Acid-base chemistry

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Key Concepts

Acid and Base Definitions:
- **Acid:** Donates a proton (H^+)
  - Example: HCl → $H^+ + Cl^-$
- **Base:** Accepts a proton
  - Example: $H^+ + NH_3 \rightarrow NH_4^+$
- **Acid–Base Pairs:**
  - Carbonic Acid/Bicarbonate (H_2CO_3/HCO_3^-)
  - Ammonium/Ammonia (NH_4^+/NH_3)
  - Monobasic/Dibasic Phosphate ($H_2PO_4^-/HPO_4^{2-}$)
  - Lactic Acid/Lactate ($C_3H_6O_3/C_3H_5O_3^-$)

Arrhenius Acids and Bases

$HCl \longrightarrow H^+ + Cl^-$

Acid - forms H^+ in water

$NaOH \longrightarrow Na^+ + {}^-OH$

Base - forms ^-OH in water

2. Acidemia vs. Alkalemia:
- **Acidemia:** Low pH (<7.35)
- **Alkalemia:** High pH (>7.45)
- **Acidosis and Alkalosis:** Processes of acid or alkali accumulation
  - *Note:* Acidosis can occur without acidemia if balanced by a corresponding alkalosis.

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pH: Key Points

Søren Sørensen first introduced the concept in 1909

Normal Range: 7.35 – 7.45

$$pH = -\log_{10}[H^+]$$

pH is a logarithmic measure of hydrogen ion concentration [H+] in a solution

each unit change in pH corresponds to a tenfold change in hydrogen ion concentration

Consequences of Abnormal pH:

- **Acidemia (pH < 7.35):**
  - Arterial vasodilation & venous vasoconstriction
  - Decreased myocardial contractility
  - Reduced hepatic & renal perfusion
  - Decreased oxygen-hemoglobin binding
  - Potential coma risk
- **Alkalemia (pH > 7.45):**
  - Cerebral vasoconstriction
  - Reduced myocardial contractility
  - Increased oxygen-hemoglobin binding (impaired O_2 delivery)
  - Potential coma risk

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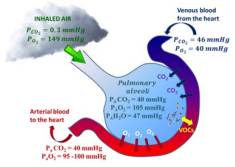
Arterial Partial Pressure of Carbon Dioxide ($PaCO_2$)

1. **Normal $PaCO_2$ Range: 35–45 mm Hg** (4.655–5.985 kPa)

2. Role of $PaCO_2$ in Assessing Lung Function:

- **Indicator of Ventilatory Adequacy:**
  - Assesses the lungs' effectiveness in excreting CO_2.

3. $PaCO_2$ and Carbonic Acid (H_2CO_3) Relationship:
- **Directly Proportional:** $PaCO_2 \times 0.03 = H_2CO_3$ concentration
- **Impact on Acid–Base Balance:**
  - Elevated $PaCO_2$ contributes to acidosis due to increased carbonic acid.



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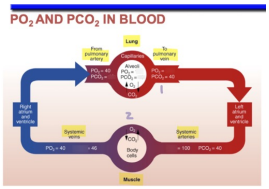
Arterial Partial Pressure of Carbon Dioxide ($PaCO_2$)

4. Effects of Ventilation on $PaCO_2$ Levels:
•**Hypoventilation:**
- Decreases CO_2 excretion → Increased $PaCO_2$ → Acidosis

•**Hyperventilation:**
- Increases CO_2 excretion → Decreased $PaCO_2$ → Alkalosis

5. Respiratory Compensation Mechanism:
•**Primary Regulation:** Ventilatory adjustments help compensate for metabolic acid–base disturbances.
•**Significance:** Key mechanism for maintaining acid–base homeostasis.



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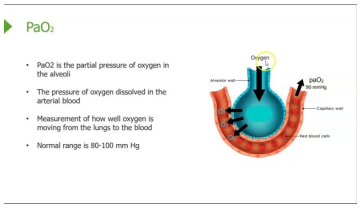
Arterial Partial Pressure of Oxygen (PaO_2)

1. Normal PaO_2 Range: 80–100 mm Hg (10.64–13.3 kPa)

2. Importance of PaO_2:
•**Indicator of Arterial Oxygenation:**
- Reflects lung function and efficiency of oxygen delivery to tissues.

