Arterial Blood Gas

Information Booklet

An information package to assist the novice practitioner in the interpretation of arterial blood gas interpretation and acid-base balance.
LEARNING OBJECTIVES

On completion of this learning package you will be able to:

1. State the component parts considered in Arterial Blood Gas (ABG) analysis.
2. Identify the normal ranges of ABG components and the significance of deviation from the normal.
3. Outline the steps in determining acid-base balance.
4. Discuss the nursing implications in the care of patients with altered acid base status.
5. Interpret ABGs accurately.

If you believe you have already mastered this skill, test yourself with the TEST PAPER provided on PAGE 17.

If you are unable to complete the test, continue with the Learning Package.

GOOD LUCK!
Evaluating arterial blood gas (ABG) studies is probably not one of your favourite nursing responsibilities. Fluctuations in pH, PaCO₂ and HCO₃, which reflect the body’s delicate checks on acid-base levels, can be very bewildering.

The meaning of all those numbers has a way of seeming perfectly clear one minute, then slipping away into confusion the next. What you need is an easy way to interpret ABG values – if not at a glance, then as quickly as possible. One method consists of four simple steps. It is easy to learn and, if used consistently, can soon become second nature.
DEFINITIONS

\( P \) = partial pressure, \( a \) = arterial blood. Therefore, an example of this would be \( \text{PaCO}_2 \), which measures the partial pressure that the gas (carbon dioxide), exerts on the fluid (arterial blood) in which it is carried.

**Acid:** A proton or hydrogen ion donor.

**pH:** Measurement of hydrogen ions. On a scale of 0 – 14, the normal pH value in humans is 7.40 (range is 7.35 – 7.45). The higher the number of hydrogen ions, the lower the pH value. The lower the number of hydrogen ions, the higher the pH value.

**Base:** A proton or hydrogen ion acceptor. Bicarbonate (\( \text{HCO}_3^- \)) accounts for the largest amount of base in the body and the remaining bases are comprised of haemoglobin, protein and phosphate (reflected as base excess/deficit). \( \text{HCO}_3^- \) levels are regulated by the kidneys.

**Carbon Dioxide (CO\(_2\)):** Byproduct of metabolism. Excretion is via the lungs and it takes part in the bicarbonate-carbonic acid buffering system:

\[
\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\]

Respiratory component of arterial blood gases = \( \text{PaCO}_2 \) and \( \text{PaO}_2 \).  
Metabolic component of arterial blood gases = \( \text{HCO}_3^- \) and Base Excess.

**SaO\(_2\):** Value obtained on haemoglobin saturation of oxygen in arterial blood.
STEP 1
EVALUATE EACH NUMBER SEPARATELY

To demonstrate how this method works, let’s go right to a set of ABG values. This patient is 70 years of age, with a history of chronic, heavy smoking. He has a pH of 7.35, a PaCO₂ of 64 mmHg and an HCO₃ (bicarbonate) level of 33 mEq/L. The first thing you want to do is take each number separately and ask yourself: Is this a normal value or does it indicate acidity or alkalinity?

The pH of 7.35 falls, just barely, within the normal range of 7.35 to 7.45. Remember, that pH reflects regulation of hydrogen ions, the body’s principal means of maintaining acid-base balance. A low pH means a high concentration of hydrogen ions, indicating acidity: a high pH means a low concentration, indicating alkalinity.

The PaCO₂ of 64 mmHg is well above the normal range of 35 – 45mmHg. PaCO₂ is the partial pressure of carbon dioxide in the blood and reflects alveolar ventilation. A high PaCO₂ indicates acidity: carbon dioxide is being retained by the lungs through hypoventilation. A low PaCO₂ indicates alkalinity – the patient is hyperventilating, blowing off carbon dioxide. So, your patient’s reading of 64 mmHg shows acidity.

The HCO₃ is also elevated (normal range is 22 to 26 mEq/L). But with HCO₃, of course, the significance of an elevated reading is just the opposite of an elevated PaCO₂. A high HCO₃ indicates alkalinity: a low reading indicates acidity.

