

GAS LAWS & APPLICATION

BOYLE'S LAW: states that @ constant temperature (T) the volume (V) of a given mass of a gas is inversely proportional to absolute pressure (P)

$$V \propto \frac{1}{P}$$

$$PV = \text{constant}$$

if T is kept constant

(5)

APPLICATION: To know the volume of O_2 gas available one has to apply Boyle's Law.

- Volume of E type of cylinder is 5 litres (V_1)
- The service pressure @ which the cylinder is filled is 2000 psig (P_1)

(@ a pressure (P_2) - 15 psig)

$$P_1 V_1 = P_2 V_2$$

$$2000 \times 5 = 15 \times V_2$$

$$V_2 = \underline{665 \text{ litres}}$$

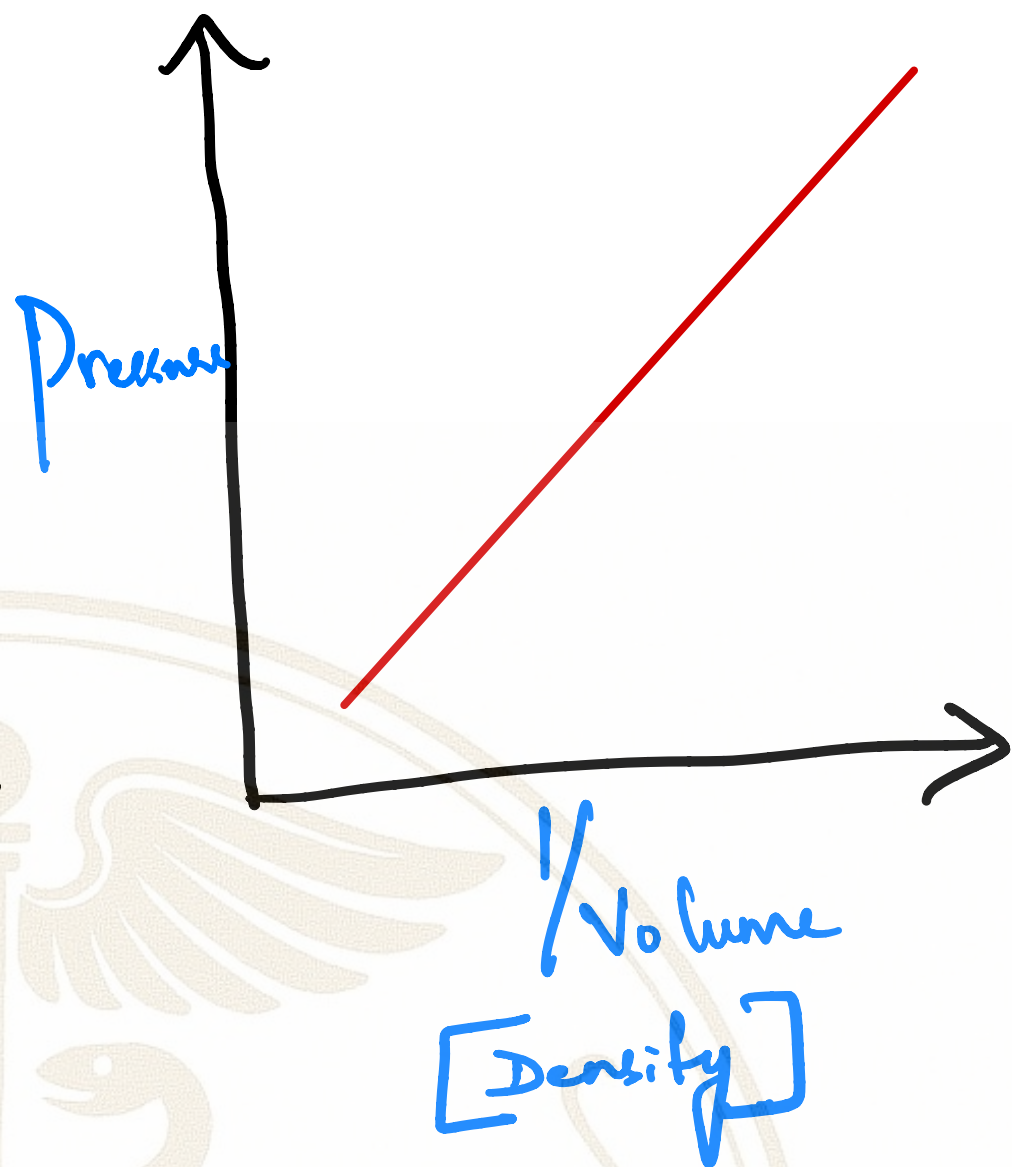
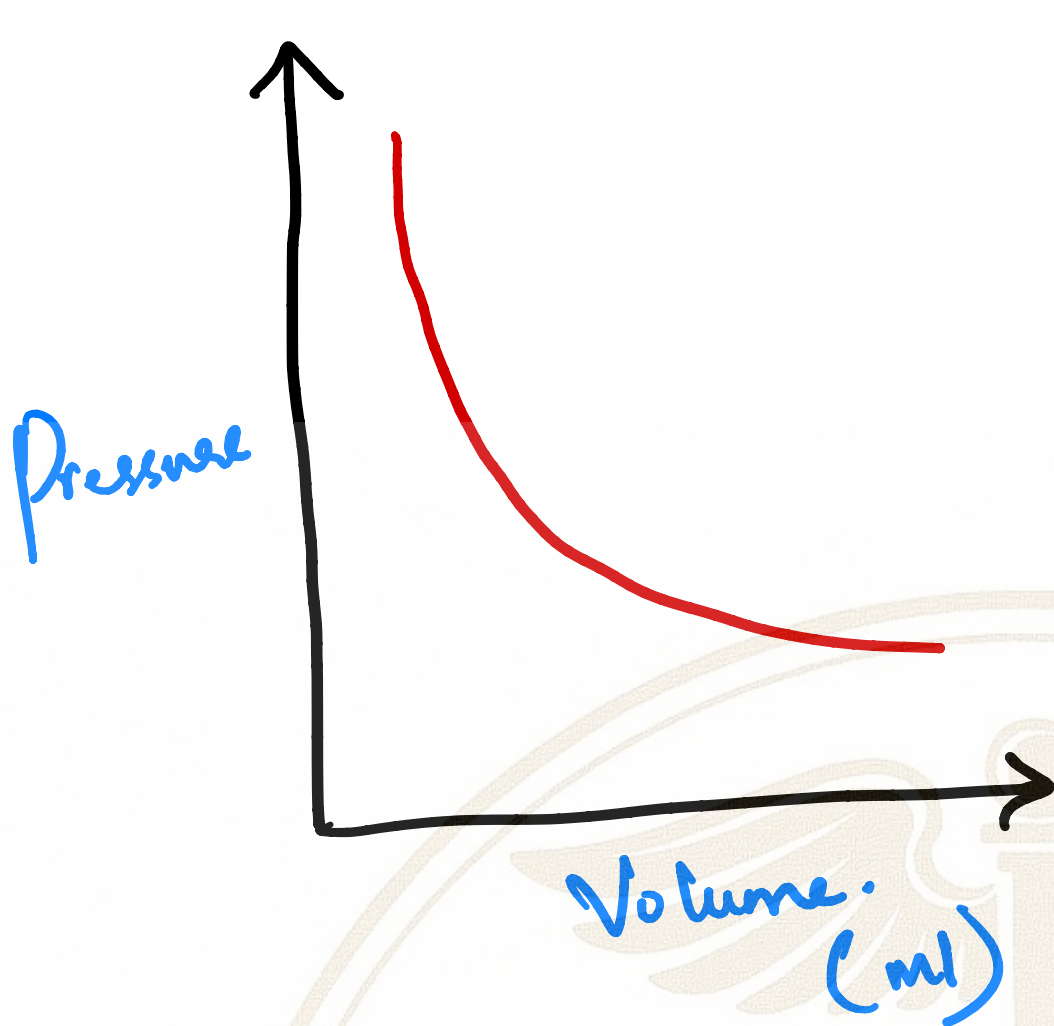
- If we use 3L of O_2 , E type full cylinder will last for ~ 220 mins.

