Ideal Gas Law

The Combined Gas Law

- Combining Boyle's Law and Charles' Law results in a new gas law, the ***Combined Gas Law***, which is used when pressure, volume and temperature all change while the number of gas molecules remain constant.

$$\frac{PV}{T} = k \quad \text{therefore} \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Avogadro's Hypothesis

- Equal volumes of gases at the same temperature and pressure contain the same number of molecules.
- The volume of a gas depends on the number of molecules in the container as long as the temperature and pressure are constant.

$$\frac{V}{n} = k$$

Calculations Involving Molar Volume at STP

- If Avogadro's Hypothesis is correct, it should be possible to obtain a definite number of gaseous molecules by measuring a definite volume of gas.
- One mole of almost any common gas at 0°C and 101.325 kPa (STP – *standard temperature and pressure*) is approximately **22.4 L/mol**.

Derivation of The Ideal Gas Law

- **Boyle's Law:** $V = k_1\left(\frac{1}{P}\right)$
- **Charles' Law:** $V = k_2T$
- **Avogadro's Law:** $V = k_3n$
- **Ideal Gas Law:** $V = \frac{k_1k_2k_3\ nT}{P}$

OR $V = \frac{R\ nT}{P}$ where R replaces $k_1k_2k_3$

OR $PV = nRT$

The Ideal Gas Law

- The greatest advantage of the ***Ideal Gas Law*** is that it can be used to calculate the volume, pressure, temperature, or number of moles of gas present at conditions other than 0°C and 101.325 kPa.

where:
P = *pressure* (kPa)
V = *volume in liters* (L)
n = *number of moles of gas* (mol)
R = *universal gas constant* $\left(\frac{8.314\ \text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}\right)$
T = *absolute temperature* (K)

Using The Ideal Gas Law

- **Example:** What mass of hydrogen is produced if the gas occupies a volume of 50.0 mL at 20.00°C and 94.01 kPa?

The Ideal Gas Law

Step 1: Calculate the number of moles of H_2.

$$n_{H_2} = \frac{PV}{RT} = \frac{(94.01\ \text{kPa})(0.0500\ \text{L})}{(8.314\ \text{kPa}\cdot\text{L}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})} = 0.00193\ \text{mol}$$

Step 2: Convert number of moles to mass.

$$m_{H_2} = nM = 0.00193\ \text{mol H}_2 \times \frac{2.02\ \text{g H}_2}{1\ \text{mol H}_2} = 0.00390\ \text{g H}_2$$