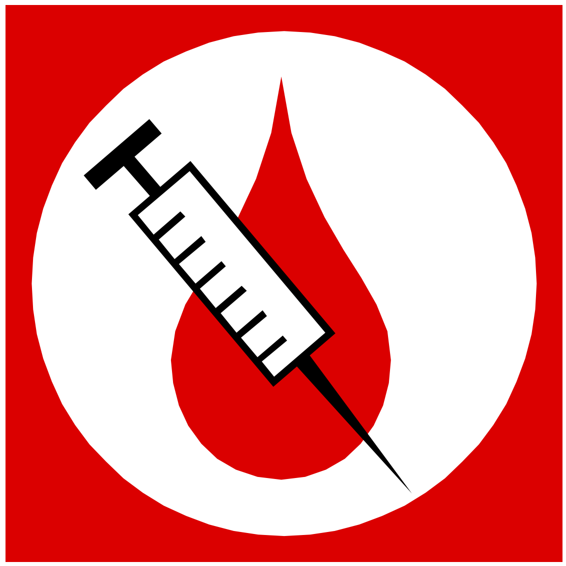
Interpretation of the Arterial Blood Gas



Self-Learning Packet

2007

This self-learning packet is approved for 2 contact hours for the following professionals:

1. **Registered Nurse**
2. **Licensed Practical Nurse**

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Purpose

The purpose of this self-learning packet is to educate patient care providers on the basic principles of acid-base balance, as well as to provide a systematic approach to the interpretation of arterial blood gases.

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Objectives

After completing this packet, the learner should be able to:

1. Describe the physiology involved in the acid/base balance of the body.
2. Compare the roles of PaO_2, pH, $PaCO_2$ and Bicarbonate in maintaining acid/base balance.
3. Review causes and treatments of Respiratory Acidosis, Respiratory Alkalosis, Metabolic Acidosis and Metabolic Alkalosis.
4. Identify normal arterial blood gas values and interpret the meaning of abnormal values.
5. Interpret the results of various arterial blood gas samples.
6. Identify the relationship between oxygen saturation and PaO_2 as it relates to the oxyhemoglobin dissociation curve.
7. Interpret the oxygenation state of a patient using the reported arterial blood gas PaO_2 value.

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Instructions

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- Complete the posttest at the end of this packet
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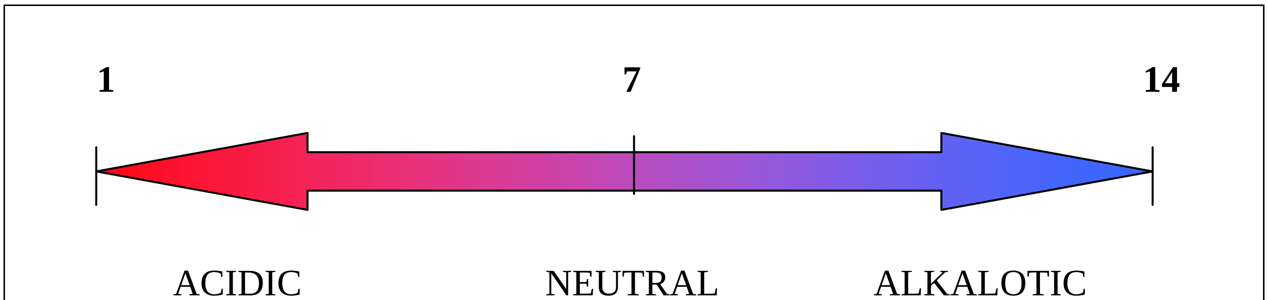
Introduction

Arterial blood gas analysis is an essential part of diagnosing and managing a patient's oxygenation status and acid-base balance. The usefulness of this diagnostic tool is dependent on being able to correctly interpret the results. This self-learning packet will examine the components of an arterial blood gas, what each component represents and the interpretation of these values to determine the patient's condition and treatment.

Acid-Base Balance

Overview

The pH is a measurement of the acidity or alkalinity of the blood. It is inversely proportional to the number of hydrogen ions (H^+) in the blood. The more H^+ present, the lower the pH will be. Likewise, the fewer H^+ present, the higher the pH will be. The pH of a solution is measured on a scale from 1 (very acidic) to 14 (very alkalotic). A liquid with a pH of 7, such as water, is neutral (neither acidic nor alkalotic).



The normal blood pH range is 7.35 to 7.45. In order for normal metabolism to take place, the body must maintain this narrow range at all times. When the pH is below 7.35, the blood is said to be *acidic*. Changes in body system functions that occur in an acidic state include a decrease in the force of cardiac contractions, a decrease in the vascular response to catecholamines, and a diminished response to the effects and actions of certain medications. When the pH is above 7.45, the blood is said to be *alkalotic*. An alkalotic state interferes with tissue oxygenation and normal neurological and muscular functioning. Significant changes in the blood pH above 7.8 or below 6.8 will interfere with cellular functioning, and if uncorrected, will lead to death.