→ Boyle's law can be used to describe the effects of altitude in gases in closed cavities in the body & to calculate the total intra-thoracic gas volume by plethysmography.

→ As altitude $\uparrow$ ambient pressure $\downarrow$ & $\therefore$ by Boyle's law; volume expansion occurs in enclosed spaces.

→ Boyle's Law - explains the use of saline in the cuff of an ETT during hyperbaric O_2 therapy; to prevent air leak d/t reduction of volume as pressure $\uparrow$.

→ When ascending from depth, if the diver holds their breath, the gases in the lungs will expand & can cause barotrauma, arterial gas embolism, mediastinal emphysema, pneumothorax.



⇒ Relationship b/w pressure
& volume is non-linear
(hyperbola)

⇒ Relationship b/w
pressure &
density is
linear

⇒ Bellows

⇒ Diaphragm contracts & Inspiration begins
relaxes & Exhalation begins

⇒ Squeezing bag to ventilate the patient

CHARLE'S LAW

States that @ constant pressure, volume of a gas is directly proportional to temperature.

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

APPLICATION

(3)

- In a thermometer, change in volume of a gas (such as hydrogen) is used to display the change in temperature.
- An adult tidal breath of 500ml of air @ room temperature will ↑ to a volume of 530ml when it reaches the site of gas exchange as it warms up to a body temp.
- One way of heat loss from the body is that the air next to body surface gets warmer & moves up & thus patient loses heat this way (esp. in Paeds Anaes)
- ETT Cuff Pressure
- Regulation of anaesthetic gas thro' metal strip
- LMA inflatable cuff expands in moisture.
- To calculate wt. of N₂ cylinder.

* Calculation of wt of N_2 cylinder ?

→ Critical temperature of N_2O is $36.5^\circ C$

(below which it will stay as liquid;
above which it will become gas)

→ Room temp: 20°C

→ Since N_2O is not in gas form, Boyle's law is not applicable.

→ Wt. of N_2O liquid in cylinder = Wt of N_2O cylinder - Tare wt (empty cylinder)

→ L → 3.3 kg. (eg)

→ Using Avogadro's law, 1 mol. wt of
a substance = 22.4 L

$$N_2O = (14 \times 2) + 16 = 44 \text{ g}$$

$$\therefore 44g \longrightarrow 22.4L$$

$$3300\text{ g} \rightarrow \frac{22.4}{44} \times 3300 = 1680\text{ L (at STP)}$$

Charles Law.

1680 — 273 K. (0°) 0°C = 273 K

1803L = ? — 293 K. (20°C) Pressure: 760 mmHg.

GAY LUSSAC'S LAW: (Third Gas law)

States that for a constant volume, the pressure is directly proportional to absolute temp.

$$\frac{P}{T} = k - \text{constant}$$

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

$\therefore$ Gas cylinders s/d filled keeping in mind the ambient temperature of storage. If the temp. in the storage place is high, the pressure inside the cylinder will $\uparrow$ leading to explosion.

APPLICATIONS:

- 1) It applies in the mechanism of pressure relief valves on the gas cylinder.
- 2) As the pressure inside the gas cylinder $\uparrow$ & $\uparrow$ in temp. above a certain pressure limit, the pressure relief valve will open to prevent explosion.

DALTON'S LAW of partial pressure states that for a mixture of non-reacting gases, the sum of partial pressure of each gas is equal to the total pressure exerted by the mixture @ constant temp. & volume.

