# Blood Gas Master Class

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# At the end of this discussion, you will be able to:

1. *Differentiate* the clinical utility and indications for arterial blood gas, co-oximetry, and venous blood gas considering patient-specific factors

2. *Analyze* blood gas results using a step-wise approach rooted in thorough understanding of acid-base physiology

3. *Integrate* an accurate blood gas analysis into clinical scenarios to guide medical decision-making

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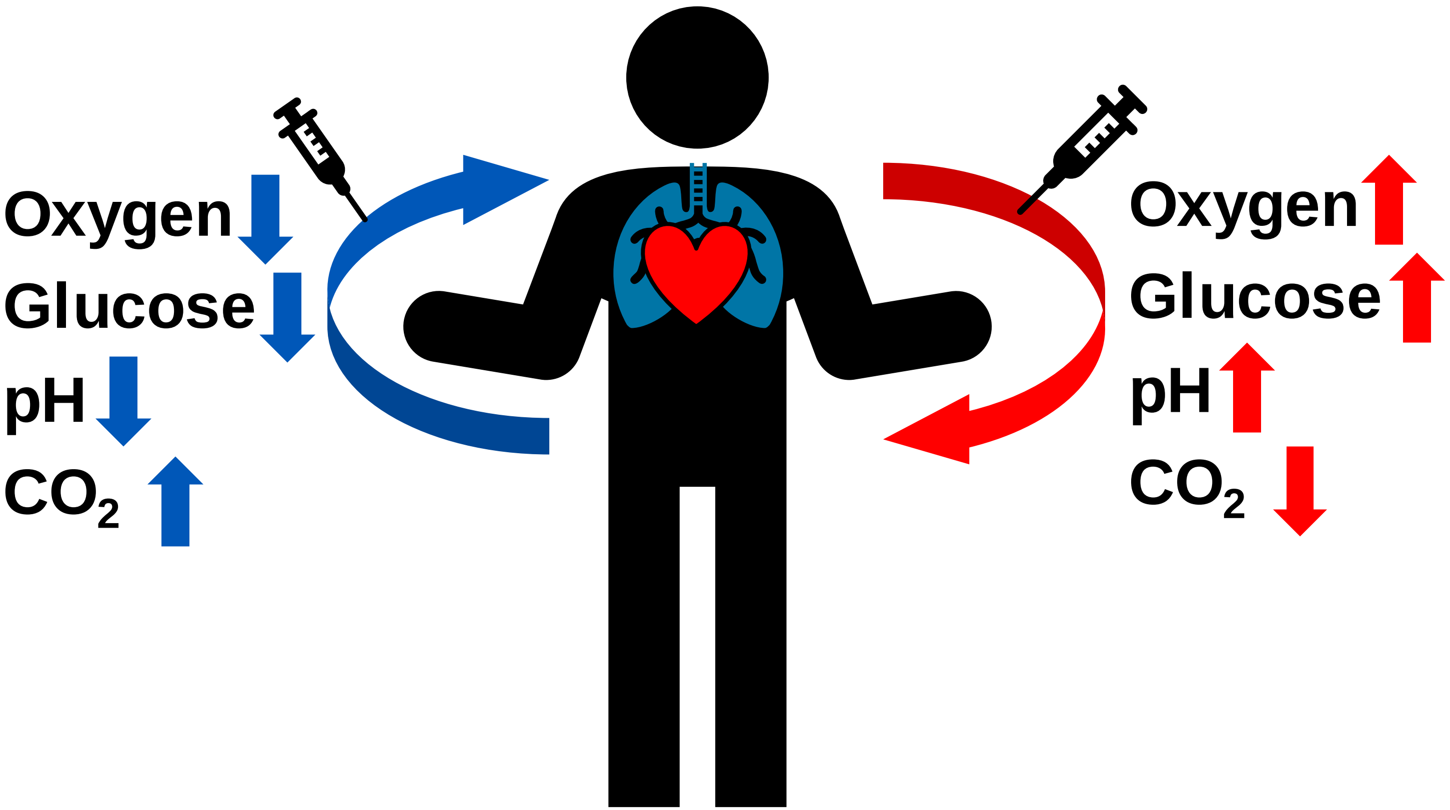
*Differentiate* the clinical utility and indications for arterial blood gas, co-oximetry, and venous blood gas considering patient-specific factors

# Components of a Blood Gas




| | | |
|---|---|---|
| Venous pO2 | Not applicable mm Hg | 26 |
| Venous pCO2 | 41 - 51 mm Hg | 47 |
| Venous pH | 7.32 - 7.43 pH | 7.39 |
| Venous Base Excess | Not applicable mmol/L | 3 |
| HCO3 | Not applicable mmol/L | 27 |
| Venous Sample Site | | Venipunct |
| pO2 | 83 - 108 mm Hg | **71** ⌄ |
| pCO2 | 35 - 48 mm Hg | 40 |
| pH | 7.35 - 7.45 pH | 7.41 |
| Base Excess | -2 - 3 mmol/L | 1 |
| HCO3 | 22 - 26 mmol/L | 25 |
| Arterial Sample Site | | R-Radial |
| Comment: Allen's test not done. | | |

# Arterial vs Venous Blood Gas

### Is there an oxygenation problem?

SPO2 works well for most patients. If there is a bad reading, or you need an A-a gradient consider an ABG

### Is hypercapnia driven by global hypoventilation or is there a component of intrinsic lung disease?

A-a gradient is only reliably assessed using an ABG

### What is the pH?

VBG accurately assesses pH (mean difference of 0.03)

### What is the $CO_2$?

VBG works well for $CO_2$ in most cases (mean difference 4 mmHg)*

Caution in shock: Significant heterogeneity in the Zeserson et al meta-analysis, animal models and clinical experience.

