# ABG Interpretation in 6 Steps

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

**ICU Basics**
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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

**Sources** (20) are listed with links at icubasics.com/sheets/abg-steps.html. For education and exam preparation only. Not medical advice; follow current guidelines and your institution's protocols. ICU Basics is an independent study aid not affiliated with any certifying body.