Sam's Acid-Base for the ICU: *Simplified*!

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There are really only 3 simple formulas and a 4 key numbers that you need to know!

1. **Look at the pH**. Check for the process that is causing the academia or alkalemia. For example, in respiratory acidosis (low pH), if the CO_2 is increased more than the bicarbonate is decreased, you have a primary respiratory acidosis rather than a primary metabolic problem. In general, there should be an increase in the **bicarbonate** by **1 meq/L for every 10 mm Hg rise** in the **$PaCO_2$** in respiratory acidosis.

2. **Calculate the anion gap**. If greater or equal to **20**, you have a metabolic acidosis no matter what. The body does not generate a large enough anion gap to compensate for a primary disorder.

3. **Calculate the excess anion gap (Δ gap)**. 12 (10-14) is the standard, so subtract the anion gap from 12. Next, add this value to your measured bicarbonate. If this is greater than **30**, you have an underlying ***metabolic alkalosis***. If this is less than **23** (a normal bicarbonate value), you have an underlying *NON gap metabolic acidosis*. The reason for this is because 1 mmol of unmeasured acid should titrate 1 mmol of bicarbonate; hence a Δ anion gap should equal the Δ bicarb under normal circumstances.

Measured Anion Gap – 12

> 30 → Underlying metabolic ALKalosis

< 23 → Underlying NON gap metabolic ACIDosis

$$AG= [Na^+ + K^+] – [Cl^- + HCO3^-]$$

4. If you are still second guessing yourself, use **Winter's formula for metabolic acidosis** to make sure your $PaCO_2$ is what it should be.

$$\mathbf{PaCO_2 = 1.5 \times measured\ HCO_3^- + 8\ (\pm 2)}.$$

5. **One other trick for metabolic acidosis**: the expected $PaCO_2$ should approximate the ***last 2 digits of the pH value***. For example, the expected $PaCO_2$ for a primary metabolic acidosis with a pH of 7.25 is 25.

6. If you are still unsure of yourself, and the patient has what you consider to be a primary respiratory disorder, use Dr. Marino's formulas:

Acute respiratory acidosis *OR* alkalosis: $\mathbf{\Delta pH = .008 \times \Delta PaCO_2}$
Chronic respiratory acidosis *OR* alkalosis: $\mathbf{\Delta pH = .003 \times \Delta PaCO_2}$

7. If you *really* have no clue as to what is going on (i.e. very complex disorder), go to www.acidbase.org and perform a Stewart's acid-base analysis of the problem. This website gives you a very nice report that essentially takes everything into account.

8. If you want to eyeball the problem from a Stewart's acid-base point of view, take into consideration the following generalizations:

Strong Ion Gap = SID = [strong cations] – [strong anions]

$\approx Na^+ - Cl^-$

$\approx$ 38 (140-102)

ACIDOSIS usually means extra anions.
The strong ion difference is **DECREASED**.
Seen in disorders where cations are decreased (potassium, sodium) or where anions are increased (hyperchloremia, lactatemia, ketoacids, etc.).

ALKALOSIS usually means extra cations.
The strong ion difference is **INCREASED**.
Seen in disorders where cations are increased (hyperkalemia, hypercalcemia, hypernatremia) or where anions are decreased (hypoalbuminemia, hypochloremia)

To summarize:

3 formulas to remember:
1. Bicarbonate increases by 1 for every rise of 10 in $PaCO_2$
2. Winter's formula for metabolic acidosis: $PaCO_2 = 1.5 \times HCO_3 + 8\ (\pm 2)$
3. $\Delta pH = .008$ OR $.003 \times \Delta PaCO_2$ for respiratory acidosis or alkalosis

4 numbers to remember:
1. $\geq$**20**: if anion gap greater than 20, metabolic acidosis no matter what

2. **≥30**: Δ anion gap plus your measured bicarb >30 = metabolic alkalosis in addition to whatever else is going on
3. **<23**: if Δ anion gap plus your measured bicarb is <23 (less than normal bicarb level), you have a non gap anion metabolic acidosis in addition to everything else
4. **Last 2 digits of pH should** = **PaCO2** for a simple metabolic acidosis

Important References:

1) Marino PL. *The ICU Book*. Baltimore: Lippincott Williams and Wilkins, 2007. Page 535.