### Is there methemoglobinemia or carboxyhemoglobinemia?

COOX with either test is equally accurate

### Is there a mixed acid-base disorder?

HCO3 is mathematically derived from pH and *dissolved* CO2 in the blood gas resulting in a small discrepancy between measured and calculated HCO3

# Methemoglobinemia

**Pathophysiology:** oxidation of the heme sub-group from ferrous to ferric form, resulting in a left shift of the oxygen dissociation curve; this manifests clinically as decreased tissue oxygenation and refractory cyanosis.

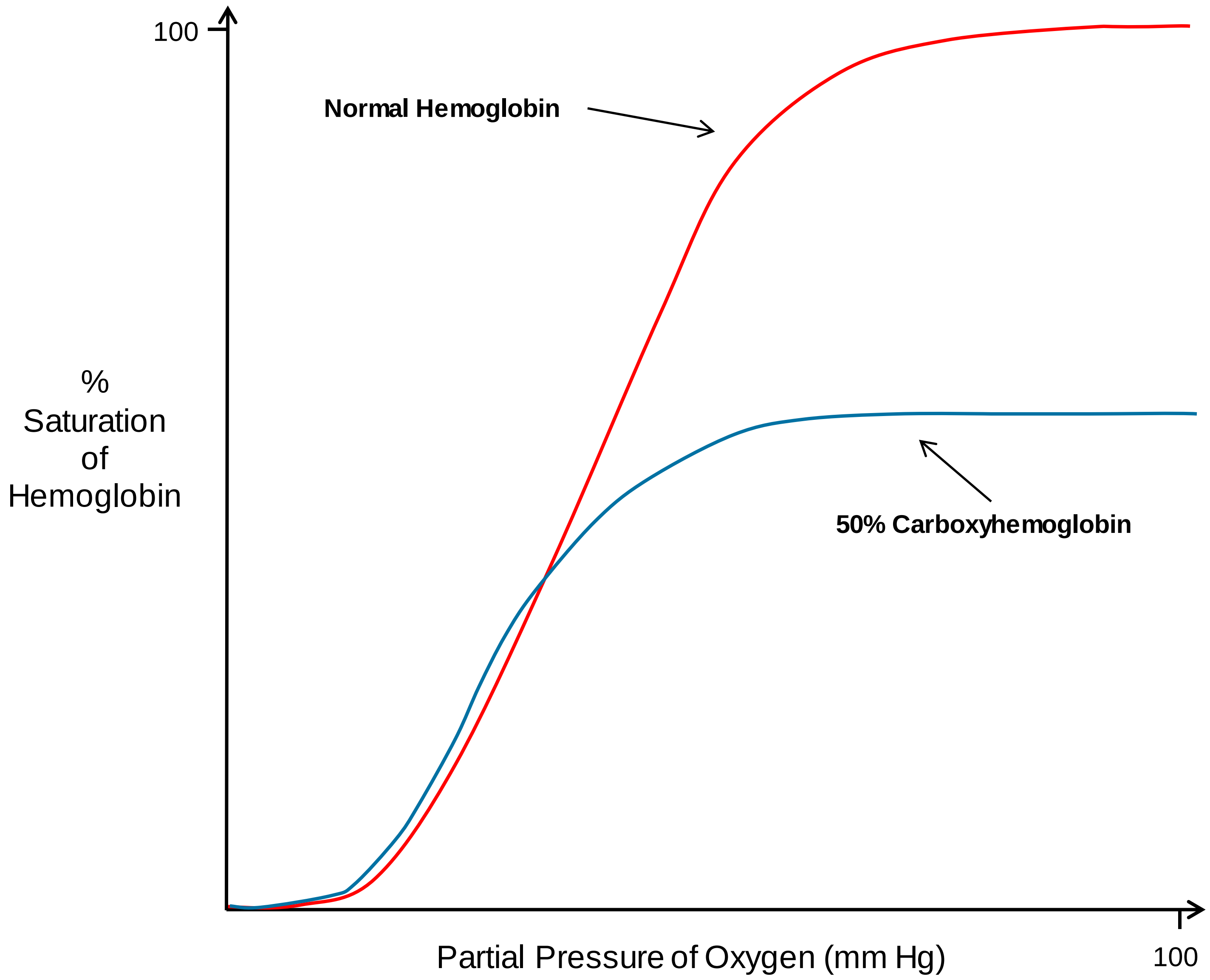
**Causes:**

- Congenital
- Drug induced (Dapsone and Benzocaine)Normal values less than 3% (10% for smokers)

- PaO2 will be normal, SPO2 will usually read about 85% regardless of actual oxygenation
- Normal values are 1-2%, higher levels when seen in conjunction with refractory cyanosis warrant treatment (methylene blue )

# Carboxyhemoglobinemia

- Shifts the oxygen dissociation curve of hemoglobin to the left and reduces the ceiling for oxygen saturation
- Standard pulse oximetry cannot distinguish between oxyhemoglobin and carboxyhemoglobin
- Normal values less than 3% (10% for smokers)
- Modest elevation (<25%) can usually be treated with high-flow oxygen; higher amounts may require hyperbaric oxygen therapy



