22 - Ideal gases

Q-1) Brownian motion.

> Observing smoke particles in a dark cell lit from the side shows the haphazzard motion of the molecules.

This suggest that the particles move in a random motion. They collide with each other and the walls of the container, exerting a pressure.

The properties of a gas are affected by:

- pressure
- temperature
- mass
- volume.

Q-2) What is the mole?

> One mole is the amount of a substance which contains the same number of particles as there are in 0.012kg of carbon-12.

$$1\,\text{mol} = 6.02 \times 10^{23} \text{ particles}$$

↳ NA ; Avogadro's constant.

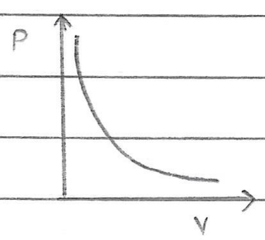
Q-3) What is Boyle's Law?

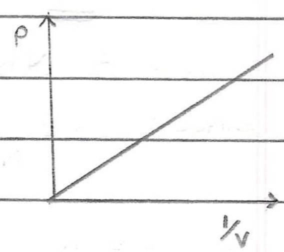
> The pressure excerted by a fixed mass of gas is inversely proportional to its volume, provided the temperature remains constant.

$P \propto \frac{1}{V}$ at a constant T

$P_1V_1 = P_2V_2$

$PV = \text{constant}$



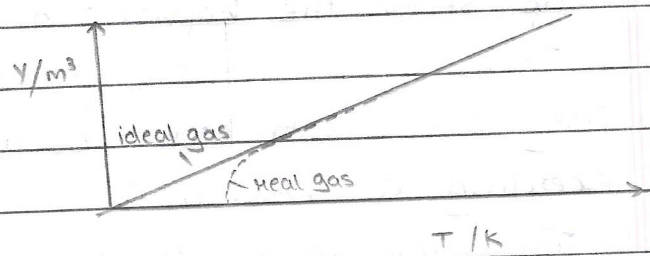


Q-4) What is Charle's law?

> The volume of a fixed mass of a gas is directly proportional to its temperature at constant pressure.

$V \propto T$ at constant P

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



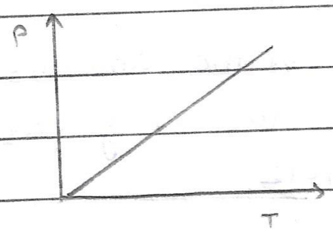
$$\frac{V}{T} = \text{constant.}$$

Q-5) What is pressure law?

> The pressure of a fixed mass of a gas is directly proportional to its temperature at constant volume.

$P \propto T$ at constant V

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$



$$\frac{P}{T} = \text{constant.}$$

Q-6) Ideal gas equation.

$$PV = nRT$$

OR

$$\frac{PV}{T} = \text{constant.}$$

P = pressure (Pa)
V = volume (m^3)
n = moles
R = 8.31 (constant)
T = temperature (K)

OR

$$PV = NkT$$

N = no. of molecules
$k = 1.38 \times 10^{-23}$ (constant)

since : $n = \frac{N}{N_A}$

& : $k = \frac{R}{N_A}$

Q-7) What is absolute zero?

> Absolute zero is the temperature at which the internal energy of a gas is minimum and no energy can be taken out of the gas.

It's the lowest possible temperature ($-273°C$ or $0K$)

Q-8) What are the assumptions of the kinetic theory of gases?

* The molecules of gas are in random motion, colliding with each other and the walls of the container. These collisions are perfectly elastic; no k.e. is lost.
  ↳ ∴ no change in temperature or internal energy.

* The volume of the particles is negligible compared to the volume occupied by the gas.

* The forces of attraction between the molecules (intermolecular forces) are negligible, except during collisions.
  ↳ ∴ $PE = 0$ and $du = k.e.$

* The time of collision is negligible compared with the time between collisions.

* Between collisions, the molecules travel in a straight line at a constant velocity.

Q-9) The pressure exerted by a gas.

Consider one molecule

> initial momentum = mc

final momentum = $-mc$

change in momentum = $-2mc$

change in momentum of wall = $2mc$

> time between collisions = $\frac{2l}{c}$

> Force = $\frac{\Delta \text{momentum}}{\text{time}}$ = $\frac{mc^2}{l}$ = due to 1 molecule.

$\frac{Nmc^2}{l}$ = Force due to N molecules

Assuming 1/3 molecules travel in one plane of the cube

$$F = \frac{Nm\langle c^2\rangle}{3l}$$

> Pressure = $\frac{F}{A}$ = $\frac{Nm\langle c^2\rangle}{3l} \div l^2$

$$p = \frac{Nm\langle c^2\rangle}{3l^3} \equiv \frac{Nm\langle c^2\rangle}{3V}$$

If $N \times m$ = mass of total gas (M), then;

$$p = \frac{M\langle c^2\rangle}{3V}$$

Note: $\langle c^2\rangle$ = mean value

i.e. $\frac{c_A^2 + c_B^2 + c_C^2}{3}$

$\therefore$ $p = 1/3\, \rho \langle c^2\rangle$

$c_{RMS} = \sqrt{\langle c^2\rangle}$

Q-10) The average transational kinetic energy

$$P = \frac{1}{3} \rho \langle c^2 \rangle$$

$$P = \frac{\frac{1}{3} Nm \langle c^2 \rangle}{V}$$

$$PV = \frac{1}{3} Nm \langle c^2 \rangle \quad \text{—①}$$

$$PV = nRT \quad \text{—②}$$

> $$\frac{1}{3} Nm \langle c^2 \rangle = nRT$$

$$m \langle c^2 \rangle = \frac{3nRT}{N} \quad \text{—o divide both sides by } \frac{1}{2}$$

$$\frac{1}{2} m \langle c^2 \rangle = \frac{3nRT}{2N} \quad \text{—o } \frac{N}{n} = N_A \text{ (avogadro's constant)}$$

$$E_K = \frac{3RT}{2N_A} \quad \text{—o } \frac{R}{N_A} = k \text{ (Boltzman constant)}$$

$$\therefore \quad E_K = \frac{3}{2} kT$$

$$E_K \propto T$$

The mean transational kinetic energy of an atom (or molecule) of an ideal gas is proportional to the thermodynamic temperature. (K)