2) Marini JJ, Wheeler AP. *Critical Care Medicine, Third Edition*. Baltimore: Lippincott Williams and Wilkins, 2006. Chapter 12, Pages 213-227.

3) Haber RJ. A practical approach to acid-base disorders. *West J Med* 1991; 155: 146-151. Note: this is singularly the best article on acid base interpretation that I have ever read.

4) Adrogue H, Madias N. Management of life-threatening acid base disorders. *N Engl J Med* 1998; 338: 26-34.

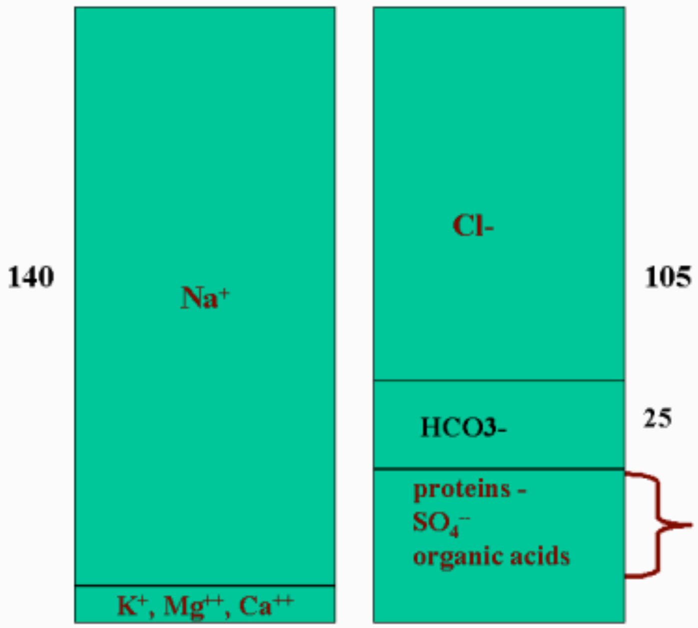
5) www.acidbase.org (click on "analysis module").

6) Galvagno SM. *Emergency Pathophysiology*. Jackson WY: Teton NewMedia, 2003.

Anion Gap Metabolic	Non-gap Metabolic Acodosis	Acute Respiratory Acidosis	Metabolic Alkalosis	Respiratory Alkalosis
"MUD PILERS" **M**ethanol **U**remia **D**KA/Alkoholic KA **P**araldohyde **I**soniazid **L**actic acidosis **E**tOH/**E**thylene glycol **R**habdo **S**alicylates	**"HARD UPS"** **H**yperalimentation **A**cetazolamide **R**enal tubular acidosis **D**iarrhea **U**retero-pelvic shunt **P**ost-hypercapnea **S**pironolactone	anything that causes hypoventilation CNS depression Airway obstruction Pneumonia Pulmonary edema Hemo/pneumothorax Myopathy (**Chronic** respiratory acidosis caused by COPD and restrictive lung disease)	**"CLEVER PD"** **C**ontraction **L**icorice **E**ndo (Conn's, Cushing's, Bartter's) **V**omiting **E**xcess Alkali **R**efeeding Alkalosis **P**ost-hyopercapnea **D**iuretics	**"CHAMPS"** anything that causes hyperventilation **C**NS disease **H**ypoxia **A**nxiety **M**echanical ventilators **P**rogesterone **S**alicylates/Sepsis

Anion Gap (AG)

$AG = (Na^+ - (Cl^- + HCO_3^-)$



-Normal AG
10-14

-AG is primarily due to albumin

-Increased AG almost always due to a rise in unmeasured anions