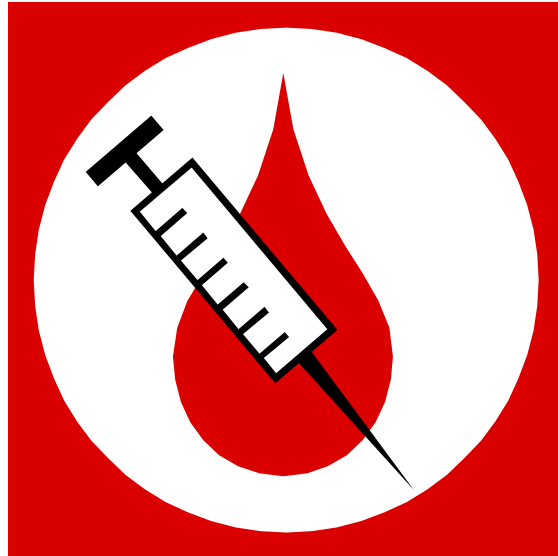


# **Interpretation of the Arterial Blood Gas**



## **Self-Learning Packet 2004**

**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<sub>2</sub>, pH, PaCO<sub>2</sub> 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<sub>2</sub> as it relates to the oxyhemoglobin dissociation curve.
7. Interpret the oxygenation state of a patient using the reported arterial blood gas PaO<sub>2</sub> value.

## Instructions

In order to receive 2.0 contact hours, you must:

- Complete the posttest at the end of this packet
- Submit the posttest to Education & Development with your payment
- Achieve an 84% on the posttest

Be sure to complete all the information at the top of the answer sheet. You will be notified if you do not pass, and you will have an opportunity to retake the posttest.

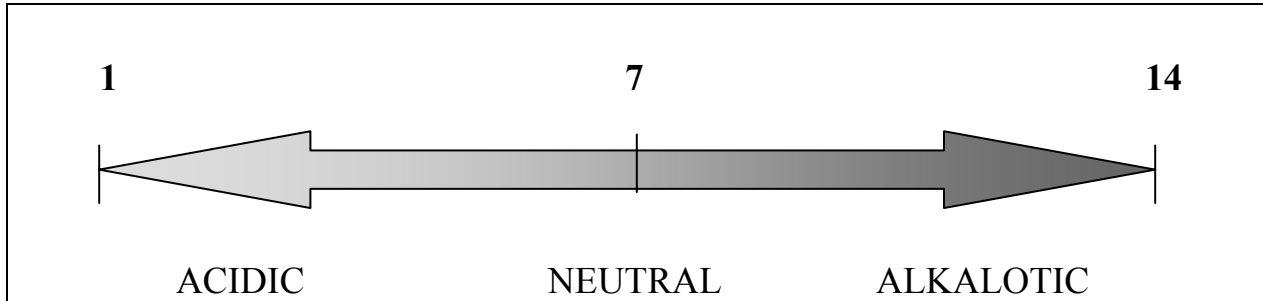
## Introduction

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 and what each component represents and interpret these values in order 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. Let's examine each system separately.

### The Respiratory 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 Buffer Response

In an effort to maintain the pH of the blood within its normal range, the kidneys excrete or retain bicarbonate ( $\text{HCO}_3^-$ ). As the blood pH decreases, the kidneys will compensate by retaining  $\text{HCO}_3^-$  and as the pH rises, the kidneys excrete  $\text{HCO}_3^-$  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  $\text{PaCO}_2$  greater than 45 mm Hg. Acidosis is caused by an accumulation of  $\text{CO}_2$  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

The signs and symptoms of respiratory acidosis are centered within the pulmonary, nervous, and cardiovascular systems. Pulmonary symptoms include dyspnea, respiratory distress, and/or shallow respirations. Nervous system manifestations include headache, restlessness, and confusion. If  $\text{CO}_2$  levels become extremely high, drowsiness and unresponsiveness may be noted. Cardiovascular symptoms include tachycardia and dysrhythmias.