So, the results of this first step in evaluating ABGs are: normal pH, an acidic PaCO₂ and an alkaline HCO₃.

STEP 2
DETERMINE THE CAUSE OF THE IMBALANCE

For this step, you may only have to look at one number: pH. The pH will usually tell you whether the primary cause of the patient’s problem is acidosis or alkalosis. If it’s above 7.45, the primary cause is alkalosis: if it’s below 7.35, the primary cause is acidosis.

If the pH is within the normal range, but the patient’s PaCO₂ or HCO₃ is abnormal, use 7.40 as your cut-off point. In other words, a pH between 7.35 and 7.40 indicates acidosis: between 7.40 and 7.45, alkalosis. So the pH in our example (7.35) tells you that your patient’s primary problem is acidosis.

What if the patient’s pH is 7.40 exactly? Then you’d have to consider his condition and history to help determine his acid-base status. In fact, this is something you’ll want to check regardless of his pH (we’ll talk a little more about this in a minute).
STEP 3
DETERMINE IF THE PROBLEM IS RESPIRATORY OR METABOLIC

For this step, all you have to do is check the PaCO\(_2\) and HCO\(_3\) levels to see which one has the same acid-base status as the pH. Step 2 told you that your patient’s pH of 7.35, though within the normal range, reflects acidosis. So does the PaCO\(_2\) reading of 64 mmHg. Since PaCO\(_2\) is the respiratory component of ABG values, you can conclude that this patient’s primary problem is respiratory acidosis. (HCO\(_3\), regulated by the kidneys, is the metabolic component)

STEP 4
DETERMINE THE EXTENT OF COMPENSATION

Compensation for an acid-base imbalance may be absent, partial or complete. Use these guidelines to determine the extent of your patient’s compensation.

**Remember:** The respiratory system should respond to changes to the pH immediately. Think about what happens when you run up the stairs – increased metabolism results in a decrease in pH (acidity) and you compensate by increasing your minute ventilation. However, metabolic compensation (renal response) does not occur for hours to days, therefore you will not see any immediate metabolic compensation for an acute respiratory acidosis as the kidneys have not had time to adjust.

**Absent:** look at the value (PaCO\(_2\) or HCO\(_3\)) that does not match the acid-base status of the patient’s pH. If it is within the normal range, then no compensation has taken place. In our example, the value that doesn’t match the acid-base status of the patient’s pH is the HCO\(_3\). But, at 33 mEq/L, it is well above the normal range, so you know that some compensation exists.

**Partial:** If the value doesn’t match the acid-base status of the pH, is above or below normal and the pH itself is also outside the normal range, then partial compensation exists. In our example, HCO\(_3\) is above normal, but the pH is within the normal range.

**Complete:** Complete compensation exists when the value that doesn’t match the pH status is above or below normal and the pH is within the normal range. That’s exactly the case with our example. The HCO\(_3\) is above normal at 33 mEq/L, but the pH of 7.35 is within the normal range. This tells you that the kidneys have completely compensated for the respiratory acidosis by retaining bicarbonate ions.

Since complete compensation takes some time to develop, the underlying condition responsible for the set of ABG values, that we have been studying, can be identified as chronic respiratory acidosis or, to be more precise: A primary respiratory acidosis with complete metabolic compensation.
PaO₂
That’s the first mention of PaO₂. Though not strictly necessary for the four-step method of analysis, you should always check your patient’s PaO₂ in the **first instance** since uncorrected hypoxaemia can cause acid-base imbalances and starve the brain and organs of oxygen. As you know, PaO₂ measures arterial blood oxygenation. Normal PaO₂ for an adult under 60 years of age is around 80 – 105 mmHg on room air. The normal range for a person over this age is somewhat lower since lung compliance decreases with age.