3. Hypoxemia Threshold:
•**Clinically Significant Hypoxemia:** PaO_2 < 60 mm Hg
- No absolute cutoff; typically assessed in relation to metabolic needs.



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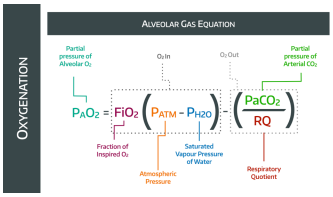
Arterial Partial Pressure of Oxygen (PaO_2)

4. Factors Influencing PaO_2:
•**Ventilation Levels**
•**Fraction of Inspired Oxygen (FiO_2)**
•**Lung Functional Capacity**
•**Oxyhemoglobin Dissociation Curve**

5. Oxyhemoglobin Dissociation Curve:
•**Relationship:** PaO_2 vs. Oxygen Saturation
•**Acidemia Shift:** Curve shifts right → Easier O_2 release from hemoglobin
•**Alkalemia Shift:** Curve shifts left → More difficult O_2 release (impaired tissue delivery)
•**Other Influencing Factors:** Temperature, 2,3-diphosphoglycerate levels



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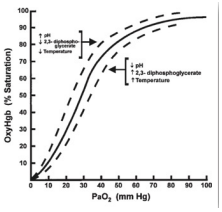
Oxygen–hemoglobin dissociation curve



Shape and Meaning: The curve is *sigmoid-shaped* (S-shaped) and shows the relationship between the partial pressure of oxygen (PO_2) and hemoglobin's saturation with oxygen. As PO_2 increases, hemoglobin binds more oxygen, up to a point where it becomes saturated.

Affinity Changes: The curve's shape reflects *hemoglobin's changing affinity* for oxygen. At high PO_2 (like in the lungs), hemoglobin has a high affinity for oxygen, binding it easily. At lower PO_2 (like in tissues), it has a lower affinity, releasing oxygen more readily.

Shifts of the Curve: The curve can *shift left or right*, depending on factors like pH, temperature, CO_2, and 2,3-DPG levels. A right shift means oxygen is released more easily (helpful in active tissues), while a left shift means oxygen is held more tightly by hemoglobin.

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Arterial Partial Pressure of Oxygen (PaO_2)

6. PaO_2 vs. Oxygen Saturation:
- **PaO_2:** Measured in mm Hg; can exceed 100 with supplemental O_2.
- **Oxygen Saturation (SaO_2):** Percentage of hemoglobin-bound O_2; cannot exceed 100%
- *Exampe:* PaO_2 of 80 mm Hg typically corresponds to SaO_2 > 93%, while SaO_2 of 80% is critically low.

7. Clinical Relevance:
- **PaO_2:** Crucial for assessing pulmonary status; does not directly affect acid–base balance.
- **SaO_2:** Directly relates to O_2 delivery adequacy, critical in hypoxic states.

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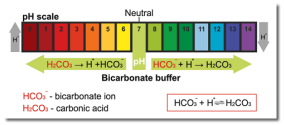
Arterial Bicarbonate (HCO_3^-)

1. Normal HCO_3^- Range:
- **22–26 mEq/L** (22–26 mmol/L)

2. Measurement of Arterial Bicarbonate:
- **Indirect Calculation:**
  - Derived from **pH** and **$PaCO_2$** via the Henderson-Hasselbalch equation in ABG (Arterial Blood Gas) analysis.

3. Comparison with Serum Bicarbonate:
- **Total CO_2 Content:** Measured on an electrolyte panel, often referred to as **serum bicarbonate**.
- **Expected Difference:**
  - HCO_3^- from ABG typically **1.5–3 mEq/L lower** than total CO_2 in a plasma panel (higher difference in venous samples).



