THERMAL PHYSICS

3.1 THERMAL CONCEPTS

THE PARTICLE MODEL OF MATTER.

Solids
↳ springs join neighbouring particles & represent particles bonds between them.

Liquids
↳ Particles are able to move around in the volume but the bonds are strong enough such that they cannot move far away.

Gases
↳ inter-particle forces are negligible. Significant force exists between only particles during collisions.

TEMPERATURE:

↳ A measure of the average kinetic energy of the particles of a substance.

↓

The direct proportionality between temperature & the average kinetic energy is only true for the absolute or the Kelvin scale.

$$T(K) = T(°C) + 273$$

The magnitude of a Kelvin scale is the same as that of a degree Celsius.

Measuring Temperature - Thermometer.

The thermometer is kept in contact with the body whose temperature is to be measured.

A thermal interaction takes place. Energy is transferred until thermal equilibrium is attained.

HEAT → Energy that is transferred from one body to another as a result of difference in temperatures.

Heating increasing increases the internal energy of a body.

↓

total random kinetic energy of the particles

+

Increasing seperation requires work to be done → interparticle potential energy of the particles.

This work goes into increasing the potential energy of the particles.

Specific heat capacity (c) is the energy required to increase the temperature of a unit mass of a body by one kelvin.

$$Q = mc\Delta T$$

LATENT HEAT:

Heat supplied does work on particles to increase seperation so there is a gain in Ep not Ek, so temperature is constant.

Latent Heat is the amount of energy required to change the phase of a unit mass at constant temperature.

$$Q = mL$$

$L_V > L_F$: Because the increase in seperation of the molecules is much larger when going from liquid to vapour than from solid to liquid. So more work is required to achieve the greater seperation & therefore more energy is required.

Method of Mixtures (to measure specific heat capacity).

- A solid is put in a container of hot water.
- After thermal equilibrium is reached, temperature is recorded & the solid is transferred to a calorimeter of known temperature & specific heat capacity. It contains water & is insulated.
- After thermal equilibrium is reached, the final temperature is noted.

$$E_{lost} = E_{gained}.$$

3.2 MODELLING A GAS:

MOLE:

One mole of a substance is a quantity of the substance that contains a number of particles equal to the Avagadro constant (6.023×10^{-23}) & whose mass in grams is equal to the molar mass of the substance.

If a substance contains N particles & the no. of particles in one mole is 6.023×10^{-23} (N_A), then the no. of moles is:

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

Atomic mass unit (u): 1/12 of the mass of one amot atom of carbon-12.

Atomic mass (in u): A grams of ${}^{A}_{Z}X$

For monoatomic substances, 1 mole of the substance = quantity of substance whose mass in grams is atomic mass.

Molar mass: For monoatomic substances ↑

For molecules → sum of atomic masses of the atoms making up the molecule. ($CO_2 = 12 + (2 \times 16) = 44gm$).

The no. of moles in a quantity of m grams of a substance with molar mass μ is:

$$n = \frac{m}{\mu}$$

PRESSURE: normal force applied per unit area.

$$P = \frac{F}{A}$$

IDEAL GAS → Theoretical model of a gas.

Assumptions:

- All molecules are point particles with negligible volume.
- Molecules have a range of speeds & move randomly.
- The duration of collisions are negligible compared to the time between collisions.
- They obey laws of mechanics.
  - → there are no forces between molecules, except when they collide.
  - the collisions are elastic (with each other & walls).
    - → the loss of E

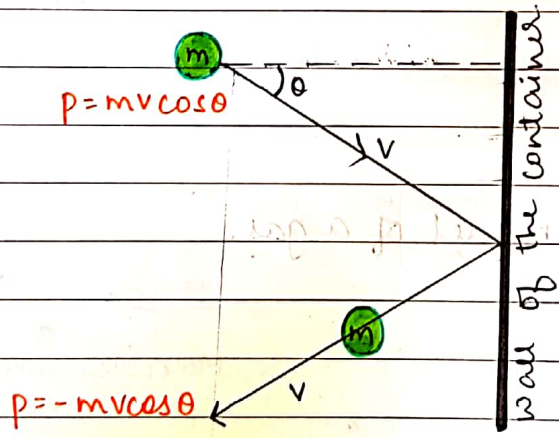
An ideal gas cannot be liquified or solidified.

