

Gases & Gas Laws

Pressure units, the gas laws, $PV=nRT$, partial pressures, molecular speeds, and gas stoichiometry.

01 Pressure units

REFERENCE

1 atm = 101,325 Pa = 760 mmHg = 760 torr $\approx$ 1.01325 bar $\approx$ 14.696 psi. torr $\equiv$ mmHg; 1 bar = 100,000 Pa exactly. Chain conversions by dimensional analysis.

02 Always use Kelvin

WATCH OUT

Every gas-law plug-in needs absolute T: $T(K) = T(^{\circ}C) + 273.15$. Never put $^{\circ}C$ or $^{\circ}F$ into a gas-law equation. STP here = 0 $^{\circ}C$ (273.15 K) and 1 atm.

03 The simple gas laws

REFERENCE

Law	Held constant	Relation
Boyle	T, n	$P_1V_1 = P_2V_2$
Charles	P, n	$V_1/T_1 = V_2/T_2$
Gay-Lussac	V, n	$P_1/T_1 = P_2/T_2$
Avogadro	T, P	$V_1/n_1 = V_2/n_2$

04 Combined gas law

CORE RULE

$P_1V_1/T_1 = P_2V_2/T_2$ when P, V, and T all change (n fixed). T in Kelvin; P and V units just have to match between the two states.

05 Ideal gas law

CORE RULE

$PV = nRT$ for a single state with 3 of 4 knowns. T in Kelvin. $P = nRT/V$, $V = nRT/P$, $n = PV/RT$, $T = PV/nR$. Pick the R whose units match P and V.

06 Choosing R

REFERENCE

R value	Use when
0.08206 L·atm/(mol·K)	P in atm, V in L
8.314 J/(mol·K)	SI; and all u_{rms} / KMT speeds
0.08314 L·bar/(mol·K)	P in bar, V in L
62.36 L·torr/(mol·K)	P in torr, V in L

07 Molar mass & density

CORE RULE

$M = mRT/(VP)$; density $\rho = PM/(RT)$. At STP one mole occupies 22.4 L, so $\rho_{STP} = M / 22.4$ (g/L). Match R to the pressure unit.

08 Partial pressures (Dalton)

CORE RULE

$P_{total} = \sum P_{partial}$. Mole fraction $X_A = n_A/n_{total} = P_A/P_{total}$, so $P_A = X_A \cdot P_{total}$. Gas over water: $P_{gas} = P_{total} - P_{H_2O}(T)$ (supplied).

09 Molecular speeds

CORE RULE

$u_{rms} = \sqrt{3RT/M}$, with M in kg/mol and R = 8.314 to get m/s. Ratio (same T): $u_{rms,A} / u_{rms,B} = \sqrt{M_B/M_A}$. (Mean = $\sqrt{8RT/\pi M}$; most probable = $\sqrt{2RT/M}$.)

10 Graham's law

CORE RULE

Effusion/diffusion: $rate_A / rate_B = \sqrt{M_B/M_A}$: lighter gases move faster. Time scales the other way: $time_A / time_B = \sqrt{M_A/M_B}$. Same temperature required.

11 Gas stoichiometry

METHOD

mass $\rightarrow$ moles $\rightarrow$ mole ratio $\rightarrow$ moles of gas $\rightarrow$ V via $PV=nRT$ (or 22.4 L/mol at STP). If reactants and products are all gases at the same T, P, mole ratios equal volume ratios directly.