If the 70-year-old patient in our example has a PaO₂ of 55 mmHg on room air, it would indicate hypoxaemia. Such a finding is consistent with a diagnosis of chronic airways limitations (CAL) i.e. high PaCO₂ and low PaO₂ levels. In this case, because the patient is unable to exhale the carbon dioxide, the complaint is a chronic one. The kidneys would have had time to retain more bicarbonate ions so the bicarbonate level would be high (as is the case in our sample ABG) and the pH would be within the parameters of 7.35 – 7.45. Therefore, there is complete compensation.

**LOOK AT THE TOTAL PICTURE**

Always take into account the patient’s condition and history. If you overlook this important consideration, you may misinterpret the ABG values. Remember, numbers alone don’t tell the whole story.

Does your interpretation fit the patient’s history and other assessment findings? The ABG values we just analysed, for example, were those of a patient who has CAL. It causes inadequate diffusion of carbon dioxide and oxygen across the alveolar membrane resulting in hypercapnia (elevated CO₂) and hypoxaemia (low PaO₂).
The aim of the body’s acid-base and respiratory functions are to maintain a homeostatic environment which usually means a ‘war’ against the accumulation of $H^+$ ions. These accumulate as a result of cellular metabolism, muscle breakdown and ingested foods.

The key to understanding the body’s response to an acid-base imbalance is hydrogen ion concentration. As free hydrogen ions accumulate, pH falls and the body’s pH trends towards acidaemia.

In response, the body can do three things. Bicarbonate can combine with some of the free hydrogen to form carbonic acid. Carbonic acid will then break down into carbon dioxide and water to be exhaled as expired gas.

$$H^+ + HCO_3^- \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_2O$$

This is the body’s chemical buffer system at work, reacting to a change in hydrogen ion concentration. Other buffers are red blood cells, proteins and phosphates.

The respiratory system does its part by getting rid of excess carbon dioxide. In the medulla, neurones are highly sensitive to changes in the pH. Also, in the peripheral system, peripheral chemoreceptors are stimulated by changes in pH. If the pH decreases, the respiratory centre increases the rate of breathing to ‘blow off’ excess $CO_2$.

The liver plays a large role in regulating pH. Lactate, produced as a result of anaerobic metabolism, is taken to the liver where it takes part in certain cellular functions and is eventually released from the liver as bicarbonate.

The renal system, which is slower to respond, excretes hydrogen ions in exchange for sodium ions. Bicarbonate is reabsorbed with the sodium ions. This gives a net loss of hydrogen ions and a net gain of bicarbonate ions. Fixed acids – i.e. those that cannot be exhaled by the lungs – are excreted via the kidneys where they attach to ammonia and phosphates which prevents them being reabsorbed.

In response to alkalaemia, the opposite occurs. The respiratory rate decreases to increase the level of hydrogen ions and the kidneys excrete bicarbonate.
RESPIRATORY ACIDOSIS

Let’s try another example. Mr Simpson, 74 years, is admitted to the ICU after suffering a cerebrovascular accident. On Mr Simpson’s third day in the unit you notice that he seems more lethargic than previously. You auscultate his lungs and find decreased air entry over the lower lobes. He is currently breathing room air.

A blood sample is drawn for ABG analysis. The results are: PaO$_2$ 59 mmHg, pH 7.33, PaCO$_2$ 55, HCO$_3$ 29. Now apply the four-step method to interpret these results:

**Look at the PaO$_2$. At 59 mmHg, this indicates hypoxia.**

**Step 1** Evaluate each number. The pH is below normal indicating acidity. The PaCO$_2$ is above normal, indicating acidity. The HCO$_3$ is above normal indicating alkalinity.

**Step 2** The pH is below 7.35. Therefore you know the primary cause of Mr Simpson’s acid-base imbalance is acidosis.

**Step 3** The PaCO$_2$ (respiratory component) matches the acid-base status of the pH, both indicating acidity. Therefore, Mr. Simpson’s imbalance is a primary respiratory acidosis.

**Step 4** The elevated HCO$_3$ indicates compensation but because the pH is below 7.35 you know it’s only partial compensation.