So how is the body able to self-regulate acid-base balance in order to maintain pH within the normal range? It is accomplished using delicate buffer mechanisms between the respiratory and renal systems.

Key Concepts:

- The only 2 ways an *acidotic* state can exist is from either too much pCO_2 or too little HCO_3.
- The only 2 ways an *alkalotic* state can exist is from either too little pCO_2 or too much HCO_3.

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The Respiratory (Lungs) Buffer Response

A normal by-product of cellular metabolism is carbon dioxide (CO_2). CO_2 is carried in the blood to the lungs, where excess CO_2 combines with water (H_2O) to form carbonic acid (H_2CO_3). The blood pH will change according to the level of carbonic acid present. This triggers the lungs to either increase or decrease the rate and depth of ventilation until the appropriate amount of CO_2 has been re-established. Activation of the lungs to compensate for an imbalance starts to occur within 1 to 3 minutes.

The Renal (Metabolic) Buffer Response

In an effort to maintain the pH of the blood within its normal range, the kidneys excrete or retain bicarbonate (HCO_3^-). As the blood pH decreases, the kidneys will compensate by retaining HCO_3^- and as the pH rises, the kidneys excrete HCO_3^- through the urine. Although the kidneys provide an excellent means of regulating acid-base balance, the system may take from hours to days to correct the imbalance. When the respiratory and renal systems are working together, they are able to keep the blood pH balanced by maintaining 1 part acid to 20 parts base.

Acid-Base Disorders

Respiratory Acidosis

Respiratory acidosis is defined as a pH less than 7.35 with a $PaCO_2$ greater than 45 mm Hg. Acidosis is caused by an accumulation of CO_2 which combines with water in the body to produce carbonic acid, thus, lowering the pH of the blood. Any condition that results in hypoventilation can cause respiratory acidosis. These conditions include:

- Central nervous system depression related to head injury
- Central nervous system depression related to medications such as narcotics, sedatives, or anesthesia
- Impaired respiratory muscle function related to spinal cord injury, neuromuscular diseases, or neuromuscular blocking drugs
- Pulmonary disorders such as atelectasis, pneumonia, pneumothorax, pulmonary edema, or bronchial obstruction
- Massive pulmonary embolus
- Hypoventilation due to pain, chest wall injury/deformity, or abdominal distension

Signs and Symptoms of Respiratory Acidosis	
Pulmonary	dyspnea respiratory distress shallow respirations
Neurological	headache restlessness confusion
Cardiovascular	tachycardia dysrhythmias

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CLINICAL APPLICATION:
If the CO_2 becomes extremely high, drowsiness and unresponsiveness may be noted.

Increasing ventilation will correct respiratory acidosis. The method for achieving this will vary with the cause of hypoventilation. If the patient is unstable, manual ventilation with a bag-valve-mask (BVM) is indicated until the underlying problem can be addressed. After stabilization, rapidly resolvable causes are addressed immediately. Causes that can be treated rapidly include pneumothorax, pain, and CNS depression related to medications. If the cause cannot be readily resolved, the patient may require mechanical ventilation while treatment is rendered. Although patients with hypoventilation often require supplemental oxygen, it is important to remember that oxygen alone will not correct the problem.

Respiratory Alkalosis

Respiratory alkalosis is defined as a pH greater than 7.45 with a $PaCO_2$ less than 35 mm Hg. Any condition that causes hyperventilation can result in respiratory alkalosis. These conditions include:

- Psychological responses, such as anxiety or fear
- Pain
- Increased metabolic demands, such as fever, sepsis, pregnancy, or thyrotoxicosis
- Medications, such as respiratory stimulants.
- Central nervous system lesions

Signs and Symptoms of Respiratory Alkalosis	
Nervous	light-headedness numbness and tingling confusion inability to concentrate blurred vision
Cardiovascular	dysrhythmias palpitations diaphoresis
Miscellaneous	dry mouth tetanic spasms of the arms and legs

CLINICAL APPLICATION:
Treatment of respiratory alkalosis centers on resolving the underlying problem. Patients presenting with respiratory alkalosis have dramatically increased work of breathing and must be monitored closely for respiratory muscle fatigue. When the respiratory muscles become exhausted, acute respiratory failure may ensue.