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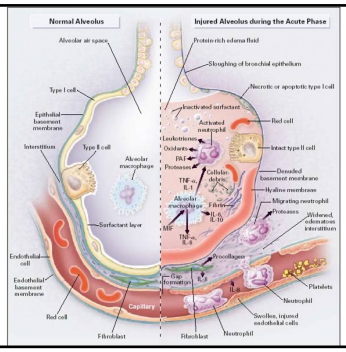

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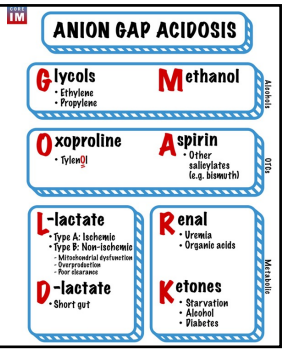
Anion Gap (AG)

1. Normal Range: 3–16 mEq/L (3–16 mmol/L)

2. Purpose of Anion Gap:
- **Estimate of Unmeasured Anions:** Useful for evaluating potential causes of **metabolic acidosis**.
- **Electrochemical Balance:** Total anions and cations should balance; the AG highlights excess unmeasured anions.

3. Anion Gap Calculation:
- **Formula**: $AG=Na^+-(Cl^-+HCO_3^-)$$AG=Na^+-(Cl^-+HCO_3^-)$
- **High AG (>16 mEq/L):** Indicates anion accumulation, often due to conditions like lactic acidosis, ketoacidosis, toxic ingestions, or renal failure.



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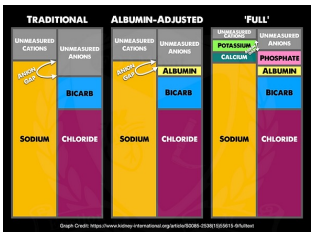
Anion Gap (AG)

4. Influence of Albumin on AG:

•**Albumin Adjustment:** For hypoalbuminemia, adjust AG by adding 2.5 for each 1 g/dL decrement in albumin:Corrected AG=AG+2.5×(4.4−meas ured albumin)Corrected AG=AG+2.5×(4.4−measured albumin)

5. Additional Factors Affecting AG:

•**Confounding Variables:** Serum phosphate, magnesium, calcium, and certain medications (e.g., β-lactam antibiotics) can impact AG interpretation.



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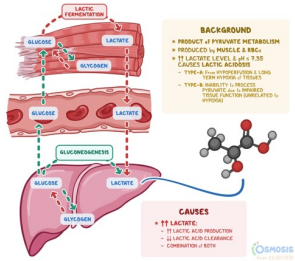
Serum Lactate

1. Normal Range: 0.6–2 mmol/L

2. Importance of Serum Lactate:
•**Byproduct of Anaerobic Metabolism:**
- Elevations indicate **inadequate tissue perfusion** or oxygenation.

3. Clinical Significance in Sepsis:
•**Sepsis Diagnostic Criteria:**
- **Lactate >1 mmol/L** as per the **Surviving Sepsis Campaign**.

•**High-Risk Threshold:**
- **Lactate >4 mmol/L** is associated with increased mortality risk.



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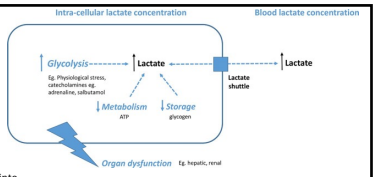
Serum Lactate



4. Use of Serial Lactate Measurements:
•**Monitoring Resuscitation:**
- Serial lactate levels provide insight into the **effectiveness of resuscitation efforts** and tissue perfusion recovery.

•**Indicator of Prognosis:**
- Persistent elevation may indicate ongoing hypoperfusion and a need for further intervention.

5. Interpretation and Clinical Decisions:
•**Rising Lactate Levels:** Suggest inadequate perfusion and potential for deteriorating patient status.
•**Decreasing Lactate Levels:** Suggest improving perfusion, a positive sign in response to therapy.

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