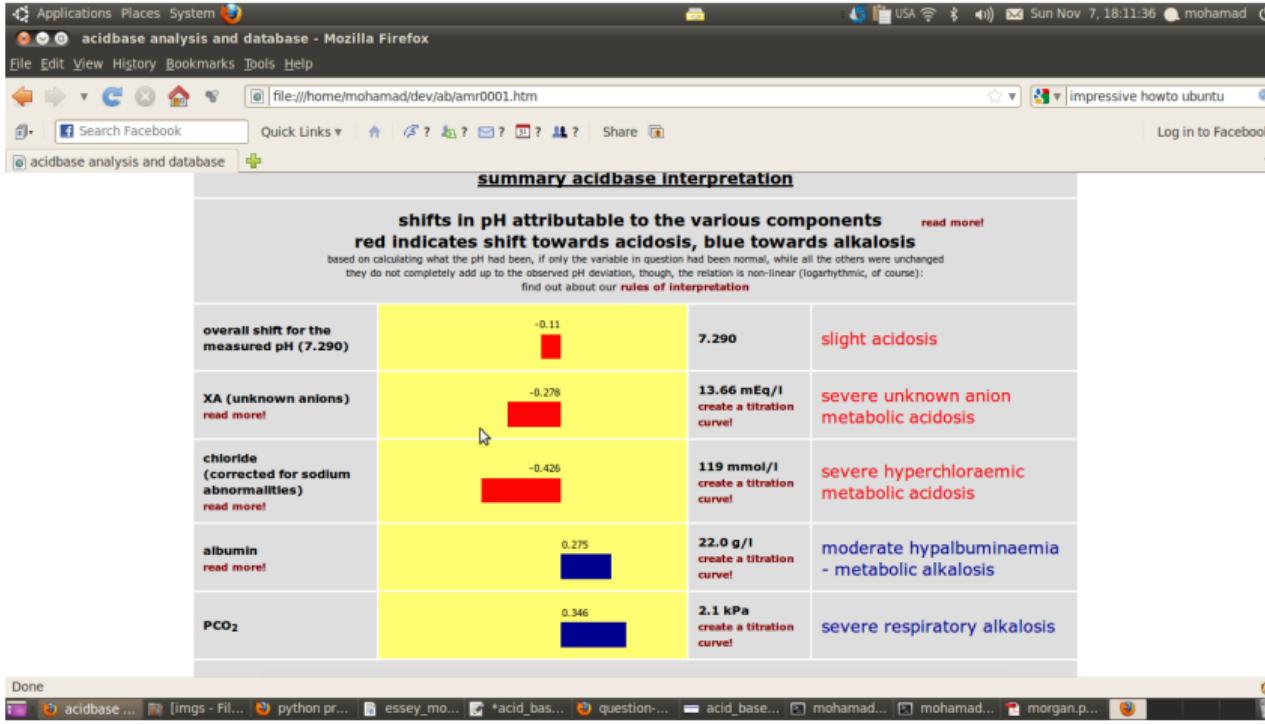
acidbase analysis and database

albumin the formula	23.4	mEq/l	6 -- 12	
chloride, corrected for absolute Na deviation (relevant for calculation of acidbase effects) read more!	119	mmol/l	102 -- 108	severe hyperchloraemic acidosis (by at least 11 mEq/l), with the sodium value (135.0 mmol/l) indicating water excess or osmotic shift of water into the extracellular space
chloride, corrected for proportional Na deviation (relevant for calculation of dilution / concentration effects) read more!	118	mmol/l	102 -- 108	relative (proportional) hyperchloraemia, at least 10 mmol/l (other than the effects of water excess or osmotic dilution indicated by the sodium of 135.0 mmol/l), - this is often due to infusion of low SID fluids like isotonic saline, "unbalanced" HAES preparations or pure glucose solutions; diarrhoea is another common reason; consider renal tubular acidosis / acidosis of chronic kidney disease, chloride reabsorption in patients with a urinary diversion; possibly a drug sideeffect (e.g. NSAIDs) (determine the urinary anion gap to help making the differential diagnosis!) more information on Timur Graham's site
SID apparent strong ion difference, based on the measured strong ions read more!	28.6	mEq/l	40 -- 46	a low apparent SID value - at least partially (>= 5.7 mEq/l) due to elevated unknown anions

Done

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Quantitative analysis Computing Method



Any Questions



Summary

- It was long way for developing vision for quantitative analysis of pH deviation
- Boston and bicarbonate Buffers
- Copenhagen and BE
- Stewart, Dependent, And Independent variables

Thank You :)

Every thing in the world sometimes seems to be random ,
however it follows a common mathematical formula