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Metabolic Acidosis

Metabolic acidosis is defined as a bicarbonate level of less than 22 mEq/L with a pH of less than 7.35. Metabolic acidosis is caused by either a deficit of base in the bloodstream or an excess of acids, other than CO_2. Diarrhea and intestinal fistulas may cause decreased levels of base. Causes of increased acids include:

- Renal failure
- Diabetic ketoacidosis
- Anaerobic metabolism
- Starvation
- Salicylate intoxication

Signs and Symptoms of Metabolic Acidosis	
Central Nervous system	headache confusion restless lethargy stupor or coma
Cardiovascular	dysrhythmias warm, flushed skin
Pulmonary	Kussmaul respirations
Gastrointestinal	nausea and vomiting

As with most acid-base imbalances, the treatment of metabolic acidosis is dependent upon the cause. The presence of metabolic acidosis should spur a search for hypoxic tissue somewhere in the body. Hypoxemia can lead to anaerobic metabolism system-wide, but hypoxia of any tissue bed will produce metabolic acids as a result of anaerobic metabolism even if the PaO_2 is normal. The only appropriate way to treat this source of acidosis is to restore tissue perfusion to the hypoxic tissues. Other causes of metabolic acidosis should be considered after the possibility of tissue hypoxia has been addressed.

CLINICAL APPLICATION:
Current research has shown that the use of sodium bicarbonate is indicated only for known bicarbonate-responsive acidosis, such as that seen with renal failure. Routine use of sodium bicarbonate to treat metabolic acidosis results in subsequent metabolic alkalosis with hypernatremia and should be avoided.

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Metabolic Alkalosis

Metabolic alkalosis is defined as a bicarbonate level greater than 26 mEq/liter with a pH greater than 7.45. Either an excess of base or a loss of acid within the body can cause metabolic alkalosis. Excess base occurs from ingestion of antacids, excess use of bicarbonate, or use of lactate in dialysis. Loss of acids can occur secondary to protracted vomiting, gastric suction, hypochloremia, excess administration of diuretics, or high levels of aldosterone.

Signs and Symptoms of Metabolic Alkalosis	
Pulmonary	Respiratory depression
Neurological	dizziness lethargy disorientation seizures coma
Musculoskeletal	weakness muscle twitching muscle cramps tetany
Gastrointestinal	nausea vomiting

Metabolic alkalosis is one of the most difficult acid-base imbalances to treat. Bicarbonate excretion through the kidneys can be stimulated with drugs such as acetazolamide (Diamox®), but resolution of the imbalance will be slow. In severe cases, IV administration of acids may be used.

CLINICAL APPLICATION:

It is significant to note that metabolic alkalosis in hospitalized patients is usually iatrogenic in nature.

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Components of the Arterial Blood Gas

The arterial blood gas provides the following values:

pH

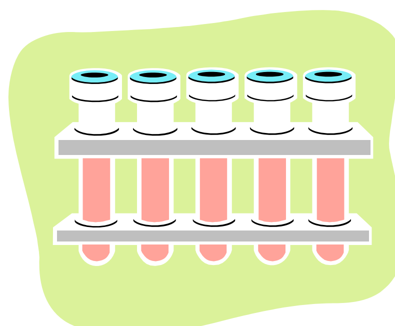
Measurement of acidity or alkalinity, based on the hydrogen (H^+) ions present.
The normal range is 7.35 to 7.45
Remember:
pH > 7.45 = alkalosis
pH< 7.35 = acidosis

PO_2

The partial pressure of oxygen that is dissolved in arterial blood.
The normal range is 80 to 100 mm Hg.

SaO_2

The arterial oxygen saturation.
The normal range is 95% to 100%.



pCO_2

The amount of carbon dioxide dissolved in arterial blood.
The normal range is 35 to 45 mm Hg.
Remember:
pCO_2 >45 = acidosis
pCO_2 <35 = alkalosis

HCO_3

The calculated value of the amount of bicarbonate in the bloodstream.
The normal range is 22 to 26 mEq/liter
Remember:
HCO_3 > 26 = alkalosis
HCO_3 < 22 = acidosis

B.E.

The base excess indicates the amount of excess or insufficient level of bicarbonate in the system.
The normal range is $^-2$ to $^+2$ mEq/liter.
Remember:
A negative base excess indicates a base deficit in the blood.

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Steps to an Arterial Blood Gas Interpretation

The arterial blood gas is used to evaluate both acid-base balance and oxygenation, each representing separate conditions. Acid-base evaluation requires a focus on three of the reported components: pH, $PaCO_2$ and HCO_3. This process involves two basic steps.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.30	(7.35-7.45)	ACID
pCO_2	55	(35-45)	ACID
HCO_3	26	(22-26)	NORMAL

The two matching values determine **<u>what</u>** the problem is. In this case, an ACIDOSIS.