**INTERPRETATION: A primary respiratory acidosis with partial or incomplete metabolic compensation in a hypoxic patient.**

Looking at the total picture, you consider the patient’s history. A CVA is one possible cause of respiratory acidosis. In acute cases, of course, compensation would be absent. But Mr Simpson’s hypercapnia developed over several days and his kidneys had time to partially compensate.

Acute respiratory acidosis may also result from numerous conditions including drug overdose, aspiration, severe pneumonia, pneumothorax and pulmonary oedema. Other possible causes include neuromuscular diseases such as Guillain-Barre syndrome and Myasthenia Gravis.

Lethargy and other mental status changes such as confusion, disorientation and restlessness are key signs and symptoms associated with respiratory acidosis. Also, look for dyspnoea, tachycardia and arrhythmias.
RESPIRATORY ALKALOSIS

Ms McGee aged 19 years is a postoperative cholecystectomy patient. Because of her anxiety and pain, she hyperventilates when asked to sit in a chair or walk. She complains that she feels “pins and needles’ in her fingers. Her ABG values on room air are as follows: PaO₂ 104, pH 7.55, PaCO₂ 28, HCO₃ 24.

PaO₂: 104 mmHg is within normal limits.

The four step method tells you that Ms McGee’s pH and PaCO₂ indicate alkalinity and the HCO₃ is normal. The pH is above 7.45 so you know the primary cause of her imbalance is alkalosis. The match-up of pH and PaCO₂ indicates that it is a respiratory alkalosis. Finally, look at the bicarbonate level – it is within the normal range indicating that no attempt at compensation has been made.

INTERPRETATION: A primary respiratory alkalosis with no metabolic compensation in a patient with normal oxygen levels.

This condition results from alveolar hyperventilation that decreases PaCO₂, producing hypocapnia. The list of conditions that can cause respiratory alkalosis is as follows: Fear, pain, head trauma, brain tumour, hepatic insufficiency, salicylate intoxication, fever and incorrect mechanical ventilation parameters. Another possible cause is hypoxaemia caused by acute asthma, pneumonia, congestive heart failure, pulmonary embolus or severe anaemia.

Signs and symptoms vary with the severity of the hypocapnia. They include light-headedness, confusion, decreased concentration and, of course, hyperventilation. Parenthesis and tetanic spasms in the arm or legs may also occur.
METABOLIC ACIDOSIS

Mr Long, aged 54 years, has acute liver failure. His ABG results are: PaO$_2$ is 80 mmHg on a non-rebreather oxygen mask. pH 7.31 (below normal, indicating acidity) PaCO$_2$ 32 mmHg (below normal indicating alkalinity) and HCO$_3^-$ 17 (below normal indicating acidity).

**PaO$_2$:** Relative hypoxaemia as a non-rebreather mask will give approx 90% oxygen and the PaO$_2$ is only 80 mmHg.

The pH and the bicarbonate match, therefore the primary problem is a metabolic acidosis. The below normal CO$_2$ level means that some respiratory compensation is occurring, however it is not sufficient to completely correct the problem.

**INTERPRETATION:** A primary metabolic acidosis with partial or incomplete respiratory compensation with relative hypoxaemia.

Because Mr Long has an intact respiratory drive and is not fully compensating for the metabolic acidosis, you need to closely observe him as he may be going into respiratory failure.

Metabolic acidosis may be caused from an excess of hydrogen ions or a loss of bicarbonate ions.

Overproduction of organic acids may also result from anaerobic metabolism which produces lactate, keto acidosis (IDDM or prolonged starvation) renal failure (inability to excrete fixed acids) or ingestion of salicylates, methanol or paraldehyde. Conditions that result in bicarbonate loss include renal failure (unable to reabsorb or regenerate bicarbonate ions) diarrhoea and GIT fistulas. Acetazolamide is a diuretic drug that prevents the action of carbonic anhydrase – the enzyme that catalyses the formation of carbonic acid from CO$_2$ and water. This results in a loss of bicarbonate ions.