REAL GAS

- There are always forces between molecules (even when they are not in contact).
- A real gas will behave like an ideal gas when the density is low (so that molecules are far apart with negligible inter-molecular forces between them) & when the temperature is not too low (otherwise the gas might liquify or solidify).

A real gas may be approximated by an ideal gas at:

1. low pressure
2. low density
3. High temperature
4. High volume.



$\Delta p = 2mv\cos\theta$ →

The fact that momentum has changed means that a force acted on the molecule (from the wall.

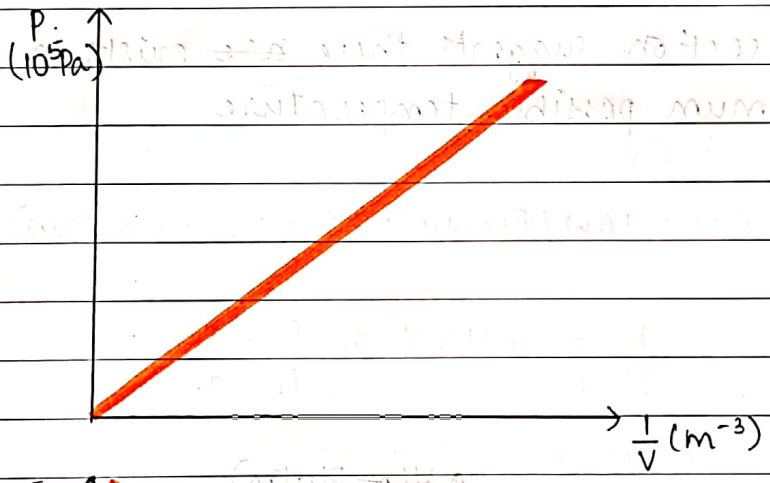
According to Newton's 3rd law:
molecule exerted an equal & opposite force on the wall

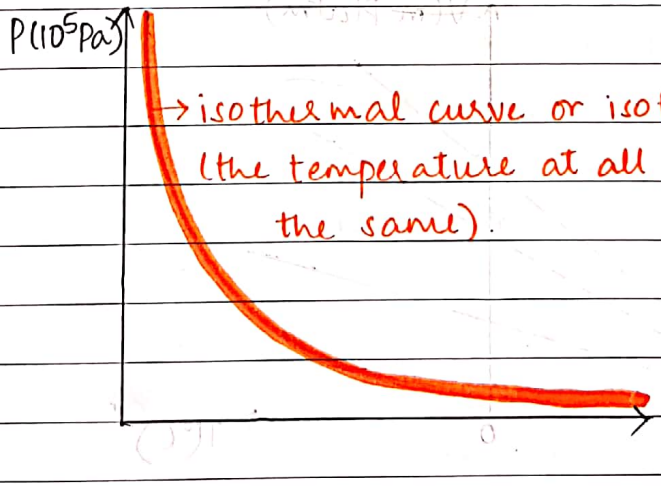
All the forces due to all the collisions with the walls result in a force & hence pressure on walls.

BOYLE'S LAW (The pressure - volume law)

At constant temperature & with a fixed quantity of gas, pressure is inversely proportional to volume, that is:

$$P \propto \frac{1}{V} \quad \text{or} \quad PV = \text{constant} \quad \text{or} \quad P_1V_1 = P_2V_2.$$

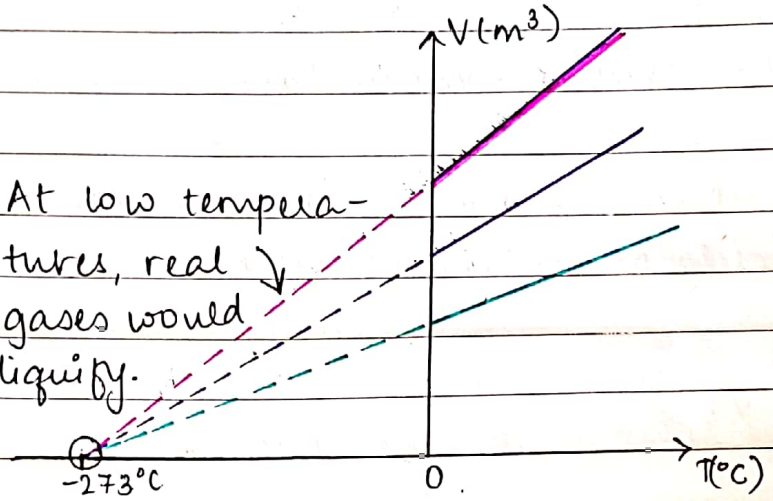




→ isothermal curve or isotherm.
(the temperature at all points is the same).