Step Two

If the ABG results are abnormal, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.30	(7.35-7.45)	ACID	
pCO_2	55	(35-45)	ACID	= Lungs
HCO_3	26	(22-26)	NORMAL	= Kidneys

Match the two **<u>abnormalities</u>**: Respiratory (lung problem) + Acidosis = ***Respiratory Acidosis.***

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Example One:

John Doe is a 55 year-old male admitted to your nursing unit with recurring bowel obstruction. He has been experiencing intractable vomiting for the last several hours despite the use of antiemtetics. His arterial blood gas result is as follows: pH 7.50, pCO_2 42, HCO_3 33.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.50	(7.35-7.45)	ALKALINE
pCO_2	42	(35-45)	NORMAL
HCO_3	33	(22-26)	ALKALINE

The two matching values determine **<u>what</u>** the problem is. In this case, an ALKALOSIS.

Step Two

If the ABG results are abnormal, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.50	(7.35-7.45)	ALKALINE	
$PaCO_2$	42	(35-45)	NORMAL	= Lungs
HCO_3	33	(22-26)	ALKALINE	= Kidneys

Match the two **<u>abnormalities</u>**: Kidneys (metabolic)) + Alkalosis = ***MetabolicAlkalosis***.

CLINICAL APPLICATION:

Treatment of this patient might include the administration of I.V. fluids and measures to reduce the excess base.

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Example 2

Jane Doe is a 55-year-old female admitted to your nursing unit with sepsis. Here is her arterial blood gas result: pH 7.31, pCO_2 39, HCO_3 17

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.31	(7.35-7.45)	ACIDOSIS
$PaCO_2$	39	(35-45)	NORMAL
HCO_3	17	(22-26)	ACIDOSIS

The two matching values determine **what** the problem is. In this case, an ACIDOSIS.

Step Two

If the ABG results are abnormal, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.31	(7.35-7.45)	ACIDOSIS
$PaCO_2$	39	(35-45)	NORMAL = lungs
HCO_3	17	(22-26)	ACIDOSIS = kidneys

Match the two **abnormalities**: Kidneys (metabolic) + Acidosis = ***Metabolic Acidosis***.

CLINICAL APPLICATION:
Treatment of this patient might include providing supplemental oxygen and administration of additional I.V. fluids.

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Example 3

Jane Doe is a 34 year-old female admitted to your nursing unit with thyrotoxicosis. Her blood gas results are as follows: pH 7.50, pCO_2 30, HCO_3 24.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.50	(7.35-7.45)	ALKALOSIS
$PaCO_2$	30	(35-45)	ALKALOSIS
HCO_3	24	(22-26)	NORMAL

The two matching values determine **<u>what</u>** the problem is. In this case, an ALKALOSIS.

Step Two

If the ABG results are abnormal, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.50	(7.35-7.45)	ALKALOSIS
$PaCO_2$	30	(35-45)	ALKALOSIS = Lungs
HCO_3	24	(22-26)	NORMAL = Kidneys

Match the two **<u>abnormalities</u>**: Respiratory (lung problem) + Alkalosis = ***Respiratory Alkalosis***.

CLINICAL APPLICATION:
Treatment of this patient might include correcting the underlying problem and slowing the respiratory rate down.

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Example 4

Jane Doe is a 19 year-old female admitted to your nursing unit with head injury. Her blood gas results are as follows: pH 7.38, pCO_2 56, HCO_3 35.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.38	(7.35-7.45)	NORMAL
$PaCO_2$	56	(35-45)	ACIDOSIS
HCO_3	35	(22-26)	ALKALOSIS

Notice now, for the first time, that **both** the pCO_2 and the HCO_3 are **abnormal**. This indicates that there is some degree of compensation taking place. This will require a slightly different approach to the blood gas analysis.

Compensation

Thus far we have looked at simple arterial blood gas values without any evidence of compensation occurring. Now see what happens when an acid-base imbalance exists over a period of time.

When a patient develops an acid-base imbalance, the body attempts to compensate. Remember that the lungs and the kidneys are the primary buffer response systems in the body. The body tries to overcome either a respiratory or metabolic dysfunction in an attempt to return the pH into the normal range.

A patient can be uncompensated, partially compensated, or fully compensated. How do you know when compensation is occurring? When an acid-base disorder is either uncompensated or partially compensated, the pH remains outside the normal range. In fully compensated states, the pH has returned to within the normal range, although the other values may still be abnormal. Be aware that neither system has the ability to overcompensate.

In our first three examples, the patients were uncompensated. In each case, the pH was outside of the normal range, the primary source of the acid-base imbalance was readily identified, but the third value (the compensatory buffering system) remained in the normal range.

Let's return to our arterial blood gas results where there is evidence of compensation.

