Physiology Equations

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1) Hb-bound O_2 content

$CaO_2(Hb) = [Hb]\ (g/dL) \times 1.34\ (mL\ O_2/g\ Hb) \times SaO_2$

Purpose: Computes how much O_2 is carried on hemoglobin per dL of blood (the major component of total O_2 content).
Notes: At full saturation: Max Hb-O_2 = [Hb] × 1.34. Typical: [Hb]=15 → ~20 mL/dL.

2) Dissolved O_2 (Henry's law)

$O_2(\text{dissolved}) = PaO_2 \times 0.003\ (mL/dL)$

Purpose: Computes the small dissolved fraction; this fraction determines PaO_2 and drives diffusion.
Notes: Example: PaO_2=100 → 0.3 mL/dL (tiny vs Hb-bound).

3) Total O_2 content

$\text{Total } O_2 = [Hb] \times 1.34 \times SaO_2 + (PaO_2 \times 0.003)$

Purpose: Adds Hb-bound + dissolved to get the true oxygen content of blood.
Notes: Use this to compare arterial vs venous content (extraction).

4) Extraction per dL

$O_2 \text{ extracted per dL} = CaO_2 - CvO_2$

Purpose: How much O_2 tissues remove from each dL of blood.
Notes: Typical rest values: CaO_2 ≈ 20, CvO_2 ≈ 15 → extraction ≈ 5 mL/dL (≈25%).

5) Oxygen consumption (Fick principle)

$VO_2 = (CaO_2 - CvO_2) \times \text{Cardiac Output}$

Purpose: Total O_2 used by the body per minute.
Notes: Unit tip: 5 L/min = 50 dL/min → 5 × 50 = 250 mL/min.

6) Respiratory exchange ratio (R)

$R = VCO_2 / VO_2$

Purpose: Links CO_2 produced to O_2 consumed; depends on diet/substrate.
Notes: Mixed diet ≈ 0.8; carbs 1.0; fats 0.7.

7) CO_2 production from R

$VCO_2 = R \times VO_2$

Purpose: Computes CO_2 production when VO_2 and R are known.
Notes: VO_2=250, R=0.8 → VCO_2=200 mL/min.

8) Alveolar gas equation

$PAO_2 = PIO_2 - (PACO_2 / R)$

Purpose: Estimates alveolar O_2; cornerstone for analyzing hypoxemia.
Notes: Sea level: PIO_2≈150, $PaCO_2$≈40, R≈0.8 → PAO_2≈100.

9) A-a O_2 gradient

A-a gradient = $PAO_2 - PaO_2$

Purpose: Assesses efficiency of O_2 transfer; helps classify hypoxemia.
Notes: Healthy lungs: small gradient (≤5 mmHg in this file).

10) Gas transfer across the respiratory membrane (Ohm's law form)

$Flow_x = \Delta P_x \times DL_x$

Purpose: Diffusion rate depends on pressure gradient and DL

Notes: ↓ΔP or ↓DL → ↓gas transfer

11) Determinants of DL

$DL \propto (A / dx) \times (S / \sqrt{MW})$

Purpose: Shows how structure & gas properties affect diffusion.
Notes: Emphysema ↓A; fibrosis ↑dx.

12) Calculating DL

DL = Flow / ΔP

Notes: $DL(O_2)$≈21 mL/min/mmHg at rest.

13) Carbon monoxide method for DL (DLCO)

DLCO = (CO absorbed per min) / PACO

Purpose: CO binds Hb strongly → capillary PCO≈0.

Notes: Capillary PCO ≈ 0 → ΔP ≈ PA,CO , Makes DL measurement practical

14) Convert DLCO to DLO_2

Purpose: $DL(O_2) \approx DL(CO) / 0.8 \approx 1.23 \times DL(CO)$

Notes: Typical $DL(CO) \approx 17 \rightarrow DL(O_2) \approx 21$ mL/min/mmHg

15) CO poisoning – estimate carboxyhemoglobin fraction (HbCO)

لأغراض الفهم

$$\text{HbCO fraction} = (M \times PCO) / (PO_2 + M \times PCO)$$

Purpose: Approximates fraction of hemoglobin bound to CO (carboxyHb) from partial pressures.

Notes: M (affinity factor) ~200–250.
Example: $M = 250$, $PCO = 0.4$ mmHg, $PO_2 \approx 100$ mmHg $\rightarrow$ HbCO ≈ 0.5 (50%).

16) CO_2 carriage (rule of thumb)

CO_2 in blood ≈ 60% HCO_3^-, 30% carbamino-Hb, 10% dissolved

Purpose: Summarizes the major forms of CO_2 transport in blood.

Notes: Bicarbonate forms inside RBC via carbonic anhydrase; HCO_3^- exits RBC via chloride shift.

17) Henry's law (dissolved gas)

$$C(\text{dissolved}) = \alpha \times P$$

Purpose: Converts a gas partial pressure into dissolved content.

Notes: $\alpha O_2 \approx 0.003$ mL/dL/mmHg , CO_2 is ~20× more soluble $\rightarrow \alpha CO_2 \approx 0.06$ mL/dL/mmHg, So $PaCO_2 \approx 40 \rightarrow$ dissolved $CO_2 \approx 2.4$ mL/dL; $PvCO_2 \approx 46 \rightarrow \approx 2.8$ mL/dL.

