COURSE TITLE : PHYSICAL CHEMISTRY I

COURSE CODE : 15U5CRCHE07

UNIT 1 : GASEOUS STATE

SESSION 2 : Gas Laws

GAS LAWS

- Gas laws describe the relationship between different gas parameters (T, V, P and n).
- Describe the general behaviour of gases.
- The volume of a given sample of gas depends on the temperature and pressure applied to it.
- Change in temperature or pressure will affect the volume of the gas

BOYLE'S LAW

STATEMENT :

The pressure of a given mass of a gas is inversely proportional to its volume at a constant temperature.

MATHEMATICAL FORM : $P \propto \frac{1}{V}$

ROBERT BOYLE
IRISH CHEMIST

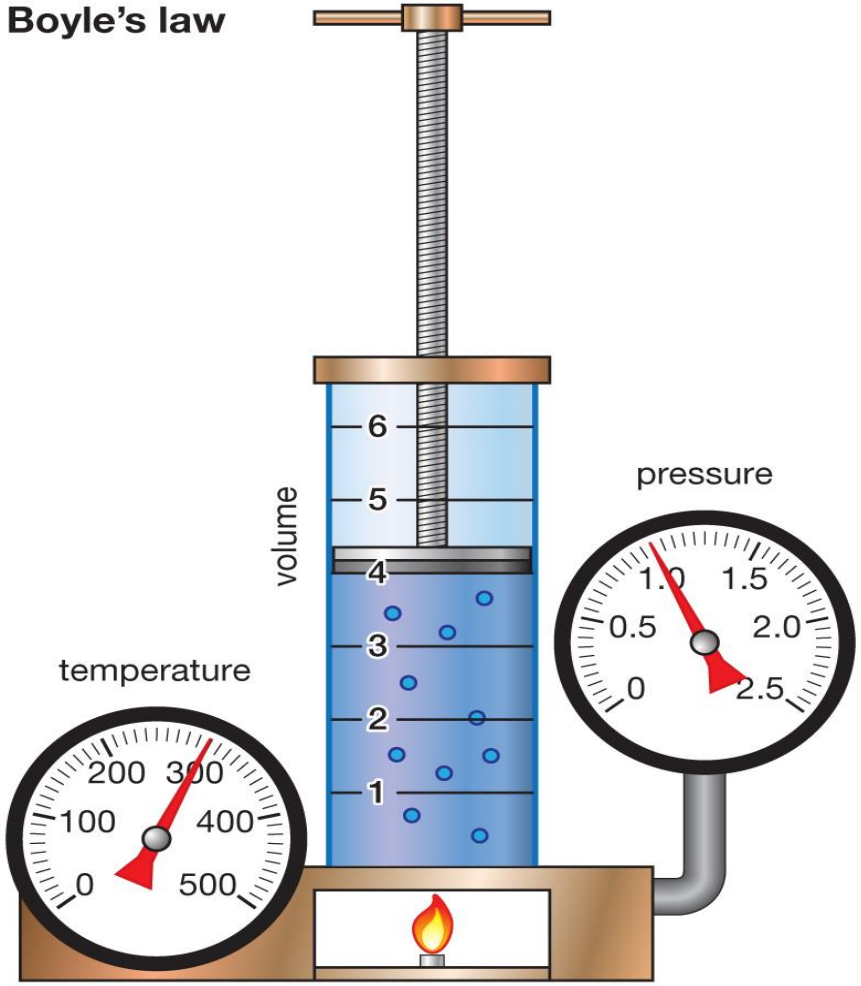
$$\mathbf{PV = \mathit{K}}$$

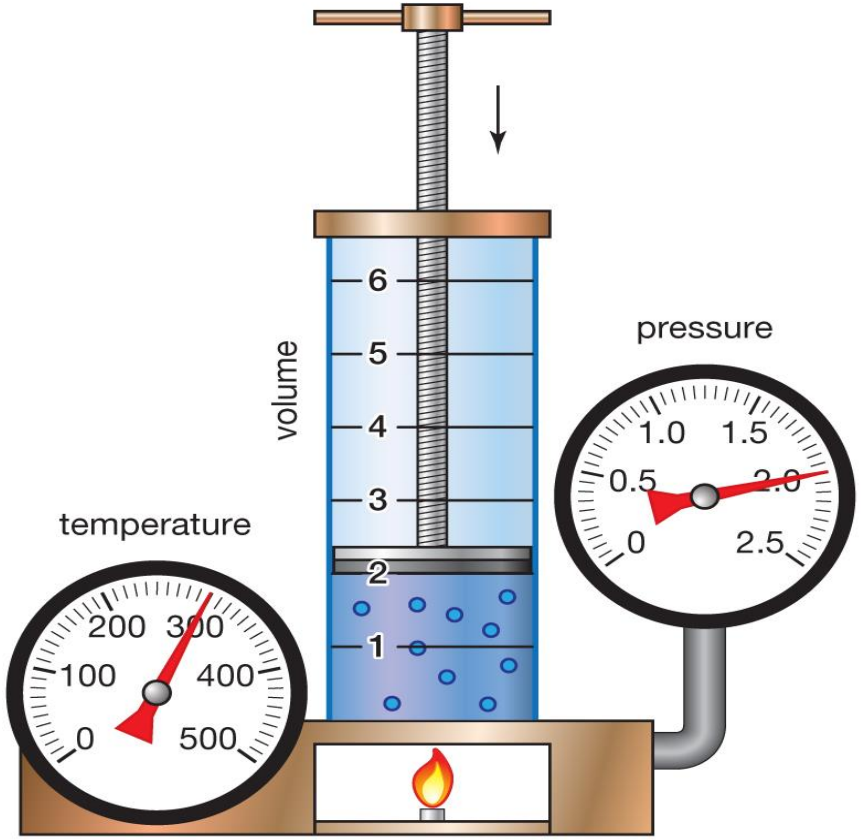
where *K* is a constant and its value depends on amount of a gas and the temperature.

Considering two conditions of pressure and volume (P_1, V_1) and volume (P_2, V_2).