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pH	7.38	(7.35-7.45)	NORMAL
$PaCO_2$	56	(35-45)	ACIDOSIS
HCO_3	35	(22-26)	ALKALOSIS

As you might recall, in step one we determined that both the pCO_2 and HCO_3 were abnormal, indicating the presence of some degree of compensation. Now we need to know two things. First, are we dealing with an acidosis or an alkalosis? Secondly, how do you know which system (respiratory or metabolic) is the primary problem and which is compensating? To determine this, we must go back and look at the pH in a slightly different way.

Step Two

If both the pCO_2 and the HCO_3 are abnormal, but the pH is in the normal range, look at the pH again. Instead of using a “normal range” of 7.35-7.45 as we have been doing, we are going to use the single value of 7.4 as our only “normal”. Any pH of <7.40 is now going to be considered acidosis. Any pH > 7.40 is now going to be considered alkalosis. Look at our pH in this example. The pH is <7.4.

pH	7.38	(7.4)	ACIDOSIS
$PaCO_2$	56	(35-45)	ACIDOSIS
HCO_3	35	(22-26)	ALKALOSIS

The two ***matching*** values determine **<u>what</u>** the problem is. In this case, an ACIDOSIS.

Key Concept:

We only use a single value of 7.40 as “normal” when *both* the pCO_2 and HCO_3 are abnormal (indicating that some degree of compensation exits) and the initial pH is normal.

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Step Three

Now, for the two *matching* values, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory). Refer to the key concept on page 4.

pH	7.38	(7.4)	ACIDOSIS
$PaCO_2$	56	(35-45)	ACIDOSIS = Lungs
HCO_3	35	(22-26)	ALKALOSIS

Match the two **abnormalities**: Respiratory (lungs) + Acidosis = ***Respiratory Acidosis***

Finally, we need to determine if the condition is *partially* or *completely* compensated.

Key Concepts:

Sometimes, the system that is compensating (respiratory or metabolic) may either have not had sufficient time to correct the situation, or is unable to completely compensate for the degree of abnormality present.

- If the pH is between 7.35-7.45, the condition is *fully compensated.*
- If the pH is outside the range of 7.35-7.45, the condition is only *partially compensated.*
- Remember, neither buffer system has the ability to overcompensate!

In the above example, because the pH is 7.38 (within the range of 7.35-7.45), the condition is fully compensated. Our final arterial blood gas analysis indicates that we have a ***Compensated Respiratory Acidosis.***

Clinical Application:
Because the acidosis is completely compensated, and we know the kidneys take hours to days to respond, we know that this patient's respiratory problem has been going on for some time.

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Example 5

Jane Doe is admitted to your nursing unit. Her admission labwork reveals an arterial blood gas with the following values: pH 7.45; pCO_2 48; HCO_3 28.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.45	(7.35-7.45)	NORMAL
pCO_2	48	(35-45)	ACIDOSIS
HCO_3	28	(22-26)	ALKALOSIS

Because both the pCO_2 and HCO_3 are abnormal, we know that some degree of compensation is occurring.

Step Two

Because the initial pH is normal, we must look again at the pH using 7.4 as the single value for "normal". Label the pH as acidotic or alkalotic.

pH	7.45	(7.4)	ALKALOSIS
pCO_2	48	(35-45)	ACIDOSIS
HCO_3	28	(22-26)	ALKALOSIS

The two ***matching*** values determine **<u>what</u>** the problem is. In this case, an ALKALOSIS.

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Step Three

For the two *matching* values, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.45	(7.4)	ALKALOSIS
pCO_2	48	(35-45)	ACIDOSIS
HCO_3	28	(22-26)	ALKALOSIS = Kidneys

Match the two **abnormalities**: Kidneys (metabolic) + Alkalosis = ***Metabolic Alkalosis.***

Finally, we need to determine if the condition is *partially* or *completely* compensated.

In this example, because the pH is 7.45 (within the range of 7.35-7.45), the condition is fully compensated. Our final arterial blood gas analysis indicates that we have a ***Compensated Metabolic Alkalosis.***

Example 6

John Doe is a trauma patient with an altered mental status. His initial arterial blood gas result is as follows: pH 7.33; pCO_2 62; HCO_3 35.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.33	(7.35-7.45)	ACIDOSIS
pCO_2	62	(35-45)	ACIDOSIS
HCO_3	35	(22-26)	ALKALOSIS

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Because both the pCO_2 and HCO_3 are abnormal, we know that some degree of compensation is occurring.

Step Two

Because the pCO_2 and HCO_3 are both abnormal, it indicates that some degree of compensation is occurring. However, because the pH is also abnormal, we do not need to look at it again since it is already labeled as abnormal.

pH	7.33	(7.35-7.45)	ACIDOSIS
pCO_2	62	(35-45)	ACIDOSIS
HCO_3	35	(22-26)	ALKALOSIS

The two ***matching*** values determine **<u>what</u>** the problem is. In this case, an ACIDOSIS.

