Physiology Team 431

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Acid-Base Disorders

-Introduction-

The balance between acids and bases is very critical for body function, and it controls many of organic function. These disorders, which we will discuss, are not physiological accident but they are associated with dysfunction of one or both of the critical organs that control this balance, Kidney and Lungs or respiratory system.

The Acid-base imbalance due to problem in Kidney is identified as Metabolic imbalance (acidosis or alkalosis), and the imbalance caused by Resp. problem is identified as Resp. imbalance (acidosis or alkalosis). The resp. system controls the acid (CO_2) through ventilation which is stimulated or inhibited by respiratory center in medulla by signals from peripheral chemoreceptor (carotid and Aortic receptors). The kidney control the base (HCO_3^-) via reabsorption or excretion and this control also some H^+ ions by the same mechanism.

Any problem in any system causes the other to compensate.

The Compensation is full if the pH has been retained into normal range 7.35-7.45 but the compensation becomes partially if pH is still outside normal range.

All acid-base imbalance are Acute medical Emergency.

How to understand Acid-Base Imbalance?

First of all we have to understand the normal ratio between acid and base:

Base/Acid = $HCO_3^-/CO_2 = 20/1$

So the kidney control the balance more than the resp. system.

If this ratio has been changed by increasing or decreasing the HCO_3^- or the CO_2 we can recognize the site of the problem.

If the change in CO_2 ⟶ Resp. Imbalance

If the cange in HCO_3^- ⟶ Metabolic Imbalance

Reference	Normal values	Resp. Acidosis	Resp. Alkalosis	Metabolic Acidosis	Metabolic Alkalosis
pH	7.35-7.45	↓	↑	↓	↑
H+	40 nEq/l	↑	↓	↑	↓
CO_2	36-46 mmHg	↑	↓	Normal	Normal
HCO_3^-	22-26 mmol/l	Normal	Normal	↓	↑
After compensa-tion		HCO_3^- ↑	HCO_3^- ↓	CO_2 ↓	CO_2 ↑

These are the acid-base imbalance. And we notice that all these conditions are in the acute phase which means before compensation of the healthy system take place.

And the last row is showing the compensation.

Respiratory acidosis

- Low pH
- High PCO2 (Hypercapnia)
  –Depressed ventilation
- HCO3= Normal (this indicated there is not a problem in metabolic mechanism)

We notice these changes in acute respiratory acidosis before compensation.

Causes of Respiratory Acidosis:

Acute conditons:

- Adult Respiratory DistressSyndrome
- Pulmonary edema
- Pneumothorax

Chronic conditions:

- Depressionof respiratory center in brain that controls breathing rate –drugs or head trauma
- Paralysisof respiratory or chest muscles
- Emphysema

Signs and Symptoms of Respiratory Acidosis:

- Breathlessness
- Restlessness
- Lethargy and disorientation
- Tremors, convulsions, coma
- Respiratory rate rapid, then gradually depressed
- Skin warm and flushed due to vasodilation caused by excess CO2

Compensation for Respiratory Acidosis:

Kidneys eliminate hydrogen ion and retain bicarbonate ion

Blood picture

- pH = Normal
- PCO2= High
- HCO3= High compensation
-

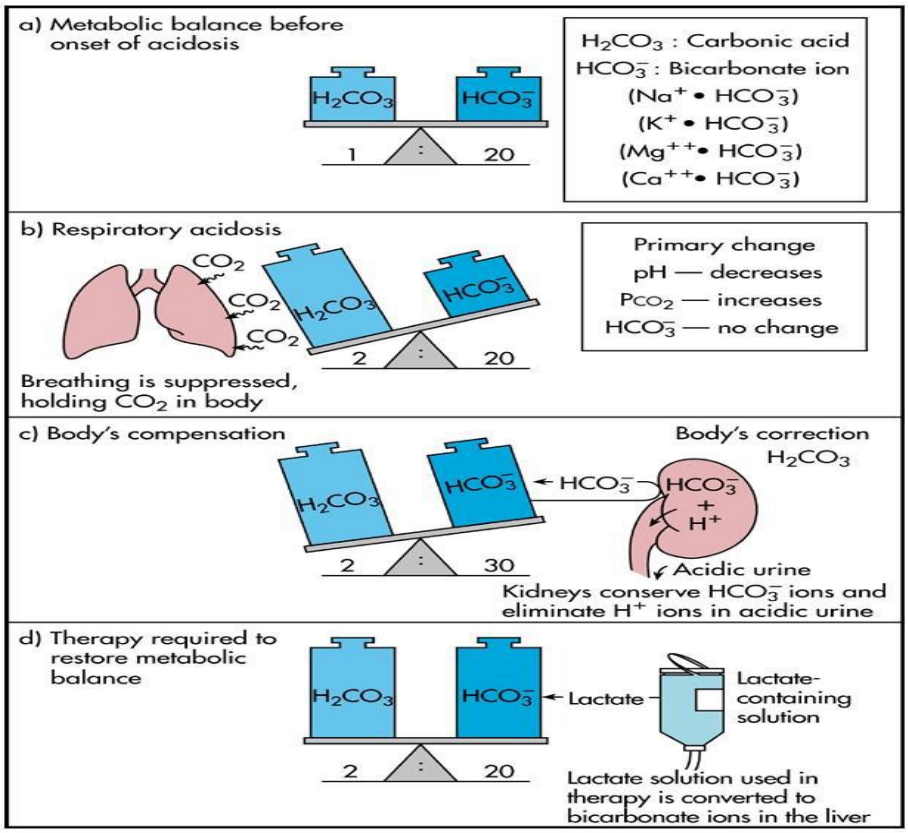
Low Urine HCO3

1-PCO2 is still high because the compensation mechanism doesn't treat underlying diseases only the regulate the PH.

2- Kidney take long time to compensate but it retains the PH to the normal range.

Treatment of Respiratory Acidosis:

- Restore ventilation.
- IV lactate solution (lactate will be converted to BCO3 in liver)
- Treat underlying dysfunction or disease.



From Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 5, St Louis, 2003, Mosby.

Respiratory Alkalosis

- high pH
- low PCO2
  - PCO2 less than 35 mm Hg (hypocapnea)

hyper ventilation
Hysterical
pneumonia

- HCO3 normal

Causes of Respiratory Alkalosis:

- Primary cause is hyperventilation
- Oxygen deficiency at high altitudes (in high altitudes the oxygen will decrease → hyperventilation will acquire that lead to wash out the CO2 → low PCO2)
- Pulmonary disease and Congestive heart failure –caused by hypoxia
- Acute anxiety
- Fever, anemia
- Early salicylate intoxication
- Cirrhosis
- Gram-negative sepsis

Compensation of Respiratory Alkalosis:

Kidneys conserve hydrogen ion and Excrete more bicarbonate ion

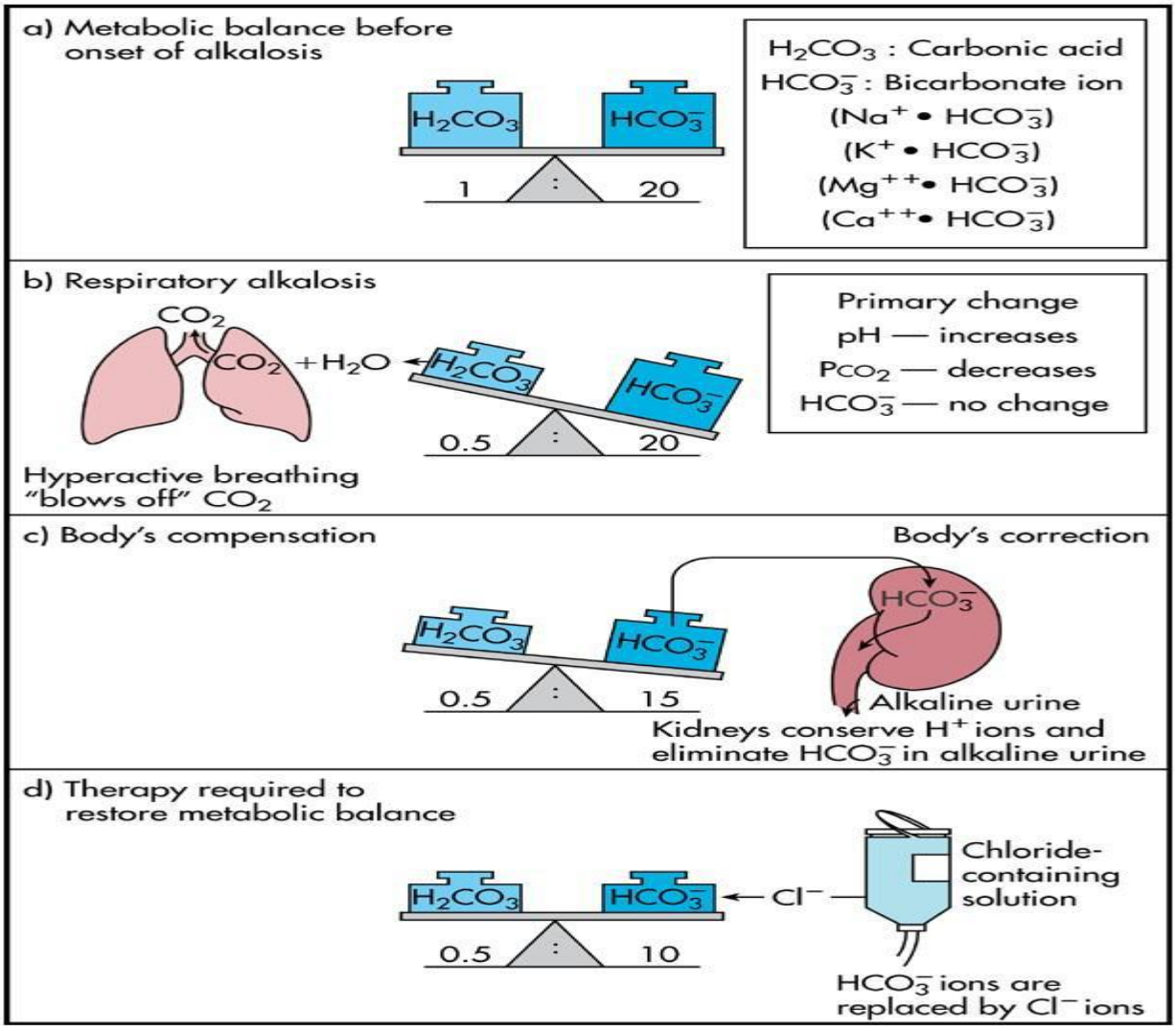
Blood picture
pH = Normal
PCO2= Low
HCO3= Low compensation

High urine HCO3

Treatment of Respiratory Alkalosis:

- Treat underlying cause
- Breathe into a paper bag.
- IV Chloride containing solution –Cl-ions replace lost bicarbonate ions

In Hysterical causes, the treatment will be breath into a paper bag coz when he breathe in bag the CO2 will increase, so that will inhibit the respiratory center in brain as result will inhibit the hyperventilation.



From Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 5, St Louis, 2003, Mosby.

Metabolic Acidosis

Low pH.

Low HCO3 Bicarbonate deficit < 22mEq/L

–Production of Lactic acid (anerobicmetabolism)
–Production of ketoacid(diabetes)
–Excessive loss of alkali (diarrhea) (intestinal secretion is alkali so in diarrhea loss the alkali)
–Renal failure

PCO2= normal.

Causes:

- Loss of bicarbonate through diarrhea or renal dysfunction
- Accumulation of acids (lactic acid or ketones)
- Failure of kidneys to excrete H+.

Symptoms of Metabolic Acidosis:

- Headache, lethargy
- Nausea, vomiting, diarrhea
- Coma
- Death

Compensation for Metabolic Acidosis:

Stimulation of ventilation (hyperventilation) → ↓PCO2→↑ pH back to normal value
Renal excretion of hydrogen ions if possible K+exchanges with excess H+in ECF (H+into cells, K+out of cells)