# Sources of Error

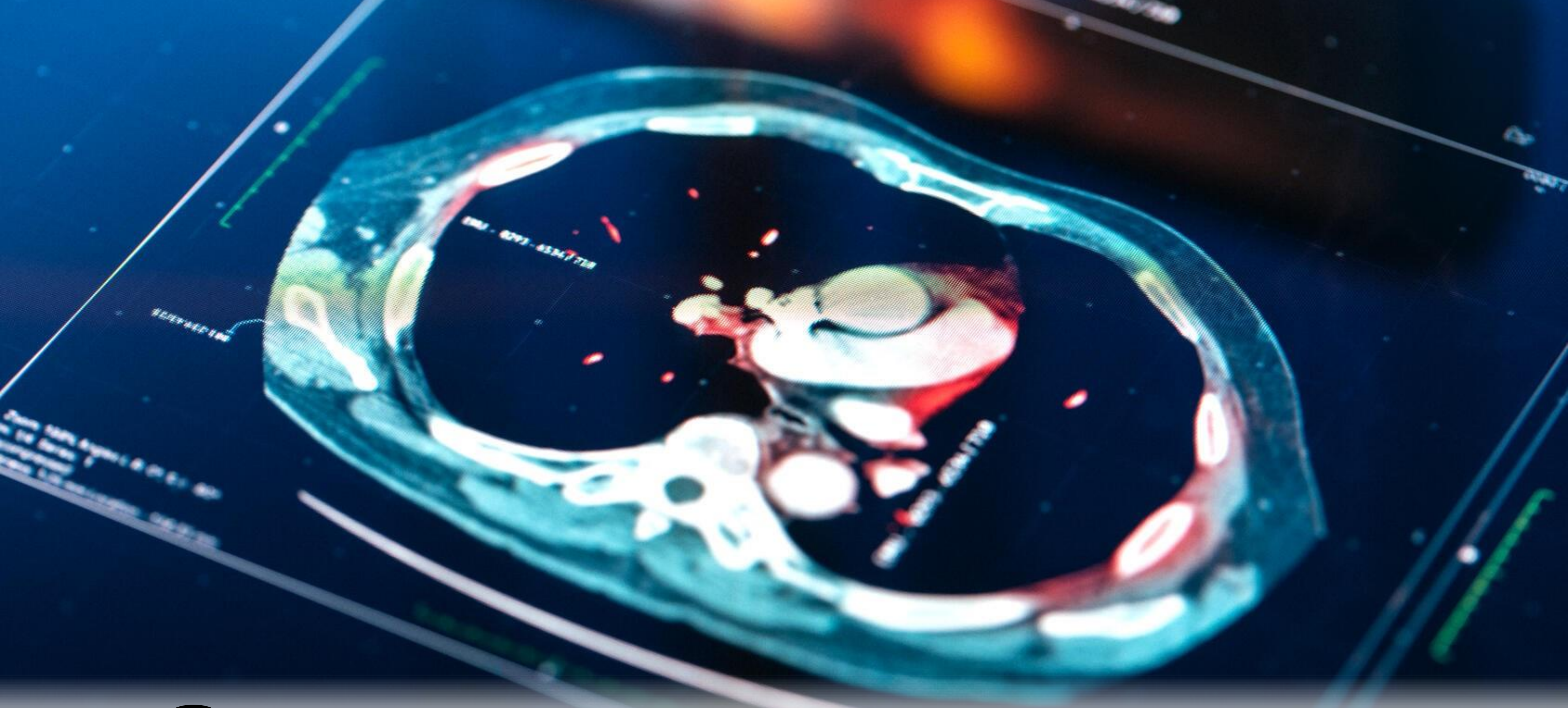
- Calibration error (very rare)

## Decreased PaO2

- Gas diffusion through tube
- Oxygen consumption by leukocytes and platelets
- Dilution secondary to excessive heparin in tube (very rare)
- Venous or mixed sample (common)

## Increased PaO2 or PaCO2

- Air bubbles in tube



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*Analyze* blood gas results using a step-wise approach rooted in thorough understanding of acid-base physiology

# 3 Players in pH Balance

Renal

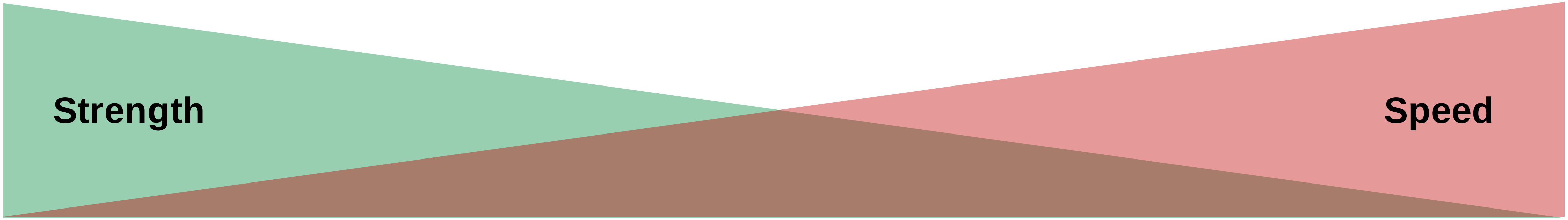
**Retention** and synthesis of bicarbonate