Applications of DALTON'S LAW

1) Anaesthetic Gas: Dalton's law helps to determine the partial pressure of each inhalational gas in the mixture.



The concentration of an anaesthetic in the lungs is directly related to its partial pressure, which can affect how quickly the pt. reaches the desired level of anaesthesia. (Inhaled anaesthetics will diffuse from the lungs to the blood until partial pressures in blood & alveoli are equal.)

2) When delivering anaes. at different altitudes, Dalton's law assist in calculating the partial pressure of O_2 (PO_2)



This is $\therefore$ for ensuring adequate oxygenation in pts.

3) Variations in partial pressures of CO_2 result from changes in mechanical ventilation

4) Dalton's law helps explain the principles of gas exchange in the alveoli. The partial pressures of O_2 & CO_2 in the alveoli drive diffusion across the alveolar-capillary membrane.

5) Dalton's law can be used to calculate total pressure & the resulting partial pressure of O_2 delivery devices like face masks, high flow nasal cannulae.

contd.....



AVAGADRO'S LAW:

Equal volume of gas @ the same temperature & pressure contain the same no. of molecules

OR

Volume occupied by an ideal gas is proportional to the no. of moles of gas & the molar volume of an ideal gas is 22.4 L @ std temp & pressure.

APPLICATION: In a cylinder, volume is constant, temp. is constant.

$$R = \text{constant} ; P = n$$

$\therefore$ $PV = nRT$ is the ideal gas equation

i.e, the pressure shown in Bourdon's gauge is proportional to the no. of molecules C is the amount of gas in a cylinder.

ANAESTHESIA INSIGHTS

SEE THE LIGHT

LAPLACE LAW

Laplace law describes the relationship between the pressure difference across the interface of a curved liquid surface & the radius of curvature of that surface.

$$\Delta P = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

ΔP = pressure difference across the liquid interface.

γ = Surface tension of the liquid.

R_1 & R_2 are the principal radii of curvature of surface

APPLICATIONS:

- ① When the ET Tube is inserted, pressure difference across the tube's wall using Laplace law. The tension in the wall of the tube must be adequate to

withstand the pressure delivered by ventilator.

② Laplace law helps to explain the pressure within alveoli. Alveoli with smaller diameters exhibit a higher internal pressure compared to larger ones, which means smaller alveoli are at greater risk of collapse (atelectasis).

③ Pressure inside a closed cavity (eg; during Lap Sx) may ↑↑. Laplace law can help assess the tension in the wall of organs or vessels in these situations, ensuring insufflation pressure does not exceed safety thresholds preventing vessel rupture / organ injury.

④ ICP Monitoring: Laplace law can apply to the balance within cranial vault, where changes in volume of edema or air may affect the pressure exerted on different structures

⑤ When using anesthetic agents that may form bubbles (eg; while administering N_2O) Laplace law can assist in avoiding complications from bubble formation during procedures.

HENRY'S LAW

Henry's law states that the amount of a gas that can dissolve in the liquid @ a given temperature is directly proportional to the partial pressure of that gas above the liquid.

$$C = K_H \times P.$$

where C = conc. of dissolved gas (usually in moles per liter)

K_H = Henry's law constant

P = partial pressure of the gas above the liquid.

APPLICATIONS:-

① Henry's law helps to understand how anaesthetic gases dissolve in blood & tissues

↓
The solubility of different gases affect their reqd dosing, onset & duration.

② O_2 & CO_2 Transport : Solubility of O_2 & CO_2 in blood is derived using Henry's law.

③ The speed at which an anaesthetic agent takes effect is affected by its solubility in blood.

④ Henry's law is ~~✗~~ to understand how gases (eg; N_2O) dissolve in blood ↓ pressure.
esp. in pts w/ R/o diving.

⑤ ↓ GA, Henry's law is used to gauge the appropriate TV & ventilation rates, ensuring adequate delivery of anaesthetic gases while maintaining oxygenation & CO_2 elimination.