Signs and symptoms of metabolic acidosis include Kussmaul’s respirations, vasodilation, restlessness, stupor, seizures and possibly gastrointestinal signs e.g. nausea and vomiting. Hyperkalaemia may also be present due to the RBC buffering of H$^+$ ions that allows K$^+$ ions to diffuse out of the RBC into plasma.
METABOLIC ALKALOSIS

Mrs Norton is 78 years of age and has a history of gastric ulcers. She had been vomiting for several days before admission. A nasogastric tube was inserted and attached to suction.

Her ABG values are: PaO$_2$ 95 on room air, pH 7.52 (above normal, indicating alkalinity), PaCO$_2$ 49 mmHg (above normal indicating acidity), HCO$_3$ 40 (above normal, indicating alkalinity).

The PaO$_2$ is normal.

The pH tells you the primary problem is alkalosis. You know it's metabolic alkalosis because the HCO$_3$ matches the pH. Both the PaCO$_2$ and pH are outside the normal ranges, indicating partial compensation.

Interpretation: A primary metabolic acidosis with partial or incomplete respiratory compensation in a patient with normal oxygen levels.

Gastric volume depletion, whether from vomiting or nasogastric suctioning, causes a loss of hydrogen, chloride and potassium ions. Replacement therapy with sodium chloride and potassium chloride corrected Ms Norton’s imbalance.

Conditions that can cause metabolic alkalosis, besides vomiting and nasogastric suctioning, include chloride loss from diarrhoea, hyperaldosteronism, Cushing’s Syndrome, severe hypokalaemia and excessive alkali intake. Loop diuretics can cause metabolic alkalosis.

Signs and symptoms depend on the severity of the alkalosis. Disorientation, muscle twitches, tetany, hypoventilation and hypokalaemia may be present.
FAST AND EASY

Try this four-step method when analysing your patient’s ABG results. You’ll find it easy to use – and fast. With practice, the number of steps can quickly boil down to three or even two. For example, once you know that the pH reflects the patient’s primary problem (acidosis or alkalosis) you can easily incorporate Step 2 into Step 1. Likewise, looking for the match-up between the pH and the PaCO₂ or HCO₃ can be done at virtually the same time.

But, take it step-by-step. Soon the method will become second nature. In time, you may find yourself looking forward to analysing ABG studies, once you understand how simple it can be.

THE FOUR STEPS AT A GLANCE

The method for evaluating ABG values involves these four steps:

1. Evaluate each number. Does it indicate acidity or alkalinity?

2. Check the pH to determine the cause of the imbalance. If it’s above 7.45, the cause is alkalosis: below 7.35 it’s acidosis (if the pH is normal but the PaCO₂ and HCO₃ indicate an imbalance, use 7.40 as your cut-off point).

3. Find the value that matches the acid-base status of the pH. If the PaCO₂ matches, the problem is respiratory, if the HCO₃ matches, it’s metabolic.

4. Determine the extent of compensation as follows:

**Absent:** The value that doesn’t match the acid-base status of the pH is normal.

**Partial:** Both the values that don’t match the acid-base status of the pH and the pH itself are above or below normal.

**Complete:** The value that doesn’t match the acid-base status of the pH is above or below normal, but the pH is normal.
ARE YOU READY

TO TRY THIS FORMULA ON SOME EXAMPLES

GOOD!