18) CO_2 hydration reaction (in RBC)

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

Purpose: Explains how most CO_2 is converted into bicarbonate in red blood cells and how blood pH is regulated.

Notes: Catalyzed by carbonic anhydrase , H^+ is buffered mainly by hemoglobin , The reaction reverses in the lungs to allow CO_2 exhalation

19) Alveolar CO_2 equation (ventilation–CO_2 relationship)

$$PACO_2 = (\dot{V}CO_2 / \dot{V}A) \times 0.862$$

Purpose: Shows that for a constant rate of CO_2 production, increasing alveolar ventilation lowers alveolar (and arterial) CO_2.

20) Relationship between alveolar O_2 and ventilation

$$PAO_2 \propto (\dot{V}A / \dot{V}O_2)$$

Purpose: States that alveolar oxygen tension increases when alveolar ventilation rises relative to oxygen consumption.

21) Henderson–Hasselbalch equation (bicarbonate buffer system)

$pH = 6.1 + \log (HCO_3^- / CO_2)$

Purpose: Explains how blood pH is regulated and how pH can remain stable despite changes in CO_2 if bicarbonate changes appropriately.

22) Inspired oxygen partial pressure

$PIO_2 = FiO_2 \times (P\_atm - P\_H_2O)$

Purpose: Calculates inspired oxygen partial pressure after humidification in the airways; starting point for alveolar gas calculations.

Notes: $P\_H_2O \approx 47$ mmHg at 37°C

اللهم لا سهل إلا ما جعلته سهلًا، وأنت تجعل الحَزْن إذا شئت سهلًا
اللهم ارزقنا فهمًا لا ننسى معه، وعلمًا نافعًا، وتوفيقًا من عندك، واجعل هذا العمل خالصًا لوجهك الكريم

اللهم اغفر لزميلنا عمر، وارحمه رحمةً واسعة، واجعل قبره روضةً من رياض الجنة، ونقِّه من الذنوب والخطايا كما يُنقَّى الثوب الأبيض من الدنس
اللهم آنس وحشته، وثبِّته عند السؤال، وارفع درجته في عليّين، واجعل ما أصابه رفعةً له وتكفيرًا لسيئاته

اللهم اربط على قلوب أهله وأحبته، وألهمهم الصبر والسلوان، ولا تحرمنا أجر الدعاء له، ولا تفتنّا بعده.

ربنا تقبّل منا، إنك أنت السميع العليم ♥♥

Symbol	What it represents
CaO_2	Arterial oxygen content (mL O_2 per dL blood)
CvO_2	Venous oxygen content (mL O_2 per dL blood)
PaO_2	Arterial partial pressure of oxygen (mmHg)
PvO_2	Venous partial pressure of oxygen (mmHg)
SaO_2	Arterial hemoglobin oxygen saturation (fraction or %)
[Hb]	Hemoglobin concentration (g/dL)
HbCO	Carboxyhemoglobin (hemoglobin bound to CO)
PCO	Partial pressure of carbon monoxide (mmHg)
PO_2	Partial pressure of oxygen (mmHg)
M	CO–Hb affinity factor (≈ 200–250)
CO	Cardiac output (L/min)
HR	Heart rate (beats/min)
SV	Stroke volume (mL/beat)
VO_2	Oxygen consumption (mL/min)
VO_2max	Maximal oxygen consumption during exercise
$\dot{V}CO_2$	Carbon dioxide production (mL/min)
R	Respiratory exchange ratio ($\dot{V}CO_2$ / VO_2)
PAO_2	Alveolar partial pressure of oxygen (mmHg)
$PACO_2$	Alveolar partial pressure of carbon dioxide (mmHg)
$PaCO_2$	Arterial partial pressure of carbon dioxide (mmHg)
PIO_2	Inspired oxygen partial pressure after humidification (mmHg)
FiO_2	Fraction of inspired oxygen (e.g. 0.21 for room air)
P_atm	Atmospheric pressure (≈ 760 mmHg at sea level)
P_H_2O	Water vapor pressure (≈ 47 mmHg at 37°C)
A–a gradient	Alveolar–arterial oxygen difference (PAO_2 − PaO_2)
$\dot{V}A$	Alveolar ventilation (L/min)
DL	Diffusing capacity of the lung (mL/min/mmHg)
DLCO	Diffusing capacity measured using carbon monoxide
ΔP	Partial pressure gradient across membrane
A	Surface area for gas diffusion
dx	Thickness of diffusion barrier
S	Gas solubility
MW	Molecular weight of gas
αO_2	Solubility coefficient for oxygen (≈ 0.003 mL/dL/mmHg)
αCO_2	Solubility coefficient for carbon dioxide (≈ 0.06 mL/dL/mmHg)
HCO_3^-	Bicarbonate ion
H^+	Hydrogen ion
pH	Measure of acidity/alkalinity
Hb	Hemoglobin
HbO_2	Oxyhemoglobin
HbH	Reduced hemoglobin (buffered with H^+)