Step Three

For the two *matching* values, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.33	(7.35-7.45)	ACIDOSIS
pCO_2	62	(35-45)	ACIDOSIS = Lungs
HCO_3	35	(22-26)	ALKALOSIS

Match the two **<u>abnormalities</u>**: Respiratory (lungs) + Acidosis = ***Respiratory Acidosis.***

Finally, we need to determine if the condition is *partially* or *completely* compensated.

In this example, because the pH is 7.33 (outside the range of 7.35-7.45), the condition is only *partially* compensated. Our final arterial blood gas analysis indicates that we have a ***Partially Compensated Respiratory Acidosis.***

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Example 7

Jane Doe is a 54-year-old female admitted to your nursing unit. Here are the last ABG results:

pH 7.29 pCO_2 30; HCO_3 18.

Step One

Identify whether the pH, pCO_2 and HCO_3 are abnormal. For each component, label it as "normal", "acid" or "alkaline".

pH	7.29	(7.35-7.45)	ACIDOSIS
pCO_2	30	(35-45)	ALKALOSIS
HCO_3	18	(22-26)	ACIDOSIS

Because both the pCO_2 and HCO_3 are abnormal, we know that some degree of compensation is occurring.

Step Two

Here, the pH out of the normal range and we have already labeled it as acidosis.

pH	7.29	(7.35-7.45)	ACIDOSIS
pCO_2	30	(35-45)	ALKALOSIS
HCO_3	18	(22-26)	ACIDOSIS

The two ***matching*** values determine **<u>what</u>** the problem is. In this case, an ACIDOSIS.

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Step Three

For the two *matching* values, determine if the abnormality is due to the kidneys (metabolic) or the lungs (respiratory).

pH	7.29	(7.35-7.45)	ACIDOSIS
pCO_2	30	(35-45)	ALKALOSIS
HCO_3	18	(22-26)	ACIDOSIS = Kidneys

Match the two **abnormalities**: Metabolic (kidneys) + Acidosis = ***Metabolic Acidosis.***

Finally, we need to determine if the condition is *partially* or *completely* compensated.

In this example, because the pH is 7.29 (outside the range of 7.35-7.45), the condition is only *partially* compensated. Our final arterial blood gas analysis indicates that we have a ***Partially Compensated Metabolic Acidosis.***

Special Considerations

Although the focus of this self-learning packet has been on interpretation of acid-base imbalances, the arterial blood gas can also be used to evaluate blood oxygenation. The component of the arterial blood gas used to evaluate this is the PaO_2. Remember that the normal blood PaO_2 value is 80-100 mm Hg.

Oxyhemoglobin Dissociation Curve

The oxyhemoglobin dissociation curve is a tool used to show the relationship between oxygen saturation and the PaO_2.

The strength with which oxygen binds to the hemoglobin molecule has important clinical implications. If the oxygen binds too loosely, the hemoglobin may give up its oxygen before it reaches the tissues in need. If the oxygen binds too tightly, it may not transfer to the tissues at all. The strength of the oxygen-hemoglobin bond is graphically represented by the oxyhemoglobin dissociation curve below.

Several variables affect the affinity of the oxygen molecule to hemoglobin. Conditions that cause enhanced release of the oxygen molecule include acidosis, fever, elevated CO_2 levels, and increased 2,3-diphosphoglycerate (2,3-DPG, a by-product of glucose metabolism). This change in affinity is called a shift to the right (C waveform). Conditions that keep the oxygen molecule tightly attached to hemoglobin include hypothermia, alkalosis, low PCO_2, and decrease in 2,3-DPG. This change is called a shift to the left (B waveform). A shift to the left has more negative implications for the patient than a shift to the right.