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<sub>2</sub> 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 are largely associated with the nervous and cardiovascular systems. Nervous system alterations include light-headedness, numbness and tingling, confusion, inability to concentrate, and blurred vision. Cardiac symptoms include dysrhythmias and palpitations. Additionally, the patient may experience dry mouth, diaphoresis, and tetanic spasms of the arms and legs.

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.

## **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<sub>2</sub>. Diarrhea and intestinal fistulas may cause decreased levels of base. Causes of increased acids include:

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

Symptoms of metabolic acidosis center around the central nervous system, cardiovascular, pulmonary and GI systems. Nervous system manifestations include headache, confusion, and restlessness progressing to lethargy, then stupor or coma. Cardiac dysrhythmias are common and Kussmaul respirations occur in an effort to compensate for the pH by blowing off more CO<sub>2</sub>. Warm, flushed skin, as well as nausea and vomiting are commonly noted.

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<sub>2</sub> 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.

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.

## **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.

Symptoms of metabolic alkalosis are mainly neurological and musculoskeletal. Neurologic symptoms include dizziness, lethargy, disorientation, seizures and coma. Musculoskeletal symptoms include weakness, muscle twitching, muscle cramps and tetany. The patient may also experience nausea, vomiting, and respiratory depression.

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

## 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

### PaO<sub>2</sub>

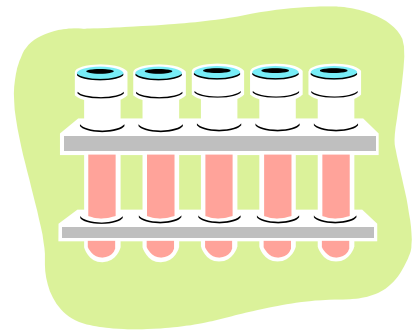
The partial pressure of oxygen that is dissolved in arterial blood.

The normal range is 80 to 100 mm Hg.

### SaO<sub>2</sub>

The arterial oxygen saturation.

The normal range is 95% to 100%.



### PaCO<sub>2</sub>

The amount of carbon dioxide dissolved in arterial blood.

The normal range is 35 to 45 mm Hg.

### HCO<sub>3</sub>

The calculated value of the amount of bicarbonate in the bloodstream.

The normal range is 22 to 26 mEq/liter

### 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.

(A negative base excess indicates a base deficit in the blood.)



## 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<sub>2</sub> and HCO<sub>3</sub>. This process involves three steps.

### Step One

Assess the pH to determine if the blood is within normal range, alkalotic or acidotic. If it is above 7.45, the blood is alkalotic. If it is below 7.35, the blood is acidotic.

### Step Two

If the blood is alkalotic or acidotic, we now need to determine if it is caused primarily by a respiratory or metabolic problem. To do this, assess the PaCO<sub>2</sub> level. Remember that with a respiratory problem, as the pH decreases below 7.35, the PaCO<sub>2</sub> should rise. If the pH rises above 7.45, the PaCO<sub>2</sub> should fall. Compare the pH and the PaCO<sub>2</sub> values. If pH and PaCO<sub>2</sub> are indeed moving in *opposite directions*, then the problem is primarily respiratory in nature.

### Step Three

Finally, assess the HCO<sub>3</sub> value. Recall that with a metabolic problem, normally as the pH increases, the HCO<sub>3</sub> should also increase. Likewise, as the pH decreases, so should the HCO<sub>3</sub>. Compare the two values. If they are moving *in the same direction*, then the problem is primarily metabolic in nature. The following chart summarizes the relationships between pH, PaCO<sub>2</sub> and HCO<sub>3</sub>.

	pH	PaCO <sub>2</sub>	HCO <sub>3</sub>
<b>Respiratory Acidosis</b>	↓	↑	normal
<b>Respiratory Alkalosis</b>	↑	↓	normal
<b>Metabolic Acidosis</b>	↓	normal	↓
<b>Metabolic Alkalosis</b>	↑	normal	↑