■Blood picture

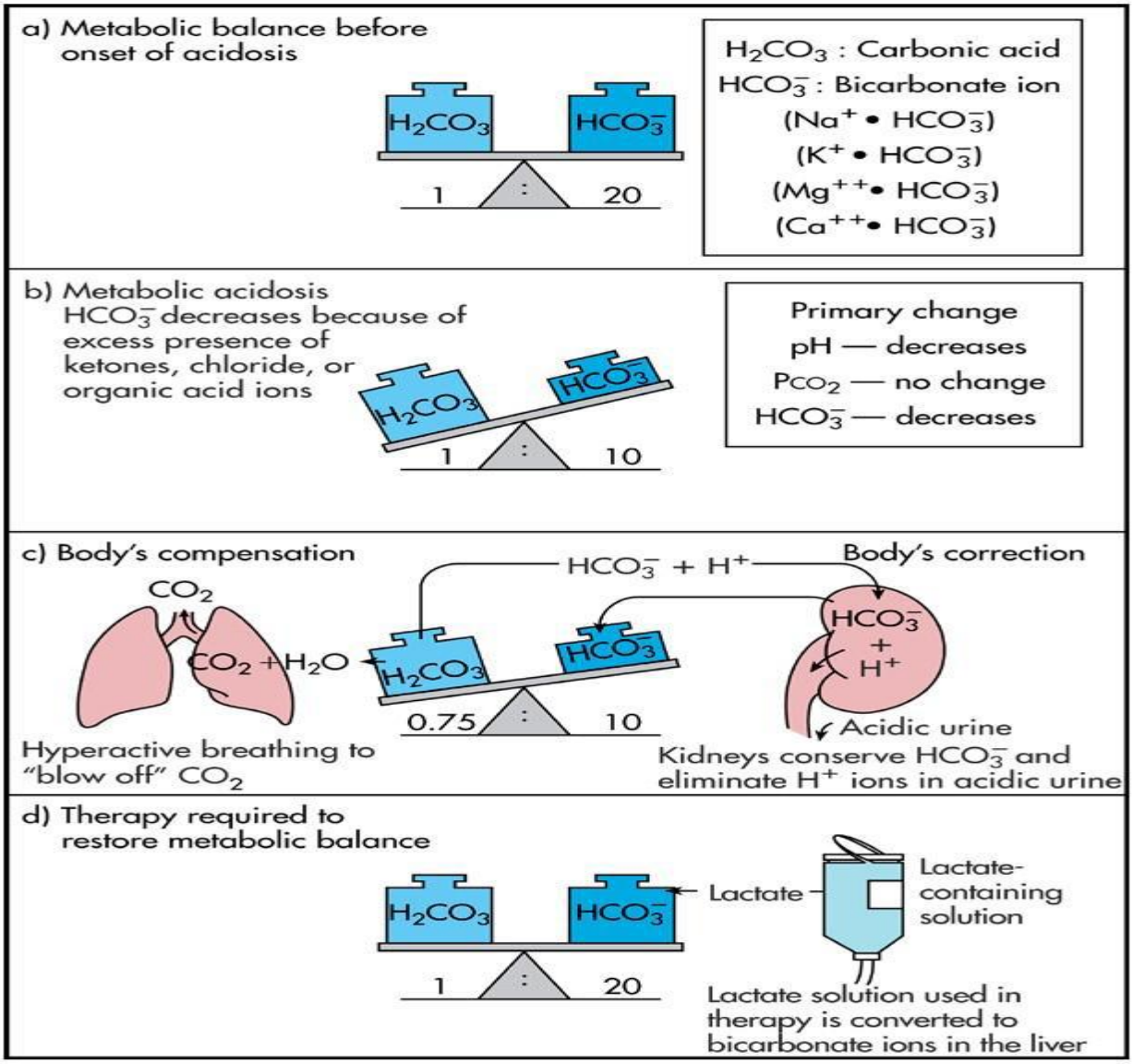
–pH = ~N (near to the normal)

–HCO3= Low

–PCO2= Low due to compensation

Treatment of Metabolic Acidosis:

IV lactate solution.



From Thibodeau GA, Patton KT: *Anatomy & physiology,* ed 5, St Louis, 2003, Mosby.