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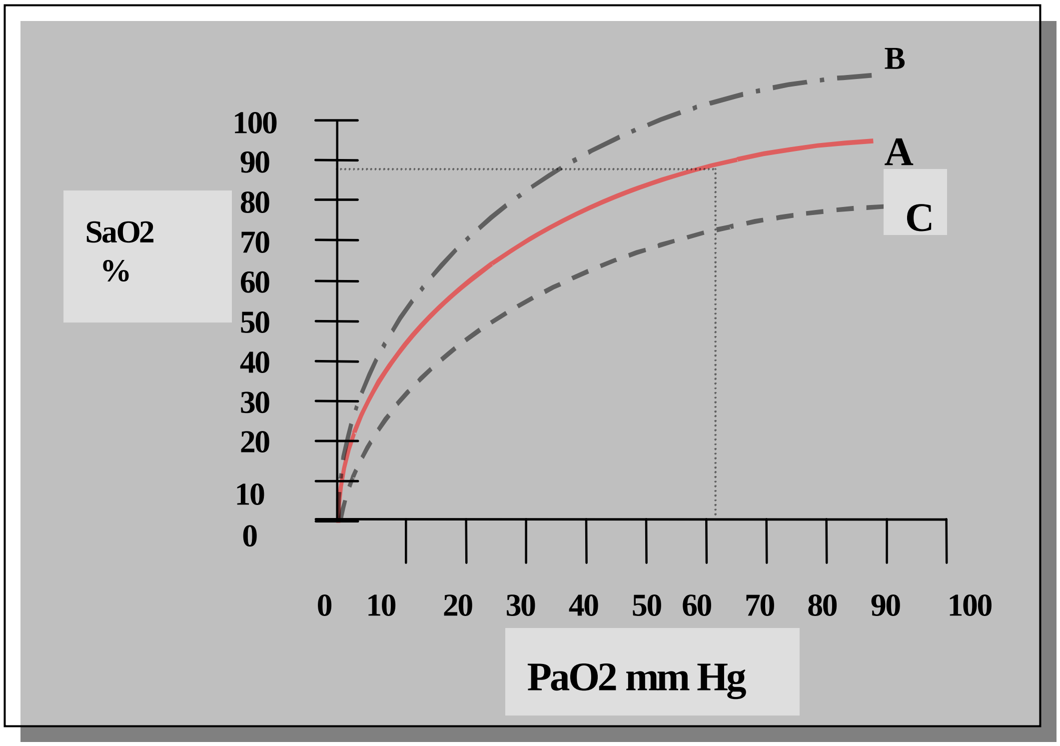
The oxyhemoglobin dissociation curve can be used to estimate the PaO_2 if the oxygen saturation is known. The illustration demonstrates that if the curve is not shifted (A waveform), an oxygen saturation of 88% is equivalent to a PaO_2 of about 60 mm Hg. With a left shift, the same saturation is equivalent to a much lower PaO_2.



If evaluation of blood oxygenation is required, you can assess this by adding one additional step to your arterial blood gas analysis.

Step Four

Assess the PaO_2. A value below 80 mm Hg can indicate hypoxemia, depending on the age of the patient. Correction of a patient's blood oxygenation level may be accomplished through a combination of augmenting the means of oxygen delivery and correcting existing conditions that are shifting the oxyhemoglobin curve.

Summary

Understanding arterial blood gases can sometimes be confusing. A logical and systematic approach using these steps makes interpretation much easier. Applying the concepts of acid-base balance will help the healthcare provider follow the progress of a patient and evaluate the effectiveness of care being provided.

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Glossary

ABG: arterial blood gas. A test that analyzes arterial blood for oxygen, carbon dioxide and bicarbonate content in addition to blood pH. Used to test the effectiveness of ventilation.

Acidosis: a pathologic state characterized by an increase in the concentration of hydrogen ions in the arterial blood above the normal level. May be caused by an accumulation of carbon dioxide or acidic products of metabolism or a by a decrease in the concentration of alkaline compounds.

Alkalosis: a state characterized by a decrease in the hydrogen ion concentration of arterial blood below normal level. The condition may be caused by an increase in the concentration of alkaline compounds, or by decrease in the concentration of acidic compounds or carbon dioxide.

Chronic obstruction pulmonary disease (COPD): a disease process involving chronic inflammation of the airways, including chronic bronchitis (disease in the large airways) and emphysema (disease located in smaller airways and alveolar regions). The obstruction is generally permanent and progressive over time.

Diamox ™: a carbonic anhydrase inhibitor that decreases H^+ ion secretion and increases HCO_3 excretions by the kidneys, causing a diuretic effect.

Hyperventilation: a state in which there is an increased amount of air entering the pulmonary alveoli (increased alveolar ventilation), resulting in reduction of carbon dioxide tension and eventually leading to alkalosis.

Hypoventilation: a state in which there is a reduced amount of air entering the pulmonary alveoli.

Hypoxemia: below-normal oxygen content in arterial blood due to deficient oxygenation of the blood and resulting in hypoxia.

Hypoxia: reduction of oxygen supply to tissue below physiological levels despite adequate perfusion of the tissue by blood.

Iatrogenic: any condition induced in a patient by the effects of medical treatment.

Kussmaul's respirations: abnormal breathing pattern brought on by strenuous exercise or metabolic acidosis, and is characterized by an increased ventilatory rate, very large tidal volume, and no expiratory pause.

Oxygen delivery system: a device used to deliver oxygen concentrations above ambient air to the lungs through the upper airway.

Oxygenation: the process of supplying, treating or mixing with oxygen.

Oxyhemoglobin: hemoglobin in combination with oxygen.

Pneumothorax: an abnormal state characterized by the presence of gas (as air) in the plueral cavity.