**Example 1**

Jane Doe is a 45-year-old female admitted to the nursing unit with a severe asthma attack. She has been experiencing increasing shortness of breath since admission three hours ago. Her arterial blood gas result is as follows:

Clinical Laboratory	
PATIENT:	DOE, JANE
DATE:	6/4/03 18:43
pH	7.22
PaCO <sub>2</sub>	55
HCO <sub>3</sub> <sup>-</sup>	25
STAT LAB	

**Follow the steps:**

1. Assess the pH. It is low (normal 7.35-7.45); therefore, we have acidosis.
2. Assess the PaCO<sub>2</sub>. It is high (normal 35-45) and in the opposite direction of the pH.
3. Assess the HCO<sub>3</sub><sup>-</sup>. It has remained within the normal range (22-26).

	pH	PCO <sub>2</sub>	HCO <sub>3</sub>
Respiratory Acidosis	↓	↑	Normal

Refer to the chart. *Acidosis* is present (decreased pH) with the PaCO<sub>3</sub> being increased, reflecting a primary *respiratory* problem. For this patient, we need to improve the ventilation status by providing oxygen therapy, mechanical ventilation, pulmonary toilet or by administering bronchodilators.

**Example 2**

John Doe is a 55-year-old male admitted to your nursing unit with a recurring bowel obstruction. He has been experiencing intractable vomiting for the last several hours despite the use of antiemetics. Here is his arterial blood gas result:

<b>Clinical Laboratory</b>	
PATIENT:	DOE, JOHN
DATE:	3/6/03 08:30
pH	7.50
PaCO <sub>2</sub>	42
HCO <sub>3</sub> <sup>-</sup>	33
STAT LAB	

**Follow the three steps again:**

1. Assess the pH. It is high (normal 7.35-7.45), therefore, indicating alkalosis.
2. Assess the PaCO<sub>2</sub>. It is within the normal range (normal 35-45).
3. Assess the HCO<sub>3</sub>. It is high (normal 22-26) and moving in the same direction as the pH.

	<b>pH</b>	<b>PCO<sub>2</sub></b>	<b>HCO<sub>3</sub></b>
<b>Metabolic Alkalosis</b>	↑	normal	↑

Again, look at the chart. *Alkalosis* is present (increased pH) with the HCO<sub>3</sub> increased, reflecting a primary *metabolic* problem. Treatment of this patient might include the administration of I.V. fluids and measures to reduce the excess base.

## 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. 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 two examples, the patients were uncompensated. In both cases, the pH was outside of the normal range, the primary source of the acid-base imbalance was readily identified, but the compensatory buffering system values remained in the normal range.

Now let's look at arterial blood gas results when there is evidence of partial compensation.

In order to look for evidence of partial compensation, review the following three steps:

1. Assess the pH. This step remains the same and allows us to determine if an acidotic or alkalotic state exists.
2. Assess the PaCO<sub>2</sub>. In an uncompensated state, we have already seen that the pH and PaCO<sub>2</sub> move in opposite directions when indicating that the primary problem is respiratory. But what if the pH and PaCO<sub>2</sub> are moving *in the same direction*? That is not what we would expect to see happen. We would then conclude that the primary problem was metabolic. In this case, the *decreasing* PaCO<sub>2</sub> indicates that the lungs, acting as a buffer response, are attempting to correct the pH back into its normal range by decreasing the PaCO<sub>2</sub> ("blowing off the excess CO<sub>2</sub>"). If evidence of compensation is present, but the pH has not yet been corrected to within its normal range, this would be described as a metabolic disorder with a *partial* respiratory compensation.
3. Assess the HCO<sub>3</sub>. In our original uncompensated examples, the pH and HCO<sub>3</sub> move in the same direction, indicating that the primary problem was metabolic. But what if our results show the pH and HCO<sub>3</sub> moving in opposite directions? That is not what we would expect to see. We would conclude that the primary acid-base disorder is respiratory, and that the kidneys, again acting as a buffer response system, are compensating by retaining HCO<sub>3</sub>, ultimately attempting to return the pH back towards the normal range.

