B3: GAS LAW

↳ How are macroscopic characteristics of a gas related to the behaviour of individual molecular?

↳ What assumptions and observations lead to universal gas law?

↳ How can models be used to help explain observed phenomena

Topic Content

- Pressure and how it arises at a microscopic level
- The mole and Avogadro constant
- How ideal gases approximate the behavior of real gases
- The ideal gas law equation
- How pressure is related to the average gas translational speed of the molecules of a gas

CORE CONCEPTS IN GAS LAW

Mole (n)

↳ The mole is the basic SI unit for 'amount of substance'

~ 1 mole of any substance = the amount of that substance that contains the same number of atoms as 0.012 kg of Carbon-12 (^{12}C)

Standard Temperature and Pressure (STP)

↳ Pressure = 1.00 atm (1.013×10^5 Pa (Nm^{-2}))

↳ Temperature = 273 K (0°C)

Avogadro constant, A_v

↳ The number of atoms in 0.012 kg of carbon-12 (^{12}C)

$A_v = 6.02 \times 10^{23}$

Molar Mass (M)

↳ The mass of one mole of a substance

The number of moles, $n = \frac{m}{M}$

where: m = the mass of the gas

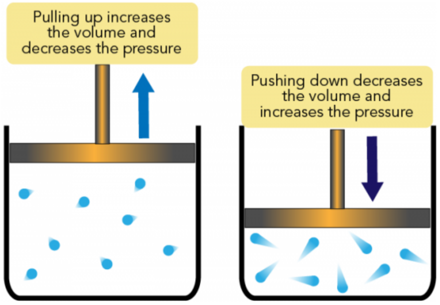
M = Molar mass (mass per mole)

Ideal Gasses

- In Gas Law, for a given sample of a gas, the pressure, volume and temperature are all related to one another
- Ideal gas is a gas which obeys the equation of state $PV = nRT$

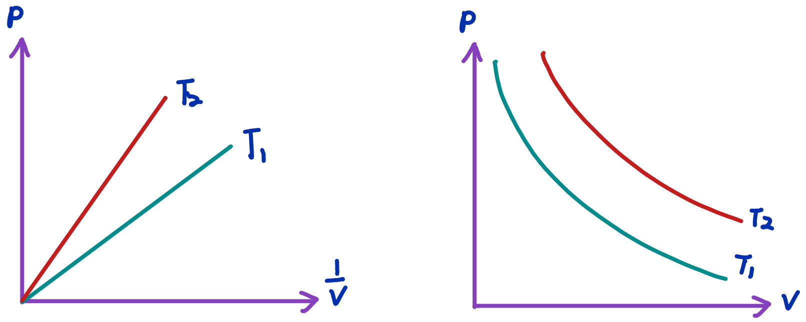
Boyle's Law

- For a fixed mass of gas at constant temperature, pV = constant



- This law states that the Volume (V) of a given mass is inversely propotional to its pressure (p)
- Boyle's Law can be stated as :

$$V \propto \frac{1}{P} \quad \text{or} \quad VP = \text{constant}$$

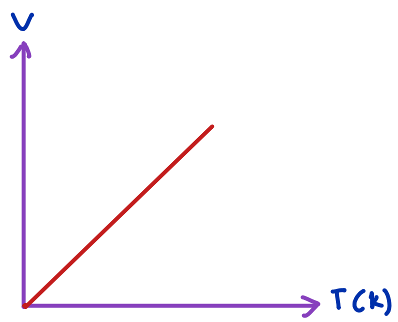


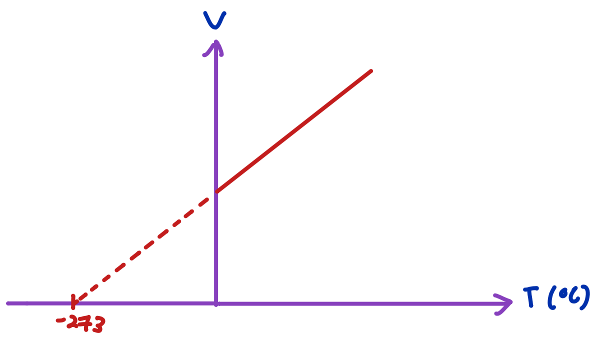
Charles's Law

↳ For a fixed mass of gas at constant pressure, the volume (V) increases with Temperature (T) in kelvin.