Respiratory

$CO_2 \leftrightarrow$ carbonic acid

Buffer System

HGB, phosphate, bicarbonate



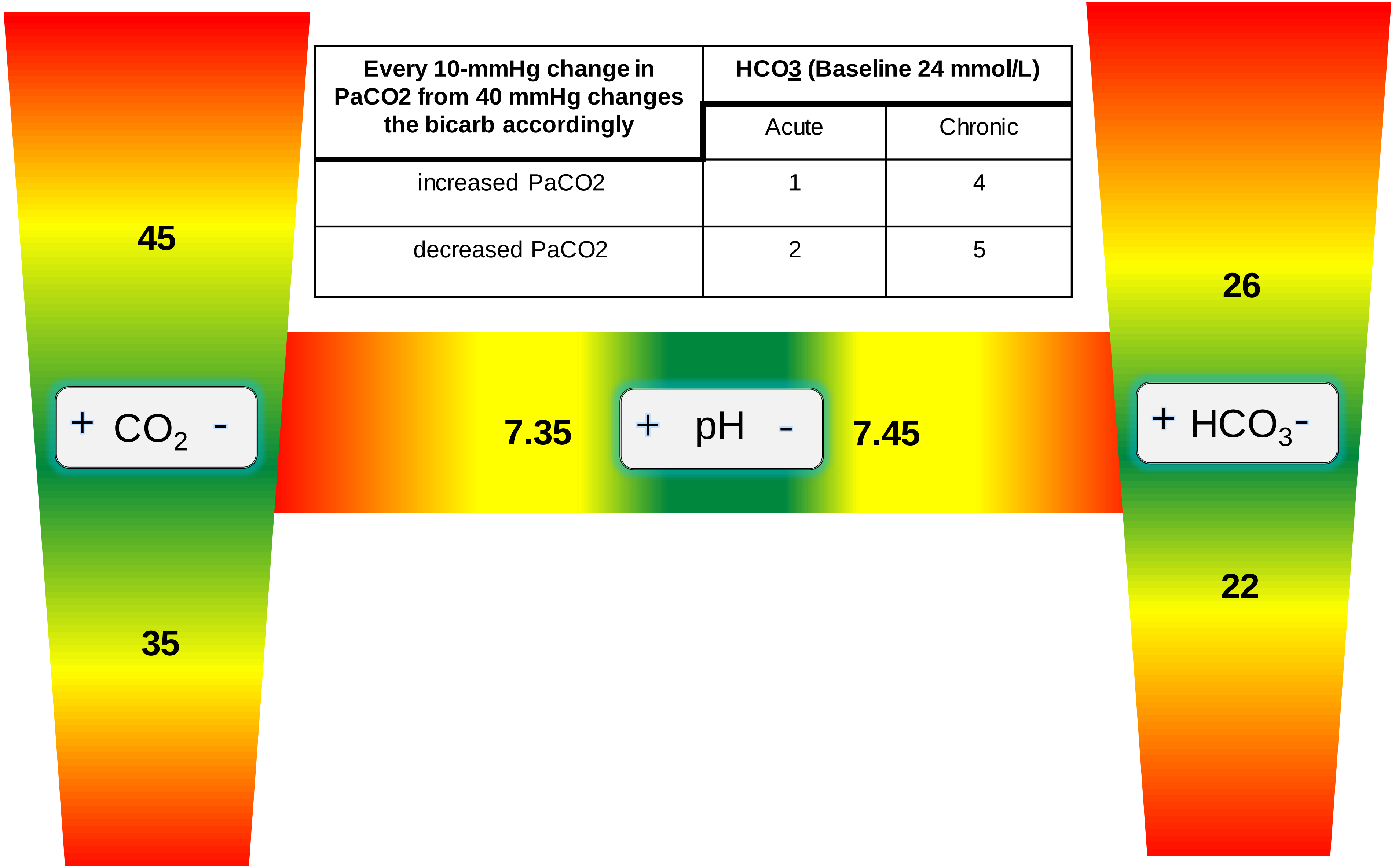
# Physiology of compensation

**Respiratory Acidosis**

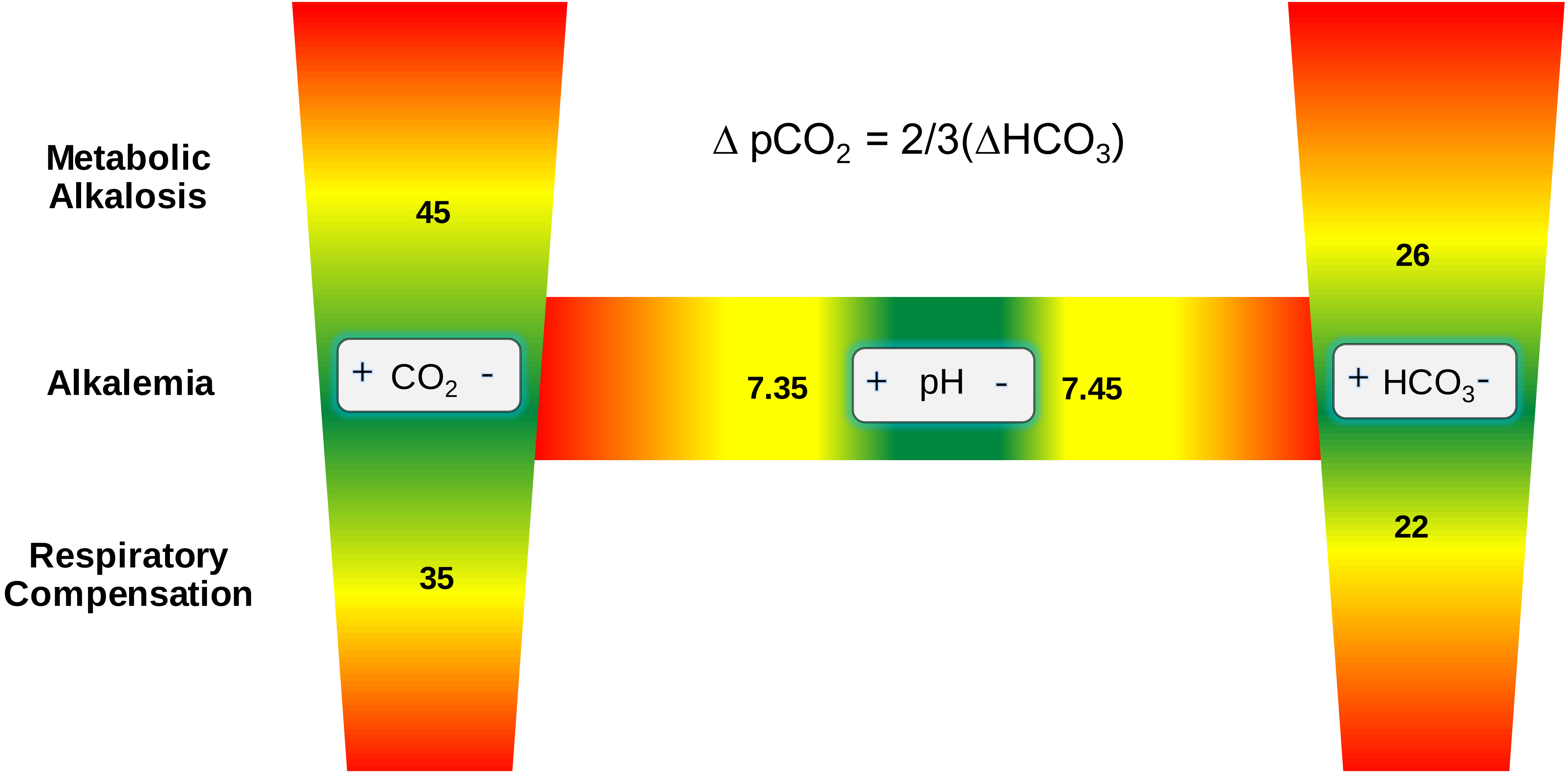