The following tables (on the next page) demonstrate the relationships between the pH, PaCO<sub>2</sub> and HCO<sub>3</sub> in partially and fully compensated states.

**Fully Compensated States**

	<b>pH</b>	<b>PaCO<sub>2</sub></b>	<b>HCO<sub>3</sub><sup>-</sup></b>
<b>Respiratory Acidosis</b>	normal, but <7.40	↑	↑
<b>Respiratory Alkalosis</b>	normal, but >7.40	↓	↓
<b>Metabolic Acidosis</b>	normal, but <7.40	↓	↓
<b>Metabolic Alkalosis</b>	normal, but >7.40	↑	↑

**Partially Compensated States**

	<b>pH</b>	<b>PaCO<sub>2</sub></b>	<b>HCO<sub>3</sub><sup>-</sup></b>
<b>Respiratory Acidosis</b>	↓	↑	↑
<b>Respiratory Alkalosis</b>	↑	↓	↓
<b>Metabolic Acidosis</b>	↓	↓	↓
<b>Metabolic Alkalosis</b>	↑	↑	↑

Notice that the only difference between partially and fully compensated states is whether or not the pH has returned to within the normal range. In compensated acid-base disorders, the pH will frequently fall either on the low or high side of neutral (7.40). Making note of where the pH falls within the normal range is helpful in determining if the original acid-base disorder was acidosis or alkalosis.

**Example 3**

John Doe is admitted to the hospital. He is a kidney dialysis patient who has missed his last two appointments at the dialysis center. His arterial blood gas values are reported as follows:

Clinical Laboratory	
PATIENT:	DOE, JOHN
DATE:	7/11/02 04:20
pH	7.32
PaCO <sub>2</sub>	32
HCO <sub>3</sub> <sup>-</sup>	18
STAT LAB	

**Follow the three steps:**

1. Assess the pH. It is low (normal 7.35-7.45); therefore we have acidosis.
2. Assess the PaCO<sub>2</sub>. It is low. Normally we would expect the pH and PaCO<sub>2</sub> to move in opposite directions, but this is not the case. Because the pH and PaCO<sub>2</sub> are moving in the same direction, it indicates that the acid-base disorder is primarily metabolic. In this case, the lungs, acting as the primary acid-base buffer, are now attempting to compensate by “blowing off excessive CO<sub>2</sub>”, and therefore increasing the pH.
3. Assess the HCO<sub>3</sub><sup>-</sup>. It is low (normal 22-26). We would expect the pH and the HCO<sub>3</sub><sup>-</sup> to move in the same direction, confirming that the primary problem is metabolic.

What is your interpretation? Because there is evidence of compensation (pH and PaCO<sub>2</sub> moving in the same direction) and because the pH remains below the normal range, we would interpret this ABG result as a *partially compensated metabolic acidosis*.

	pH	PaCO <sub>2</sub>	HCO <sub>3</sub> <sup>-</sup>
<b>Metabolic Acidosis</b>	↓	↓	↓

**Example 4**

Jane Doe is a patient with chronic COPD being admitted for surgery. Her admission labwork reveals an arterial blood gas with the following values:

Clinical Laboratory	
PATIENT:	DOE, JANE
DATE:	2/16/03 17:30
pH	7.35
PaCO <sub>2</sub>	48
HCO <sub>3</sub> <sup>-</sup>	28
STAT LAB	

**Follow the three steps:**

1. Assess the pH. It is within the normal range, but on the low side of neutral (<7.40).
2. Assess the PaCO<sub>2</sub>. It is high (normal 35-45). We would expect the pH and PaCO<sub>2</sub> to move in opposite directions if the primary problem is respiratory.
3. Assess the HCO<sub>3</sub>. It is also high (22-26). Normally, the pH and HCO<sub>3</sub> should move in the same direction. Because they are moving in opposite directions, it confirms that the primary acid-base disorder is respiratory and that the kidneys are attempting to compensate by retaining HCO<sub>3</sub>. Because the pH has returned into the low normal range, we would interpret this ABG as a *fully compensated respiratory acidosis*.