CHARLE'S LAW (Volume - temperature law).

$\frac{V}{T(K)}$ = constant $\Rightarrow$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

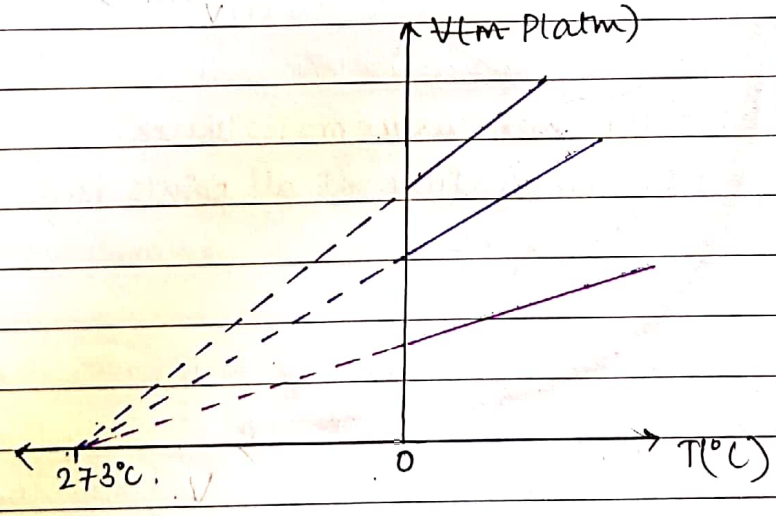


At low temperatures, real gases would liquify.

Intersection suggests there ~~are~~ exists a minimum possible temperature

AMONTON'S LAW (Pressure - temperature law).

$\frac{P}{T(K)}$ = constant $\Rightarrow$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

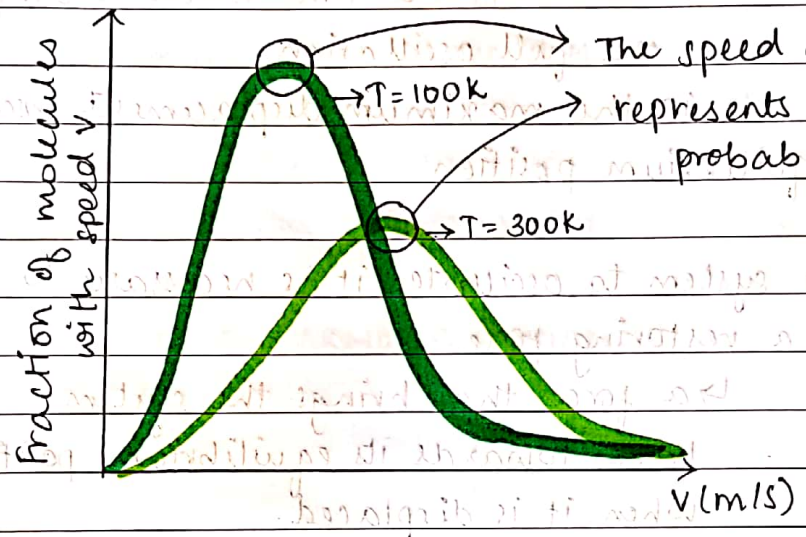


STATE OF AN IDEAL GAS EQUATION.

$PV = nRT$

- R → gas constant ($8.31\ JK^{-1}mol^{-1}$)
- T → temperature in Kelvin.
- n → no. of moles

THE BOLTZMANN EQUATION.



The speed at the peak represents the most probable speed of molecules.

$$E_K = \frac{3}{2}\frac{R}{N_a}T$$

Boltzmann's Constant:

$$K_B = \frac{R}{N_A} = 1.38 \times 10^{-23}\ JK^{-1}$$

$$E_K = \frac{3}{2}K_B T$$

→ This expression can be used to for the internal energy of an ideal gas since molecules of an ideal gas don't have potential energy.

Suppose a gas has N molecules,

$$U = \frac{3}{2}\frac{N}{N_A}RT \longrightarrow U = \frac{3}{2}nRT$$

$$U = \frac{3}{2}PV$$