↳ Charles's law states that the volume (V) of a given mass, at constant temperature is directly proportional to the Temperature (T):

$$V \propto T \quad \text{or} \quad \frac{V}{T} = \text{constant}$$

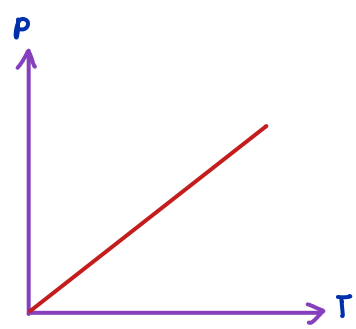




Pressure Law

↳ For a fixed mass of gas at constant volume, the pressure (P) increases with Temperature (T) in kelvin.

↳ Charles's law states that the pressure (P) of a given mass, at constant volume is directly proportional to the Temperature (T): $P \propto T$ or $\frac{P}{T} = \text{constant}$

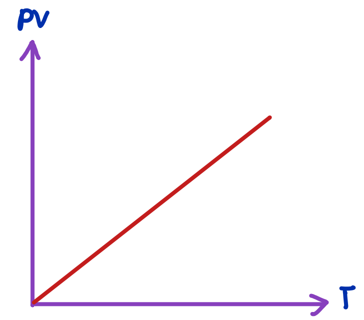


Equation Of States

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

$\frac{PV}{nT}$ = Universal constant, R (molar gas constant $J\,mol^{-1}\,K^{-1}$)

$PV = nRT$ - Ideal Gas Law



Graph of PV against T

Condusion of Ideal Gasses

↳ Ideal gasses do not exist. However, real gasses approximate to ideal gas behaviour at low densities (@ low pressure) and at high temperature well above their liquifying points, and should not liquify or solidify

↳ These gasses deviate from ideal gas laws because:

- Real gas molecules attract one of another
- Real gas molecules occupy infinite volume

Pressure from collisions at surface

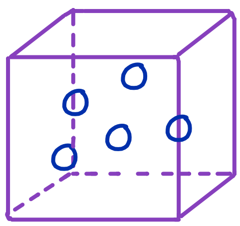
↳ When particles hit walls, they change momentum (impulse, $J = F\Delta T$)

↳ There is a resultant force (and since $P = \frac{F}{A}$), a resultant pressure on walls.

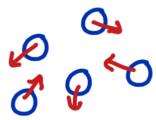
$$P = \frac{1}{3}\rho v^2$$

Kinetic Model Of an Ideal Gas

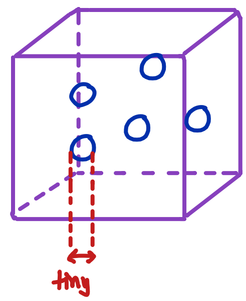
IDEAL GAS ASSUMPTIONS



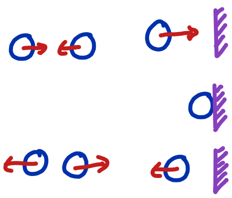
① Consist of many identical particles (sphere, treated as point masses)



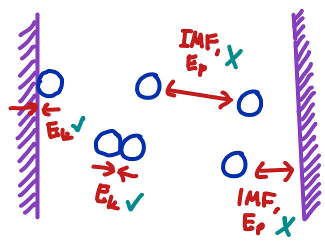
② Particles are in random motion



③ Total volume of particles are negligible compared to the volume of the container.

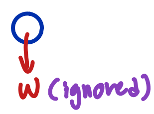


④ Elastic Collision between particles and with wall (E_k and p conserved)



⑤ IMF between particles and the walls are negligible except during collisions. (only E_k contribute to ΣU)

⑥ Duration of collisions are negligible compared to time between collisions



⑦ External factor like gravity is ignored

Internal Energy of a gas (U)

- U is the total of E_k dan E_p of its particles
- E_k exist because particles are moving (translational & rotational)
- E_p exist because of the intermolecular force
- Temperature is a measure of E_k of the molecules
- Average E_k of a molecule:

$$\bar{E}_k = \frac{3}{2}kT$$

k = Boltzman constant (1.38×10^{-23} JK^{-1})

- for a given number of molecules:

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

- A mole of a gas contains 6.02×10^{23} (N_A), so:

$$\Sigma E_k = \frac{3}{2}N_AkT \quad @ \quad \Sigma E_k = \frac{3}{2}RT$$

N_Ak = Universal gas constant ($8.31\ J\,mol^{-1}K^{-1}$), also denoted as R

- U of a gas is the total of E_k, so:

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