	pH	PaCO <sub>2</sub>	HCO <sub>3</sub> <sup>-</sup>
<b>Respiratory Acidosis</b>	normal, but <7.40	↑	↑

**Example 5**

John Doe is a trauma patient with an altered mental status. His initial arterial blood gas result is as follows:

Clinical Laboratory	
PATIENT:	JOHN DOE
DATE:	7/12/02 07:30
pH	7.33
PaCO <sub>2</sub>	62
HCO <sub>3</sub>	35
STAT LAB	

**Follow the three steps:**

1. Assess the pH. It is low (normal 7.35-7.45). This indicates that an acidosis exists.
2. Assess the PaCO<sub>2</sub>. It is high (normal 35-45). The pH and PaCO<sub>2</sub> are moving in opposite directions, as we would expect if the problem were primarily respiratory in nature.
3. Assess the HCO<sub>3</sub>. It is high (normal 22-26). Normally, the pH and HCO<sub>3</sub> should move in the same direction. Because they are moving in opposite directions, it also confirms that the primary acid-base disorder is respiratory in nature. In this case, the kidneys are attempting to compensate by retaining HCO<sub>3</sub> in the blood in an order to return the pH back towards its normal range. Because there is evidence of compensation occurring (pH and HCO<sub>3</sub> moving in opposite directions), and seeing that the pH has not yet been restored to its normal range, we would interpret this ABG result as a *partially compensated respiratory acidosis*.



**Example 6**

Jane Doe is a 54-year-old female admitted for an ileus. She had been experiencing nausea and vomiting. An NG tube has been in place for the last 24 hours. Here are the last ABG results:

Clinical Laboratory	
PATIENT:	Jane Doe
DATE:	3/19/02 07:30
pH	7.43
PaCO <sub>2</sub>	48
HCO <sub>3</sub>	36
STAT LAB	

**Follow the three steps:**

1. Assess the pH. It is normal, but on the high side of neutral (>7.40).
2. Assess the PaCO<sub>2</sub>. It is high (normal 35-45). Normally, we would expect the pH and PaCO<sub>2</sub> to move in opposite directions. In this case, they are moving in the same direction indicating that the primary acid-base disorder is metabolic in nature. In this case, the lungs, acting as the primary acid-base buffer system, are retaining CO<sub>2</sub> (hypoventilation) in order to help lower the pH back towards its normal range.
3. Assess the HCO<sub>3</sub>. It is high (normal 22-26). Because it is moving in the same direction, as we would expect, it confirms the primary acid-base disorder is metabolic in nature.

	pH	PaCO <sub>2</sub>	HCO <sub>3</sub> <sup>-</sup>
<b>Metabolic Alkalosis</b>	Normal, but >7.40	↑	↑

What is your interpretation? Because there is evidence of compensation occurring (pH and PaCO<sub>2</sub> moving in the same direction) and because the pH has effectively been returned to within its normal range, we would call this *fully compensated metabolic alkalosis*.

## 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<sub>2</sub>. Remember that the normal blood PaO<sub>2</sub> value is 80-100 mm Hg.