**Acidemia**

**Metabolic Compensation**

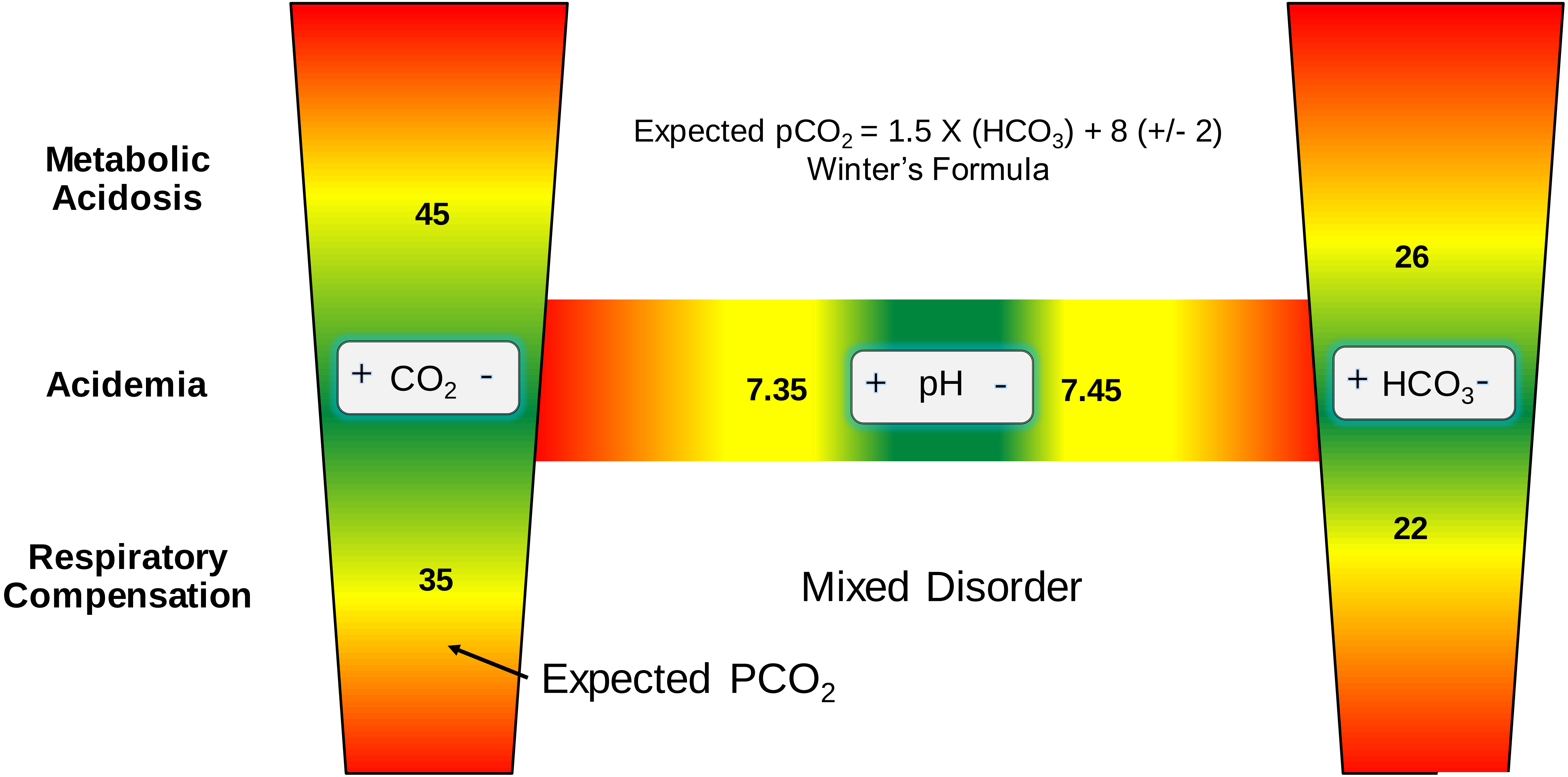
| Every 10-mmHg change in PaCO2 from 40 mmHg changes the bicarb accordingly | HCO3 (Baseline 24 mmol/L) | |
|---|---|---|
| | Acute | Chronic |
| increased PaCO2 | 1 | 4 |
| decreased PaCO2 | 2 | 5 |