LET'S GO
<table>
<thead>
<tr>
<th>pH</th>
<th>PaCO₂</th>
<th>PaO₂</th>
<th>HCO₃⁻</th>
<th>Base</th>
<th>SaO₂</th>
<th>Interpretation</th>
</tr>
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<tbody>
<tr>
<td>1)</td>
<td>7.49</td>
<td>32</td>
<td>112</td>
<td>24</td>
<td>0</td>
<td>97% on 30% O₂</td>
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<tr>
<td>2)</td>
<td>7.38</td>
<td>30</td>
<td>95</td>
<td>17</td>
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<td>94% on 50% O₂</td>
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<tr>
<td>3)</td>
<td>7.31</td>
<td>39</td>
<td>64</td>
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<td>4)</td>
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<td>88</td>
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<td>+3</td>
<td>94% on 60% O₂</td>
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<tr>
<td>5)</td>
<td>7.52</td>
<td>37</td>
<td>105</td>
<td>29</td>
<td>+6</td>
<td>96% on 21% O₂</td>
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<td>130</td>
<td>17</td>
<td>-8</td>
<td>99% on 25% O₂</td>
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<tr>
<td>7)</td>
<td>7.44</td>
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<td>96</td>
<td>32</td>
<td>+7</td>
<td>96% on 21% O₂</td>
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<td>8)</td>
<td>7.30</td>
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<td>75</td>
<td>29</td>
<td>+3</td>
<td>93% on 45% O₂</td>
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<td>9)</td>
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<td>66</td>
<td>17</td>
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<td>92% on 80% O₂</td>
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<td>10)</td>
<td>6.92</td>
<td>10</td>
<td>174</td>
<td>2</td>
<td>-27</td>
<td>99% on 35% O₂</td>
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</table>

**NORMAL VALUES**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>PH</td>
<td>7.35 to 7.45</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>35 to 45 mmHg</td>
</tr>
<tr>
<td>PaO₂</td>
<td>80 to 105 on room air</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>22 to 26 mEq/L</td>
</tr>
<tr>
<td>Base</td>
<td>+2 to –2</td>
</tr>
</tbody>
</table>

**HINT** - The above values all indicate an abnormality in respiratory and/or acid-base balance.
ANSWERS TO ABG ANALYSIS QUESTIONS

1) **Primary respiratory alkalosis with no metabolic compensation.** Oxygenation within normal limits. pH indicates alkalosis, PaCO₂ indicates alkalosis, HCO₃ and base are within normal limits – therefore, there is no compensation.

2) **Primary metabolic acidosis with complete respiratory compensation.** Oxygenation appears normal, however the inspired oxygen is 50%. pH is normal but on the acidic side of 7.40. HCO₃ and base indicate acidosis, CO₂ indicates alkalosis – a response that has bought the pH back to within normal limits

3) **Primary metabolic acidosis with no respiratory compensation.** PaO₂ of 64 on 90% oxygen indicates hypoxia. pH indicates acidosis, HCO₃ and base indicate acidosis, PaCO₂ is normal, therefore, no attempt at compensation. This patient is heading for respiratory failure due to the inability to respond to the metabolic acidosis by increasing respiratory effort and lowering PaCO₂.

4) **Primary respiratory acidosis with complete metabolic compensation.** PaO₂ of 88 on 60% inspired oxygen indicates poor oxygenation. pH is within normal limits (7.35 – 7.45), however it is less than 7.40, therefore, it points towards the primary problem being an acidosis. The PaCO₂ indicates acidosis and the HCO₃ and base indicate alkalosis – therefore there is full metabolic compensation as the pH is normal.

5) **Primary metabolic alkalosis with no respiratory compensation.** Oxygenation within normal limits. pH indicates alkalosis. The HCO₃ and base indicate alkalosis and the PaCO₂ is normal – therefore there is no respiratory compensation. The patient was sedated and mechanically ventilated, therefore he was unable to decrease his respiratory rate to allow the CO₂ to raise and compensation to occur.
6) **Primary metabolic acidosis with partial respiratory compensation.** Oxygenation is within normal limits. pH is low therefore it points towards the primary problem being an acidosis. The HCO$_3^-$ and base indicate acidosis, PaCO$_2$ indicates alkalosis – a response which has slightly altered the pH but not to the extent that the pH is normal.

7) **Primary metabolic alkalosis with complete respiratory compensation.** Oxygenation is normal. pH is within normal range but on the alkaline side of 7.40. HCO$_3^-$ and base indicate alkalosis. PaCO$_2$ indicates acidosis – a response that has altered the pH so that it is within normal limits.

8) **Primary respiratory acidosis with partial metabolic compensation.** Oxygenation is not optimal. pH indicates acidosis, PaCO$_2$ indicates acidosis, HCO$_3^-$ and base indicate alkalosis – a response that has altered the pH but not to the extent that pH is normal.

