ABG Interpretation in 6 Steps

pH, $PaCO_2$, HCO_3^-, compensation, anion gap and oxygenation, with worked examples

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NORMAL VALUES

Typical adult arterial values at sea level.

VALUE	NORMAL	NOTE
pH	7.35–7.45	Midpoint 7.40
$PaCO_2$	35–45 mm Hg	Respiratory (acid)
HCO_3^-	22–26 mEq/L	Metabolic (base)
Base excess	–2 to +2 mEq/L	Metabolic only; negative = acidosis
PaO_2	80–100 mm Hg	Room air; some labs 75–100
SaO_2	95–100%	Room air
Anion gap	About 12	Lab ranges vary

SAFETY Sampling: Allen test before a radial stick; no air bubbles; analyze promptly; hold firm pressure, longer if anticoagulated; after O_2 or vent changes, wait per protocol.

THE 6 STEPS

1. pH: below 7.35 acidemia, above 7.45 alkalemia.
2. $PaCO_2$ and HCO_3^-: mark each high, normal or low.
3. Primary disorder: the value that explains the pH (ROME).
4. Compensation: compare the other value with the expected range.
5. Metabolic acidosis? Anion gap, albumin correction, delta ratio.
6. Oxygenation: PaO_2, P/F ratio, A–a gradient.

EXAM TIP ROME: Respiratory Opposite, Metabolic Equal (pH versus $PaCO_2$ or HCO_3^-). NCLEX stages: uncompensated (only the primary value off), partially compensated (both off, pH abnormal), fully compensated (pH normal; under 7.40 leans acid).

SAFETY Compensation seldom returns pH fully to normal. A normal pH with abnormal $PaCO_2$ and HCO_3^- is often two disorders at once.

EXPECTED COMPENSATION

Row 1 is Winter's formula. A value well outside the range suggests a second disorder.

PRIMARY	EXPECTED RESPONSE	COMPLETE IN
Metabolic acidosis	$PaCO_2 = 1.5 \times HCO_3^- + 8$ (±2)	12–24 h
Metabolic alkalosis	$PaCO_2$ up 0.6–0.7 per 1 HCO_3^- rise; rarely over 55	24–36 h
Acute resp. acidosis	HCO_3^- up 1 per 10 $PaCO_2$ rise	Immediate
Chronic resp. acidosis	HCO_3^- up about 4 per 10	3–5 days
Acute resp. alkalosis	HCO_3^- down 2 per 10 $PaCO_2$ fall	Immediate
Chronic resp. alkalosis	HCO_3^- down 4–5 per 10	2–3 days

SAFETY DKA: a $PaCO_2$ above the Winter's range signals a tiring patient. Acute asthma: $PaCO_2$ runs low early; normal or above 45 signals impending respiratory failure. Escalate early.

ANION GAP AND DELTA RATIO

- Anion gap = $Na^+ - (Cl^- + HCO_3^-)$
- Corrected gap = gap + 2.5 × (4 – albumin in g/dL)
- Delta ratio = (corrected gap – 12) ÷ (24 – HCO_3^-), a rough guide
- Ratio under 1: added normal-gap acidosis
- Ratio 1–2: pure high-gap acidosis
- Ratio over 2: added metabolic alkalosis

EXAM TIP Exams test which acidoses raise the gap: DKA, lactate and toxic alcohols do; diarrhea and large-volume saline do not. Kussmaul breathing is the classic compensation cue.

OXYGENATION

- P/F = $PaO_2 \div FiO_2$ (as a decimal)
- ARDS (intubated, PEEP 5 or more): mild over 200 to 300, moderate over 100 to 200, severe 100 or less
- SpO_2/FiO_2 315 or less (if SpO_2 97% or less) can stand in for P/F 300 (2024 definition)
- $PAO_2 = FiO_2 \times (760 - 47) - PaCO_2 \div 0.8$ at sea level; room air about $150 - 1.25 \times PaCO_2$
- A–a gradient = $PAO_2 - PaO_2$; normal about age ÷ 4 + 4
- Low PaO_2 + normal A–a: hypoventilation or low inspired O_2 (altitude)
- Low PaO_2 + high A–a: lung problem (V/Q mismatch, shunt, diffusion)

COMMON CAUSES

DISORDER	COMMON CAUSES
Respiratory acidosis	Opioids, sedatives, COPD, asthma fatigue, neuromuscular weakness
Respiratory alkalosis	Pain, anxiety, hypoxemia, PE, early sepsis, pregnancy, salicylates
High-gap metabolic acidosis	Lactate, ketoacidosis, kidney failure, toxic alcohols, salicylates
Normal-gap metabolic acidosis	Diarrhea, large-volume saline, renal tubular acidosis
Metabolic alkalosis	Vomiting, NG suction, diuretics, hypokalemia

SAFETY Potassium: acidemia tends to shift K^+ out of cells, alkalemia shifts it in. In DKA, serum K^+ may be normal or high despite a total-body deficit, and it falls once insulin starts.

WORKED EXAMPLES

1. DKA, Kussmaul breathing: pH 7.22, $PaCO_2$ 25, HCO_3^- 10, Na^+ 138, Cl^- 100, albumin 4.0

- Metabolic acidosis; Winter's 23 (21–25), $PaCO_2$ 25 fits
- Gap 138 – 110 = 28; delta ratio 16 ÷ 14 ≈ 1.1
- Answer: high-gap metabolic acidosis, compensated as expected (NCLEX: partially compensated)

2. Opioid overdose, age 24, room air: pH 7.26, $PaCO_2$ 60, HCO_3^- 26, PaO_2 68

- Respiratory acidosis; acute rule predicts 26, matches
- A–a: 150 – 75 – 68 = 7, normal for age
- Answer: acute (uncompensated) respiratory acidosis; hypoxemia from hypoventilation

3. Septic shock, 5 L saline, ventilated, PEEP 10, FiO_2 0.6: pH 7.29, $PaCO_2$ 30, HCO_3^- 14, Na^+ 140, Cl^- 112, albumin 2.0, PaO_2 90

- Metabolic acidosis; Winter's 29 (27–31), $PaCO_2$ 30 fits
- Corrected gap 14 + 5 = 19; delta ratio 7 ÷ 10 = 0.7
- Answer: high-gap (likely lactate) plus normal-gap (saline) acidosis; P/F 150, moderate ARDS range

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