Gases — A Summary

Ideal Gases follow the law:

Ideal Gas Law $\boxed{PV = nRT}$ ($R = 0.08206 \frac{L \cdot atm}{K \cdot mol}$ ← "Gas constant")

The state of a pure gas is described by 4 variables: P, V, T, n

If we know 3 of the 4 variables, we can solve for the unknown one.

If we keep 2 of the 4 variables constant, we have 2 remaining variables that can change, but only according to a relationship dictated by the Ideal Gas Law.

If we keep n & T constant: $PV = \underbrace{nRT}_{constant}$ ⇒ PV = constant ← some value determined by n, T, R

So, if in state 1 we have P_1V_1 = constant
and, in state 2 we have P_2V_2 = constant } $\boxed{P_1V_1 = P_2V_2}$ Boyle's Law

If we keep n & P constant: $PV = nRT$ (P const., n const.) ⇒ $\frac{V}{T} = \frac{nR}{P}$ (const.) ⇒ $\frac{V}{T}$ = constant ← some value determined by n, P, R

So, if in state 1 we have $\frac{V_1}{T_1}$ = constant
and, in state 2 we have $\frac{V_2}{T_2}$ = constant } $\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$ Charles's Law

Similarly we can derive:

$\boxed{\frac{V_1}{n_1} = \frac{V_2}{n_2}}$ Avogadro's Law

As well as laws relating P & T at constant n & V ⇒ $\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$

n & P at constant V & T ⇒ $\boxed{\frac{P_1}{n_1} = \frac{P_2}{n_2}}$

etc.

We can also derive a "Combined Gas Law": $\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$

Laws like Boyle's Law and Charles's Law are used in questions involving a <u>change</u> where two variables are held constant, and two variables change.

Combined Gas Law is also used when a <u>change</u> in the state of the gas is involved, in this case <u>three</u> variables (P, V, T) changing while one (n) is constant.

PV = nRT needs to be used directly if we need to <u>find an unknown property</u> (any one of the variables P, V, n, T) given known values for <u>three</u> of them, <u>without involving a change in any of the variables</u>

Ideal Gas Law can be derived from the Kinetic Molecular Theory of Gases, using the following approximations and definitions:

1. No inter-particle forces } gas density too low for intermolecular forces to operate
2. No particle volume } and the gas volume is too large for particle volume to be
3. Pressure is due to the collision of gas particles with the container walls
4. Temperature in Kelvins is the proper temperature scale to use, and is defined such that $T \propto$ (average kinetic energy of the particles)

Real Gases:

To the extent that approximations 1 and 2 above are violated, the ideal gas law is violated. Real gases deviate from those approximations more when the density is high enough. At high P and low T, the molar density (or particle density) is high, and real gases deviate from $PV = nRT$ and the other laws that follow from it.

By the way, the "Standard Temperature and Pressure" (STP) provides a convenient data point relating the ideal gas volume per mole (molar volume) at $T = 0°C = 273.15\,K$ and $P = 1$ atm: Volume of 1 mol of ideal gas @ STP = 22.4 L

Some questions rely on using this information for quick access to the volume value. It can, of course, be calculated from $PV = nRT \Rightarrow V = \frac{nRT}{P} = \frac{(1)(0.08206)(273.15)}{(1)} = 22.4\,L$

Since ideal gases have particles that are not "aware" of other particles (because there are no inter-particle forces), ideal gases in a mixture can be treated as if they are alone in the container, happening to share the same volume.

Each gas has its own pressure, determined from $PV = nRT$

- P: pressure due to the particular gas in the mixture ("partial pressure")
- V: same for all components
- n: moles of the particular gas
- T: same for all components

$$P_A = n_A \frac{RT}{V}$$
$$P_B = n_B \frac{RT}{V}$$
$$P_C = n_C \frac{RT}{V}$$
$$\vdots$$
$$\Rightarrow P_{total} = P_A + P_B + P_C$$
$$P_{total} = \underbrace{(n_A + n_B + n_C + \cdots)}_{n_{total}} \frac{RT}{V}$$

$$P_A = \frac{n_A}{n_{total}} P_{total}$$

Some questions can combine stoichiometric problems with gas laws. All we need to do is to use the gas laws to obtain moles, and proceed with the reaction stoichiometry as usual.