

GASEOUS STATE

A substance exists in gaseous state if the thermal energy of molecules predominates over intermolecular forces, molecules are sufficiently apart from one another (intermolecular distances $10^{-7} - 10^{-5}$ cm), have large rotatory, vibratory and translatory motions and are most energetic.



Ideal gases

Gases which follow gas laws under all conditions of temperature and pressure.

Boyle's law

$$P \propto \frac{1}{V}$$
 (at constant T and n)

$$\therefore P_1 V_1 = P_2 V_2 = \text{constant} \Rightarrow \frac{P_1}{P_2} = \frac{V_2}{V_1}$$

Avogadro's law

 $V \propto n \text{ (at constant } P \text{ and } T)$ $\Rightarrow \frac{V}{} = \text{constant}$

Charles' law

 $V \propto T(\text{at constant } P \text{ and } n)$ $\therefore \frac{V_1}{T_1} = \frac{V_2}{T_2} = \text{constant}$

Gay-Lussac's law

$$P \propto T \text{ (at constant } V, n)$$

 $\frac{P}{T} = \text{constant} \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$

Ideal gas equation

$$PV \propto nT$$
; $PV = nRT$
or $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ [Equation of state]

Dalton's law of partial pressures

 $P_{\text{total}} = p_1 + p_2 + p_3 + p_4 \dots$ (at constant T, V) where, $p_1 = x_1 P_{\text{total}}$ $p_2 = x_2 P_{\text{total}}; p_3 = x_3 P_{\text{total}}$ $P_{\text{dry gas}} = P_{\text{moist gas}} - \text{aqueous tension}$

Molecular velocities of gaseous molecules

• Average velocity:

Gas

$$U_{av} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8PV}{\pi M}}$$

· Root mean square velocity:

$$U_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}}$$

· Most probable velocity:

$$U_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2PV}{M}}$$

$$- U_{mp}: U_{av}: U_{rms} = 1:1.128:1.224$$

Kinetic molecular theory of gases

- The actual volume of the molecules is negligible as compared to the space between them
 and hence they are considered as the point masses.
- Interaction between the particles is negligible.
- Particles of a gas are always in constant and random motion and the collisions between them are perfectly elastic.
- Pressure of the gas is due to the collisions of gaseous molecules with the walls of the container.

Real gases

Gases which do not follow gas laws under all conditions of temperature and pressure.

Liquefaction of gases

It is carried out by increasing

pressure or decreasing

temperature.

Van der Waal's equation

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

- a (atm L^2 mol⁻²) is measure of intermolecular forces.
- b (L mol⁻¹) measure of effective size.

Kinetic gas equation

$$PV = \frac{1}{3}mnu^2 \implies u = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3RT}{M}}$$
; Average K.E./ molecule $= \frac{3}{2}\frac{RT}{N} = \frac{3}{2}kT$

Compressibility factor, Z

- For ideal gas, compressibility factor *i.e.*, Z=PV/nRT=1
- For real gas, Z = PV_{real}/nRT, Z≠1. Hence, two cases arise:
 - When Z < 1, it is a negative deviation i.e., easily compressible.
 - When Z > 1, it is a positive deviation i.e., difficult to compress.

Critical temperature (T_c)

It is the highest temperature above which a gas cannot be liquefied; $T_c = 8a/27Rb$

Critical volume (V_c)

Volume of one mole of a gas at critical temperature; $V_c = 3b$

Critical pressure (P_c)

Pressure of one mole a gas at its critical temperature; $P_c = a/27b^2$.