9) **Combined metabolic and respiratory acidosis.** Oxygenation is poor (PaO$_2$ 66mmHg on 80% inspired O$_2$). pH indicates acidosis, HCO$_3^-$, base and PaCO$_2$ all indicate acidosis. This patient is in respiratory failure as he/she should be hyperventilating to correct the pH.

10) **Primary metabolic acidosis with partial respiratory compensation.** Oxygenation is normal / oxygen can be reduced. pH indicates acidosis, HCO$_3^-$ and base indicate acidosis, PaCO$_2$ is well below normal – a response that has slightly altered the pH but not to the extent that pH is within normal limits. It is the body’s ability to dramatically reduce CO$_2$ that has kept this patient alive. This gas result can be seen with diabetic ketoacidosis.
ARTERIAL BLOOD GAS QUIZ

1. How is hydrogen ion concentration reflected in the pH?
   Low pH = ……… concentration of H⁺ ions in the blood.
   High pH = ……… concentration of H⁺ ions in the blood.

2. PaCO₂ is the partial pressure of carbon dioxide in the blood and reflects alveolar ventilation. What does a high PaCO₂ indicate?
   ________________________________________________________________
   ________________________________________________________________

3. What is the significance of HCO₃⁻?
   ________________________________________________________________
   ________________________________________________________________

4. What indicates whether a patient’s primary problem is acidosis or alkalosis?
   ________________________________________________________________
   ________________________________________________________________

5. How do you determine then, whether the problem is respiratory or metabolic?
   ________________________________________________________________
   ________________________________________________________________

6. Match the left column with the expected indicators in the right column.
   a) Respiratory Acidosis
      i) Low pH, Low PaCO₂
      ii) High pH, High PaCO₂
   b) Respiratory Alkalosis
      iii) Low pH, High PaCO₂
      iv) High pH, Low PaCO₂
   c) Metabolic Acidosis
      v) Low pH, Low HCO₃⁻
      vi) High pH, High HCO₃⁻
   d) Metabolic Alkalosis
      vii) Low pH, High HCO₃⁻
      viii) High pH, Low HCO₃⁻
7. Signs and symptoms of respiratory acidosis may include:


8. Determine what the following Arterial Blood Gases indicate and what level of compensation is present.

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>PaCO₂</th>
<th>HCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>7.53</td>
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<td>b)</td>
<td>7.49</td>
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<td>c)</td>
<td>7.36</td>
<td>58</td>
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<td>d)</td>
<td>7.29</td>
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<td>e)</td>
<td>7.25</td>
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<td>26</td>
</tr>
<tr>
<td>f)</td>
<td>7.45</td>
<td>47</td>
<td>34</td>
</tr>
</tbody>
</table>

a) 

b) 

c) 

d) 

e) 

f)
Q1. A low pH means a high concentration of hydrogen ions = acidaemia.

A high pH means a low concentration of hydrogen ions = alkalaemia.

Q2. A high PaCO₂ indicates acidaemia as a result of inadequate ventilation or as compensation for a metabolic alkalosis.

Q3. The HCO₃ levels are regulated by the kidneys and indicate the status of the metabolic component of acid-base status.

Q4. pH

Q5. PaCO₂ = respiratory.
HCO₃ = metabolic.
Look at the pH. Is it acid or alkaline? Look at the PaCO₂ and HCO₃. Find which one matches the pH.

Q6. a) iii vii  
b) iv viii  
c) i v  
d) vi ii

Q7. Lethargy, confusion, disorientation, restlessness, dyspnoea, tachycardia, arrhythmias.

Q8. a) Primary respiratory alkalosis - no metabolic compensation  
b) Primary metabolic alkalosis - partial respiratory compensation  
c) Primary respiratory acidosis - complete metabolic compensation  
d) Primary metabolic acidosis - partial respiratory compensation  
e) Primary respiratory acidosis - no metabolic compensation  
f) Primary metabolic alkalosis - complete respiratory compensation