# Physiology of compensation

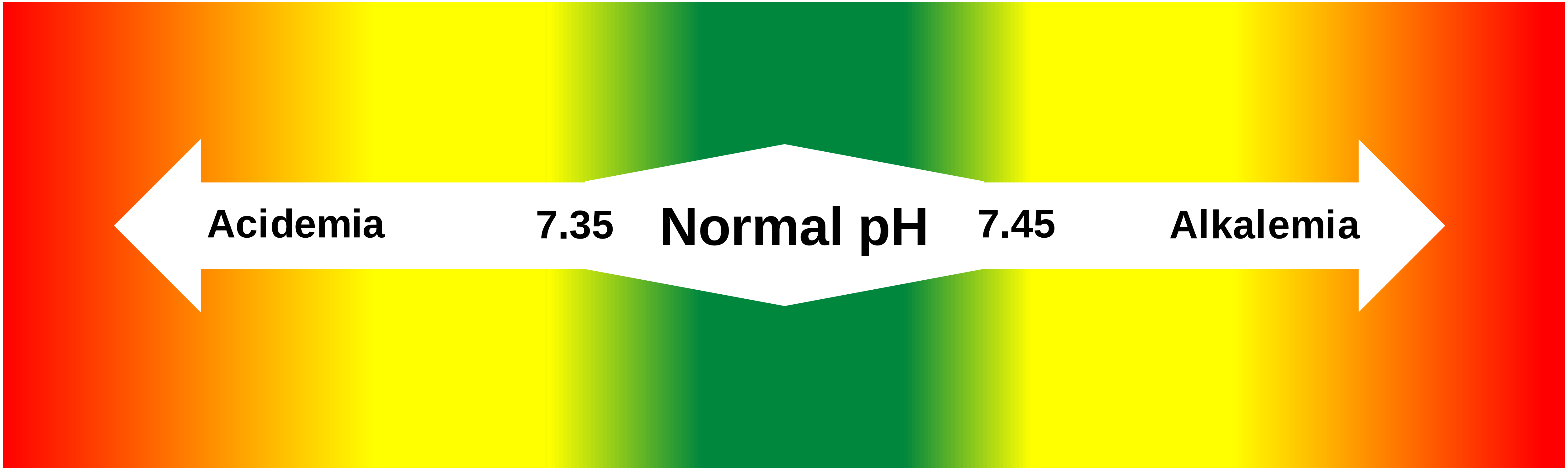


# Physiology of compensation



# Step 1

## Assess pH




Recall definitions of acidosis and alkalosis; if one of these conditions results in abnormal pH, it is called **acidemia** or **alkalemia**

# Step 2

Determine the primary disorder

**Look for either $PaCO_2$ or $HCO_3$ to be out of normal range, consider the clinical picture**

**If both are out of range, the primary disorder is the one that explains the pH disturbance**

**If both explain the pH disturbance, the primary disorder is the one most deranged**

# Determine the primary disorder

**ABG Normal Range**

**pH** 7.35-7.45

**$PaO_2$** 83-108 mmHg

**$PaCO_2$** 35-48 mmHg

**$HCO_3$** 22-26 mEq/L

**Name the pH abnormality**

**Is CO2 or bicarb driving this?**

| 7.2 ↓ | / | 22 ↓ | / | 68 | / | 20 ↓ |
| --- | --- | --- | --- | --- | --- | --- |
| pH | | $pCO_2$ | | $pO_2$ | | $HCO_3$ |

Metabolic Acidosis with acidemia

# Determine the primary disorder

**ABG Normal Range**

**pH** 7.35-7.45

**$PaO_2$** 83-108 mmHg

**$PaCO_2$** 35-48 mmHg

**$HCO_3$** 22-26 mEq/L

**Name the pH abnormality**

**Is CO2 or bicarb driving this?**

| 7.49 | / | 52 | / | 59 | / | 40 |
|---|---|---|---|---|---|---|
| pH ↑ | | $pCO_2$ ↑ | | $pO_2$ | | $HCO_3$ ↑ |

Metabolic Alkalosis with alkalemia

# Determine the primary disorder

**ABG Normal Range**

**pH** 7.35-7.45

$\mathbf{PaO_2}$ 83-108 mmHg

$\mathbf{PaCO_2}$ 35-48 mmHg

$\mathbf{HCO_3}$ 22-26 mEq/L

**Name the pH abnormality**

**Is CO2 or bicarb driving this?**

| 7.6 | / | 22 | / | 65 | / | 20 |
| --- | --- | --- | --- | --- | --- | --- |
| pH | | $pCO_2$ | | $pO_2$ | | $HCO_3$ |