Metabolic Alkalosis

high pH

High HCO3

- Bicarbonate > 26 mEq/L

–Loss of gastric acid (vomiting)

–Excessive intake of alkali (antiacid)

PCO2= Normal

Causes:

–Excess vomiting= loss of stomach acid

–Excessive use of alkaline drugs

–Certain diuretics

–Heavy ingestion of antacids

Compensation for Metabolic Alkalosis:

- Correction
  depress ventilation →↑ blood PCO2 → ↓ pH back to normal value (limited byhypoxia)
- Alkalosis most commonly occurs with renal dysfunction, so can't count on kidneys
- Blood picture
  –pH = ~N

  –HCO3= High

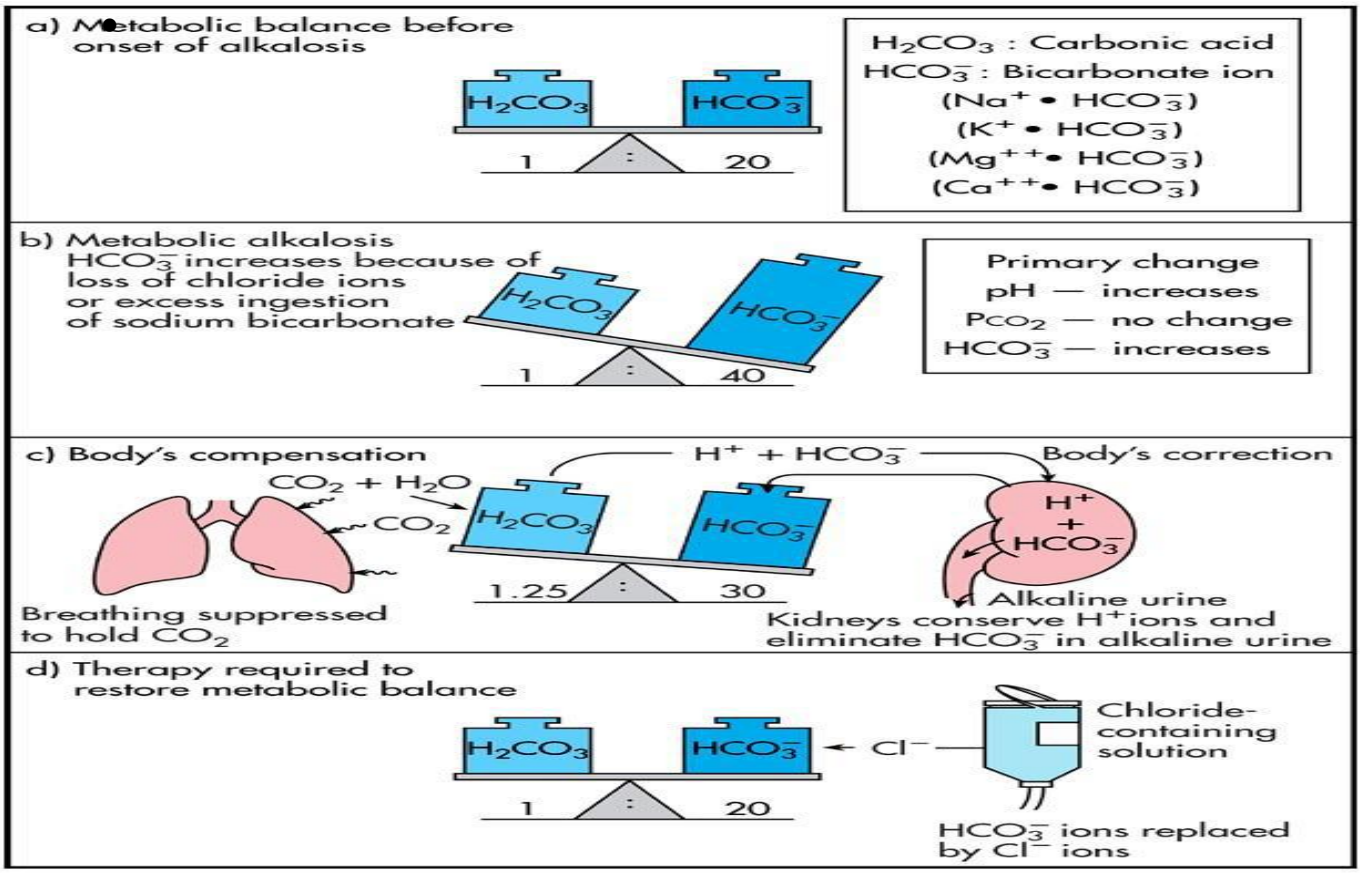
  –PCO2= High due to compensation

Symptoms of Metabolic Alkalosis:

- Respiration is slowand shallow
- Hyperactive reflexes tetany
- Often related to depletion of electrolytes
- Atrial tachycardia
- Dysrhythmias

Treatment of Metabolic Alkalosis:

- Electrolytes to replace those lost
- IV chloride containing solution
- Treat underlying disorder



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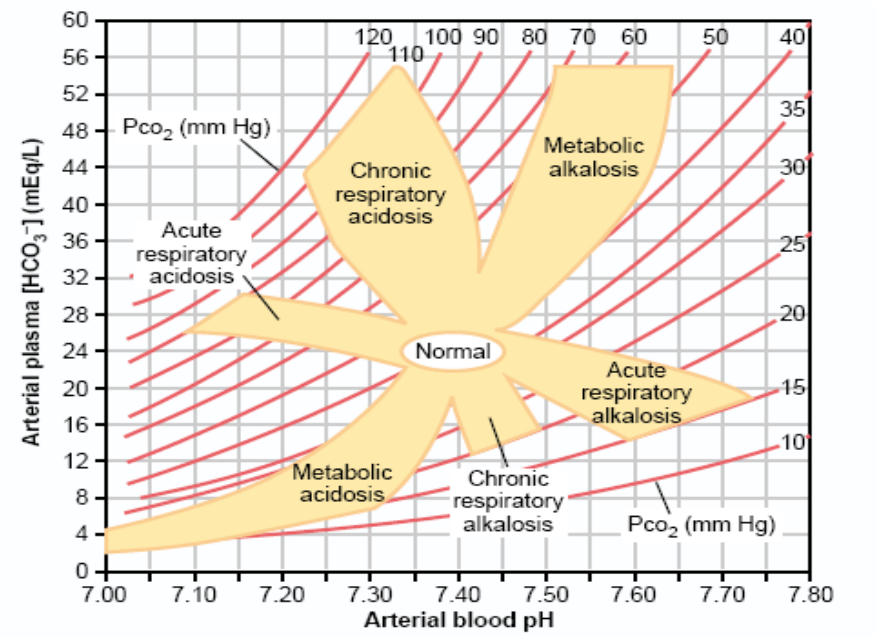

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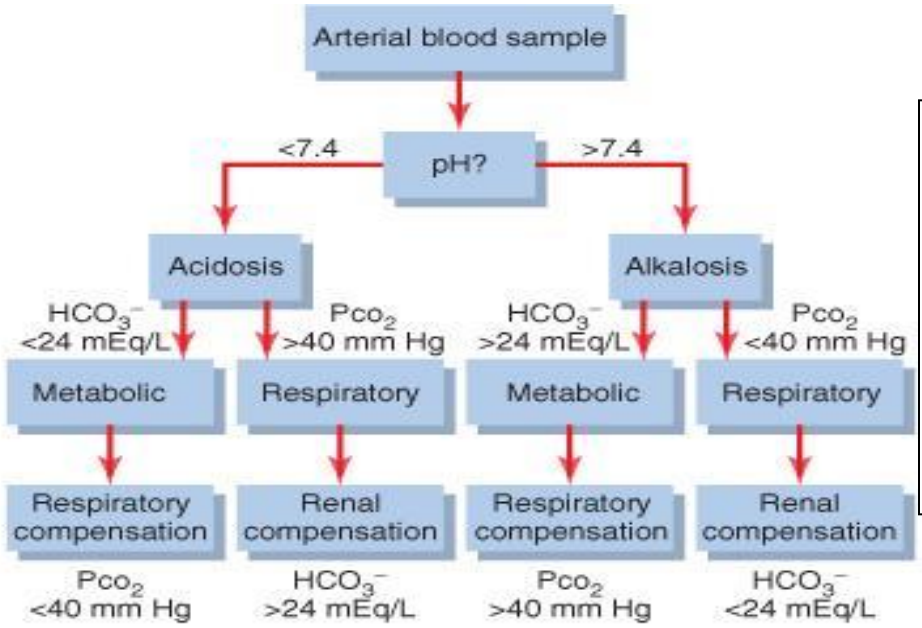
Acid-base nomogram is showing arterial blood pH, arterial plasma HCO_3^-, and PCO_2 values. The central open circle shows the approximate limits for acid-base status in normal people. The shaded areas in the nomogram show the approximate limits for the normal compensations caused by simple metabolic and respiratory disorders. For values lying outside the shaded areas, one should suspect a mixed acid-base
disorder.