Pulmonary Embolism: the lodgment of a blood clot in the lumen of a pulmonary artery, causing a severe dysfunction in respiratory function.

Thyrotoxicosis: toxic condition due to hyperactivity of the thyroid gland. Symptoms include rapid heart rate, tremors, increased metabolic basal metabolism, nervous symptoms and loss of weight.

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Posttest.

1. The solution that would be most alkalotic would be the one with a pH of:
   A. Four
   B. Seven
   C. Nine
   D. Fourteen

2. The normal pH range for blood is:
   A. 7.0 – 7.25
   B. 7.30 – 7.40
   C. 7.35 – 7.45
   D. 7.45 – 7.55

3. The respiratory system compensates for changes in the pH level by responding to changes in the levels of:
   A. CO_2
   B. H_2O
   C. H_2CO_3
   D. HCO_3

4. The kidneys compensate for acid-base imbalances by excreting or retaining:
   A. Hydrogen ions
   B. Carbonic acid
   C. Sodium Bicarbonate
   D. Water

5. All of the following might be a cause of respiratory acidosis <u>except</u>:
   A. Sedation
   B. Head trauma
   C. COPD
   D. Hyperventilation

6. A patient with a prolonged episode of nausea, vomiting and diarrhea has an ABG ordered on admission. You might expect the results to show:
   A. Metabolic acidosis
   B. Metabolic alkalosis
   C. Respiratory acidosis
   D. Respiratory alkalotic

7. A calculated ABG value that indicates excess or insufficiency of sodium bicarbonate in the system is:
   A. HCO_3
   B. Base excess
   C. PaO_2
   D. pH

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8. Which of the following may be a reason to order an ABG on a patient?
   - A. The patient suddenly develops shortness of breath
   - B. An asthmatic is starting to show signs of tiring
   - C. A diabetic has developed Kussmaul respirations
   - D. All of the above

9. You are reviewing the results of an ABG. When the pH and the $PaCO_2$ values are moving in opposite directions, the primary problem is:
   - A. Respiratory
   - B. Renal
   - C. Metabolic
   - D. Compensation

10. When an acid-base imbalance is caused by a metabolic disturbance, the pH and the HCO_3 will move:
    - A. In opposite directions
    - B. Totally independent of each other
    - C. In the same direction

11. The oxyhemoglobin dissociation curve represents the relationship between the:
    - A. O_2 saturation and hemoglobin level
    - B. O_2 saturation and PaO_2
    - C. PaO_2 and the HCO_3
    - D. PaO_2 and the pH

12. On the normal oxyhemoglobin curve, if the O_2 saturation is 88%, it would correlate with a PaO_2 of approximately:
    - A. 60 mm Hg
    - B. 80 mm Hg
    - C. 90 mm Hg
    - D. 100 mm Hg

Interpret the following ABG results.

13. pH 7.33 pCO_2 60 HCO_3 34
    - A. Normal ABG values
    - B. Respiratory acidosis without compensation
    - C. Respiratory acidosis with partial compensation
    - D. Respiratory acidosis with full compensation

14. pH 7.48 pCO_2 42 HCO_3 30
    - A. Metabolic acidosis without compensation
    - B. Respiratory alkalosis with partial compensation
    - C. Respiratory alkalosis with full compensation
    - D. Metabolic alkalosis without compensation

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15. pH 7.38 pCO_2 38 HCO_3 24
    - A. Respiratory alkalosis
    - B. Normal
    - C. Metabolic Alkalosis
    - D. None of the above

16. pH 7.21 pCO_2 60 HCO_3 24
    - A. Normal
    - B. Respiratory acidosis without compensation
    - C. Metabolic acidosis with partial compensation
    - D. Respiratory acidosis with complete compensation

17. pH 7.48 pCO_2 28 HCO_3 20
    - A. Respiratory alkalosis with partial compensation
    - B. Respiratory alkalosis with complete compensation
    - C. Metabolic alkalosis without compensation
    - D. Metabolic alkalosis with complete compensation

18. pH 7.50 pCO_2 29 HCO_3 24
    - A. Normal
    - B. Respiratory acidosis with compensation
    - C. Respiratory alkalosis without compensation
    - D. Metabolic alkalosis with partial compensation

19. pH 7.28 pCO_2 40 HCO_3 18
    - A. Respiratory acidosis without compensation
    - B. Respiratory alkalosis with partial compensation
    - C. Metabolic alkalosis with partial compensation
    - D. Metabolic acidosis without compensation

20. pH 7.45 pCO_2 26 HCO_3 16
    - A. Normal
    - B. Respiratory acidosis fully compensated
    - C. Respiratory alkalosis fully compensated
    - D. Metabolic alkalosis fully compensated

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