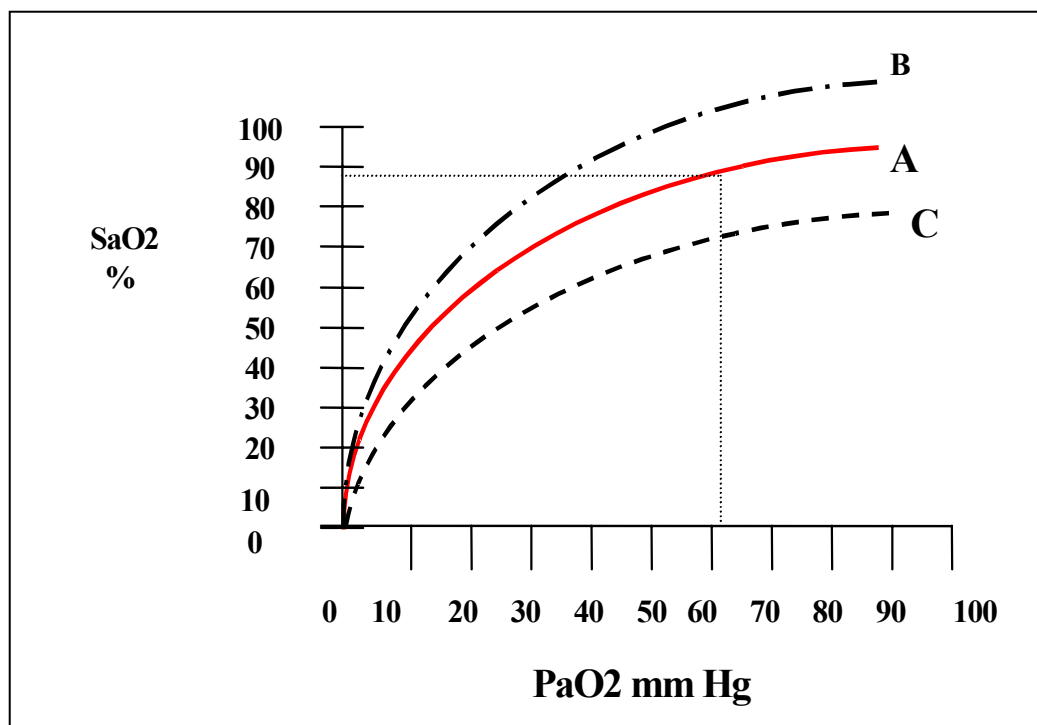
## Oxyhemoglobin Dissociation Curve

The oxyhemoglobin dissociation curve is a tool used to show the relationship between oxygen saturation and the PaO<sub>2</sub>.

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<sub>2</sub> 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<sub>2</sub>, 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.

The oxyhemoglobin dissociation curve can be used to estimate the PaO<sub>2</sub> 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<sub>2</sub> of about 60 mm Hg. With a left shift, the same saturation is equivalent to a much lower PaO<sub>2</sub>.



If evaluation of blood oxygenation is required, you can assess this by adding one additional step to your arterial blood gas analysis (Steps One, Two, and Three on page 9):

#### **Step Four**

Assess the PaO<sub>2</sub>. 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.

## 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 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 pleural 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.



**Education & Development Answer Sheet**

Complete all lines and PLEASE PRINT

Orlando Regional Healthcare Employee: ( ) No ( ) Yes

Employee # \_\_\_\_\_

Date \_\_\_\_\_

Last Name \_\_\_\_\_

First Name \_\_\_\_\_

If employee, Department Name & Number \_\_\_\_\_

Street Address \_\_\_\_\_

City \_\_\_\_\_

State \_\_\_\_\_

Zip \_\_\_\_\_

( ) RN ( ) LPN ( ) Rad Tech ( ) Other \_\_\_\_\_

License # \_\_\_\_\_

Darken the correct circle, you may use pencil or black ink

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>		<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
1.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	26.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	27.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	28.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	29.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	30.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	31.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	32.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	33.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	34.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	35.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	36.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	37.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	38.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	39.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	40.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	41.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	42.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	43.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	44.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	45.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	46.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	47.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	48.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	49.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	50.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please also complete the self-learning packet evaluation at the end of the packet.

In order to receive 2.0 contact hours, you must:

- Submit the answer sheet and payment (\$5.00 for Orlando Regional Healthcare employees / \$10.00 for non-employees) to:  
Orlando Regional Healthcare  
Education & Development, MP 14  
1414 Kuhl Ave.  
Orlando, FL 32806
- Achieve an 84% on the posttest. (You will be notified if you do not pass and will be asked to retake the posttest.)