Analysis of simple acid-base disorders. If the compensatory responses are markedly different from those shown at the bottom of the figure, one should suspect a mixed acid-base disorder.

Notes:

1-Sometimes there is mixed acidosis or mixed alkalosis.

2- How to if this problem is compensated?

If both acid and base are changed so it is compensated, but if one is still in the normal range of it so it is not compensated.

3- a-How to judge if this problem is acidosis or alkalosis, then b-how can we know is it resp. or metabolic after compensation?

a-If pH is higher than 7.4 = Alkalosis and if it is lower than 7.3 = Acidosis.

b- Always the compensator is going in reverse direction with pH and the main site for problem is going with the same direction of pH.

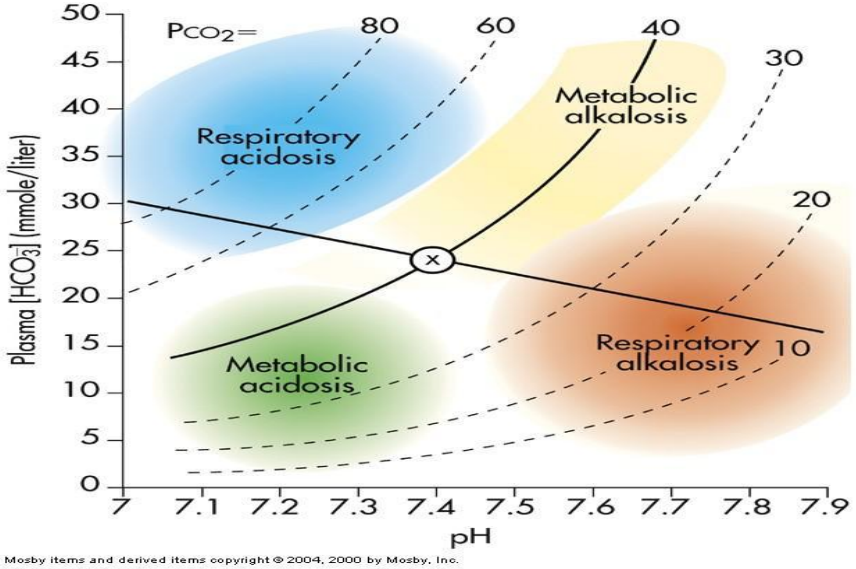
Summary

Acidosis:

Abnormalities				
pH	⇩	⇔	⇩	⇔
PCO2	⇧	⇧	⇔	⇩
HCO3	⇔	⇧	⇩	⇩
Type	Resp	Resp	Metab	Metab
Correction	No	Yes Metab	No	Yes Resp

Alkalosis:

Abnormalities				
pH	⇧	⇔	⇧	⇔
PCO2	⇩	⇩	⇔	⇧
HCO3	⇔	⇩	⇧	⇧
Type	Resp	Resp	Metab	Metab
Correction	No	Yes Metab	No	Yes Resp



Questions:

1-A patient is in intensive care because he suffered a severe myocardial infarction 3 days ago. The lab reports the following values from an arterial blood sample:
–pH 7.3

–HCO_3^-= 20 mEq/ L (22 -26)

–pCO_2= 32 mm Hg (35 -45)

What is the diagnosis?

a) Metabolic acidosis With partial compensation
b) Metabolic acidosis With complete compensation
c) Metabolic alkalosis With partial compensation
d) Metabolic acidosis With complete compensation

2- Which one is proper treatment of Respiratory Acidosis?
a) Diuretic drug
b) Breathe into a paper bag
c) IV lactate solution
d) IV sodium containing solution

3- What is the Primary cause of Respiratory Alkalosis?
a) Hyperventilation
b) diabetes
c) vomiting
d) renal dysfunction

Answers: 1-a, 2-c, 3-a.