Respiratory alkalosis with alkalemia

# Determine the primary disorder

**Normal Range**

**pH** 7.35-7.45

**PaO2** generally >80 mmHg

**PaCO2** 35-48 mmHg

**HCO3** 22-26 mEq/L

**Name the pH abnormality**

**Is CO2 or bicarb driving this?**

**Both increased $CO_2$ and decreased bicarb explain acidemia**

$pCO_2$: (40-50) / 40 = 25%

$HCO_3$: (24-19) / 24 = 20%

| 7.2 / | 50/ | 85 / | 19 |
|---|---|---|---|
| pH | pCO2 | pO2 | HCO3 |

**Which one is further from normal?**

Primary Respiratory Acidosis

Concomitant Metabolic Acidosis

# Step 3a

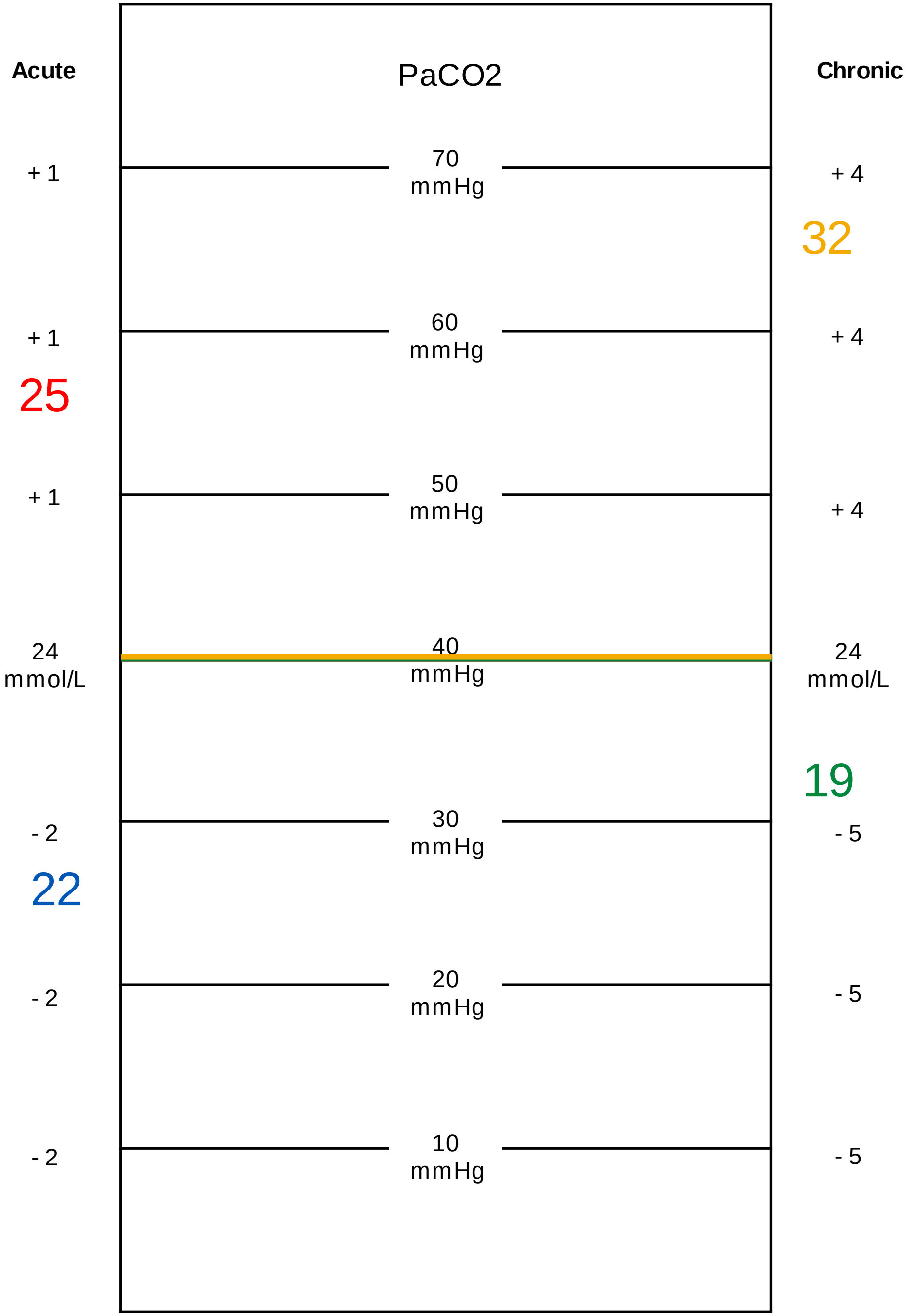
## Assess compensation – Respiratory Disorder

## 12345 Rule

| **Every 10-mmHg change in $PaCO_2$ from 40 mmHg changes the bicarb accordingly** | **HCO3 (Baseline 24 mmol/L)** | |
|---|---|---|
| | Acute | Chronic |
| increased PaCO2 | 1 | 4 |
| decreased PaCO2 | 2 | 5 |

What is the expected bicarb for a patient with:

1) An acute increase in PaCO2 to 54? 25
2) An acute decrease in PaCO2 to 23? 22
3) A chronic decrease in PaCO2 to 30? 19
4) A chronic increase in PaCO2 to 62? 32



# Step 3b

## Assess compensation – Metabolic Disorder

| Metabolic Acidosis | Metabolic Alkalosis |
|---|---|
| Expected $pCO_2 = 1.5 \times (HCO_3) + 8$ (+/- 2)<br>Winter's Formula | $\Delta$ $pCO_2 = 2/3(\Delta HCO_3)$ |

(Consider normal to be 40 and 24)

# Step 4

If there is a metabolic acidosis, calculate the anion gap

**Anion Gap**

Glycols
Oxoproline
L-Lactate
D-Lactate
Methanol
Aspirin
Renal failure (uremia)
Ketoacidosis

**Difference between anions and cations**

**(Na + K) - ( $HCO_3$ + Cl )**

**Normal Range is 8-16 mEq/L**

**Non Anion Gap**

GI losses
Ureteral Diversions
Renal Tubular Acidosis
Medications
  -Spironolactone
  -Amphotericin B

**This is used to narrow your differential**

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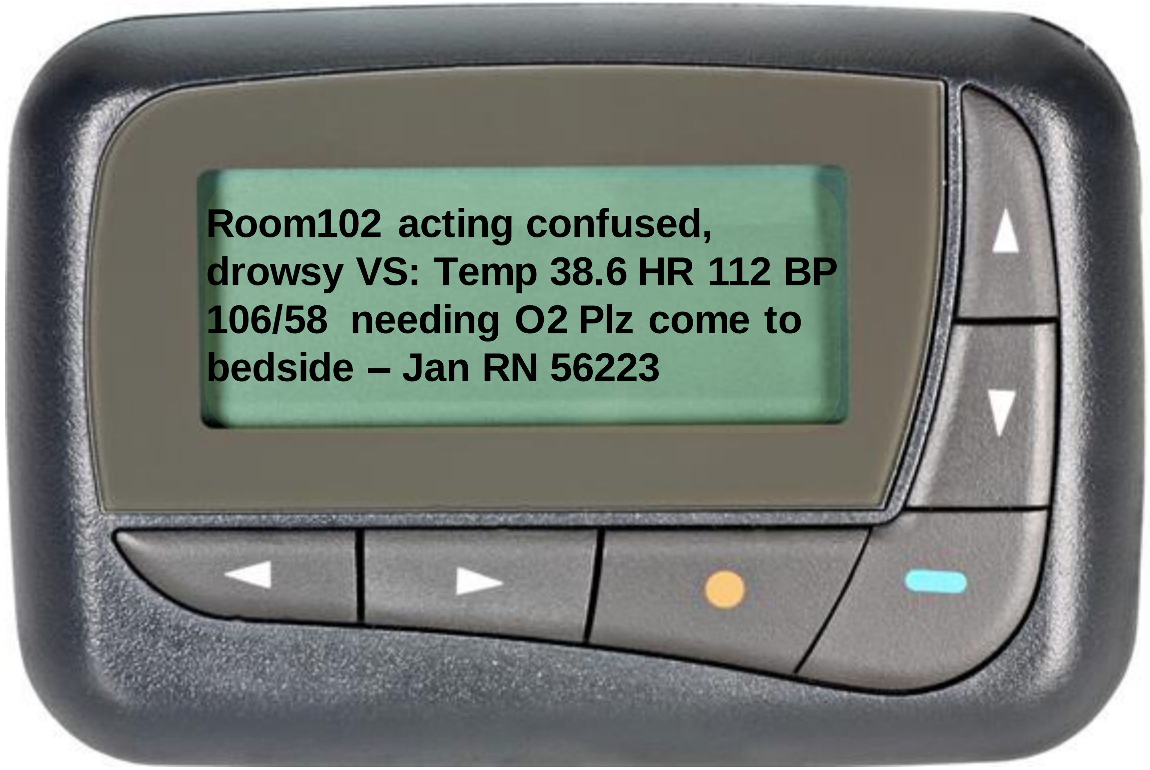
*Integrate* an accurate blood gas analysis into clinical scenarios to guide medical decision-making