**Posttest**

**Directions:** Complete this test using the answer sheet provided.

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<sub>2</sub>
  - B. H<sub>2</sub>O
  - C. H<sub>2</sub>CO<sub>3</sub>
  - D. HCO<sub>3</sub>
  
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 except:
  - 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<sub>3</sub>
  - B. Base excess
  - C. PaO<sub>2</sub>
  - D. pH

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<sub>2</sub> 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<sub>3</sub> will move:
- A. In opposite direction
  - B. Totally independent of each other
  - C. In the same direction
11. The oxyhemoglobin dissociation curve represents the relationship between the:
- A. O<sub>2</sub> saturation and hemoglobin level
  - B. O<sub>2</sub> saturation and PaO<sub>2</sub>
  - C. PaO<sub>2</sub> and the HCO<sub>3</sub>
  - D. PaO<sub>2</sub> and the pH
12. On the normal oxyhemoglobin curve, if the O<sub>2</sub> saturation is 88%, it would correlate with a PaO<sub>2</sub> 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                      PaCO<sub>2</sub> 60                      HCO<sub>3</sub> 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                      PaCO<sub>2</sub> 42                      HCO<sub>3</sub> 30
- A. Metabolic acidosis without compensation
  - B. Respiratory alkalosis with partial compensation
  - C. Respiratory alkalosis with full compensation
  - D. Metabolic alkalosis without compensation

15. pH 7.38                      PaCO<sub>2</sub> 38                      HCO<sub>3</sub> 24  
A. Respiratory alkalosis  
B. Normal  
C. Metabolic Alkalosis  
D. None of the above
16. pH 7.21                      PaCO<sub>2</sub> 60                      HCO<sub>3</sub> 24  
A. Normal  
B. Respiratory acidosis without compensation  
C. Metabolic acidosis with partial compensation  
D. Respiratory acidosis with complete compensation
17. pH 7.48                      PaCO<sub>2</sub> 28                      HCO<sub>3</sub> 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                      PaCO<sub>2</sub> 29                      HCO<sub>3</sub> 24  
A. Normal  
B. Respiratory acidosis with compensation  
C. Respiratory alkalosis without compensation  
D. Metabolic alkalosis with partial compensation
19. pH 7.28                      PaCO<sub>2</sub> 40                      HCO<sub>3</sub> 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                      PaCO<sub>2</sub> 26                      HCO<sub>3</sub> 16  
A. Normal  
B. Respiratory acidosis fully compensated  
C. Respiratory alkalosis fully compensated  
D. Metabolic alkalosis fully compensated



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### Self-Learning Packet Evaluation

Name of Packet: \_\_\_\_\_ Date: \_\_\_\_\_

Employee  Non-Employee

**Your position?**

RN  LPN  Respiratory  Radiology   
Lab  Social Work  Rehab  Clin Tech




Other: \_\_\_\_\_

**If RN/LPN, which specialty area?**

Med/Surg  Adult Critical Care  OR/Surgery  ED   
Peds  Peds Critical Care  OB/GYN  L&D   
Neonatal  Behavioral Health  Cardiology  Oncology

Other: \_\_\_\_\_

**Please take a few moments to answer the following questions by marking the appropriate boxes.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5) The course was:  Mandatory  Optional

- 1) The content provided was beneficial.
- 2) The packet met its stated objectives.
- 3) The packet was easy to read.
- 4) The posttest reflected the content of the packet.

**Please answer the following questions:**

How long did this packet take you to complete? \_\_\_\_\_

What have you learned that you will apply in your work? \_\_\_\_\_

What was the best part of the packet? \_\_\_\_\_

What would you suggest be done differently? \_\_\_\_\_

**Additional Comments:**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Thank you for your input.

Please return this evaluation to **Education & Development**, either in person or by mail:  
**Mailpoint #14, 1414 Kuhl Avenue, Orlando, FL 32806**