# Practice Case

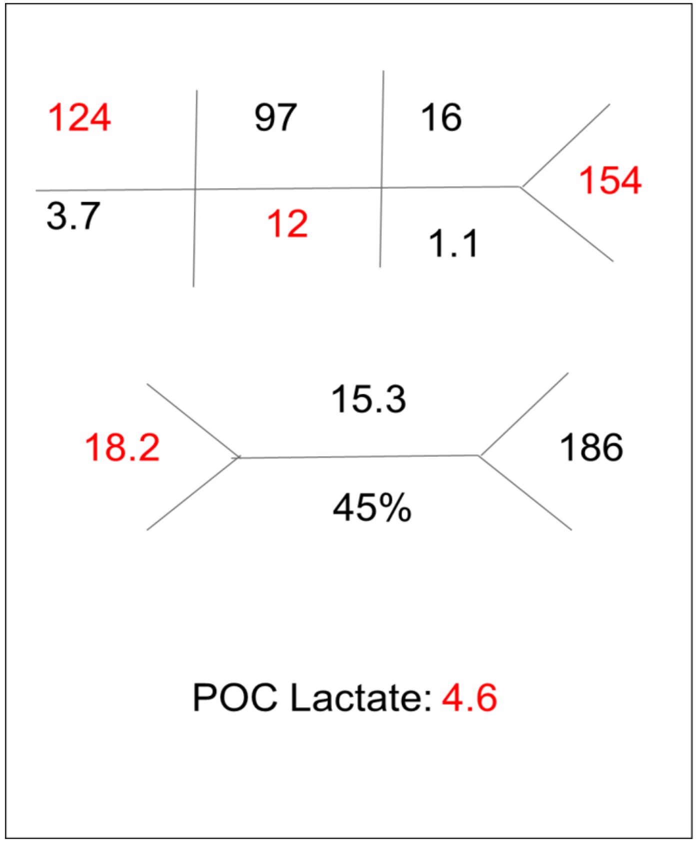

Room102 acting confused,
drowsy VS: Temp 38.6 HR 112 BP
106/58 needing O2 Plz come to
bedside – Jan RN 56223

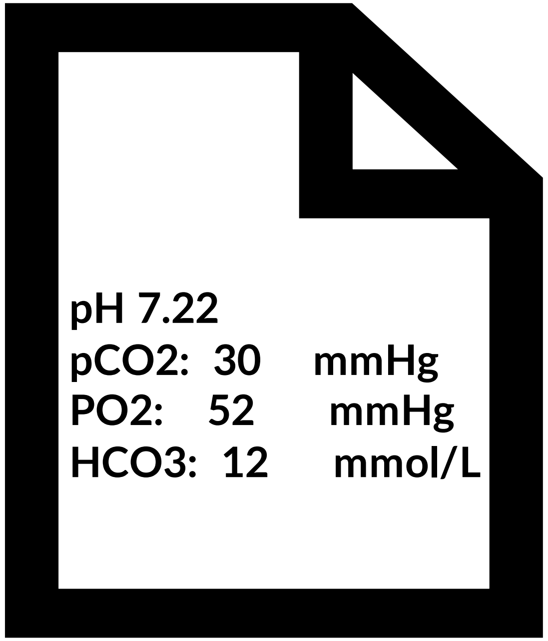
66-year-old woman admitted 3 hours earlier for pain related to kidney stones.

<u>Medical History</u>
HTN
COPD
OSA
Depression

<u>Meds</u>
lisinopril
acetaminophen
albuterol
oxycodone

# You are handed this….




# Practice case

**Normal Range**
**pH** 7.35-7.45
**$PaO_2$** generally >80 mmHg
**$PaCO_2$** 35-48 mmHg
**$HCO_3$** 22-26 mEq/L

## ABG

**pH** 7.22 ↓

**paO2** 52 ↓

**pCO2** 30 ↓

**HCO3** 12 ↓

Step 1
pH Disturbance?
pH < 7.35
↓
**Acidemia**

Step 2
Primary Disorder?

pH ↓

pCO2 ↓

↓
**Primary Metabolic Acidosis**

# Practice case

Step 3b
Check for mixed disorders
expected PaCO2 = (1.5 x [HCO3-]) +8

26 = (1.5 x [12]) +8

Expected PaCO2 is 26 +/- 2
Actual PaCO2 = 30

↓

**Mixed Disorder**
**(Primary metabolic acidosis with concomitant respiratory acidosis)**

Step 4
Calculate the Gap
(124+3)-(12+97) = 18

↓

**Anion gap metabolic acidosis**

## <u>ABG</u>

**pH** 7.22 ↓

**paO2** 52 ↓

**pCO2** 30 ↓

**HCO3** 12 ↓

# How did the blood gas analysis change management?

Recognizing hypercapnic respiratory failure, analgesia was reduced, and the patient received BiPAP in the ICU improving recovery.


# Thank You

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