Then $$\mathbf{P_1 \times V_1 = P_2 \times V_2}$$

Boyle's law





CONDITION 1

P = 1 atm V = 4 L

T = 300 K

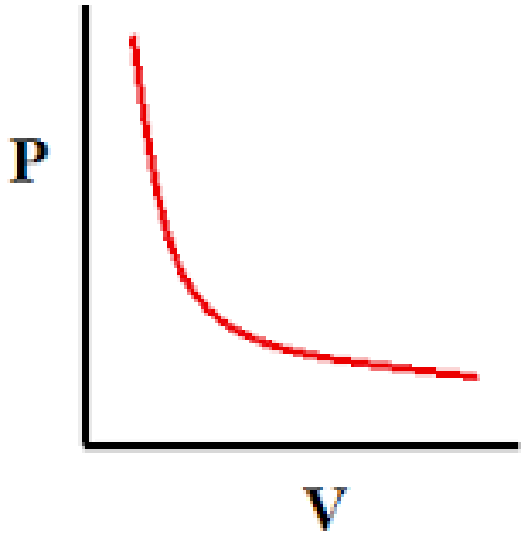
CONDITION 2

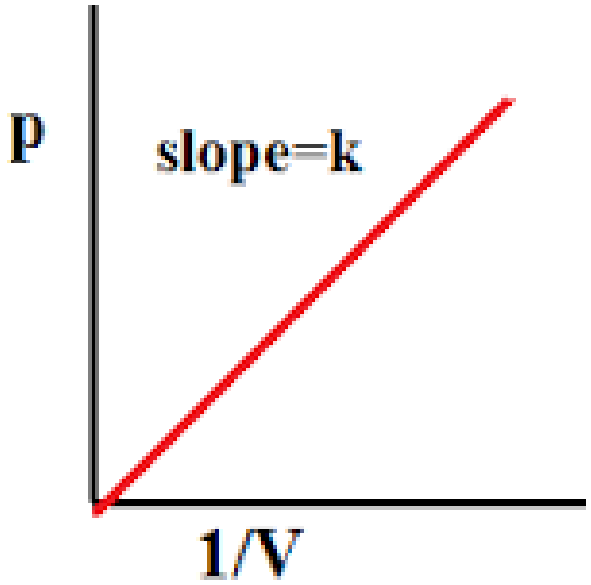
P = 2 atm V = 2 L

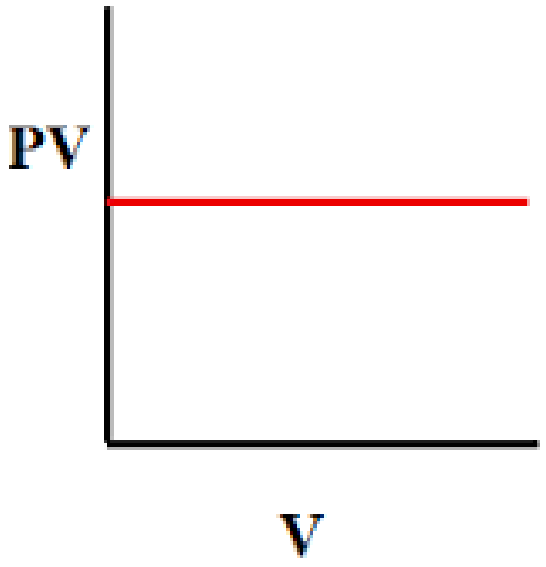
T = 300 K

As P increases, V decreases. T and n remained constant

Graphical Representation of Boyle's Law

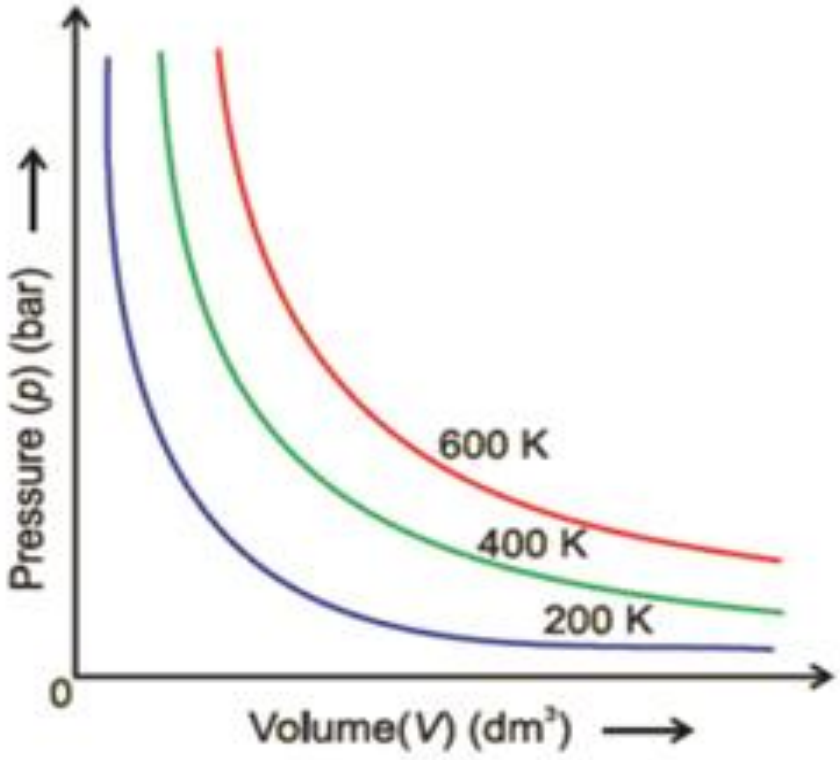






Graphical curves at constant temperature are known as isotherms.

Isotherms at Different Temperatures



CHARLES' LAW

JACQUES CHARLES
FRENCH SCIENTIST

- Charles Law relates the **V** and **T** of a given mass of a gas at constant pressure.
- Charles law states that '*At constant pressure, the volume of a given mass of a gas increases or decreases by 1/273.15 of its volume at 0 ^{0}C for every one degree rise or fall in temperature*'.
- Let V_0, V_t are the volumes of gas at 0 °C and t °C. Then according to Charles law:

$$V_t = V_0 + \frac{V_0}{273.15} \times t\ ^0C \qquad V_t = V_0\left(\frac{t\ ^0C + 273.15}{273.15}\right)$$

At absolute zero or –273 °C, all molecular motions would stop and the volume of the gas would become zero.

$$T \text{ (in K)} = t\ ^0C + 273.15 \qquad T_0 = 273.15\ ^0\text{C}$$

Then $$V_t = V_0\left(\frac{t\ ^0C + 273.15}{273.15}\right)$$ becomes $$V_t = V_0\left(\frac{T}{T_0}\right)$$

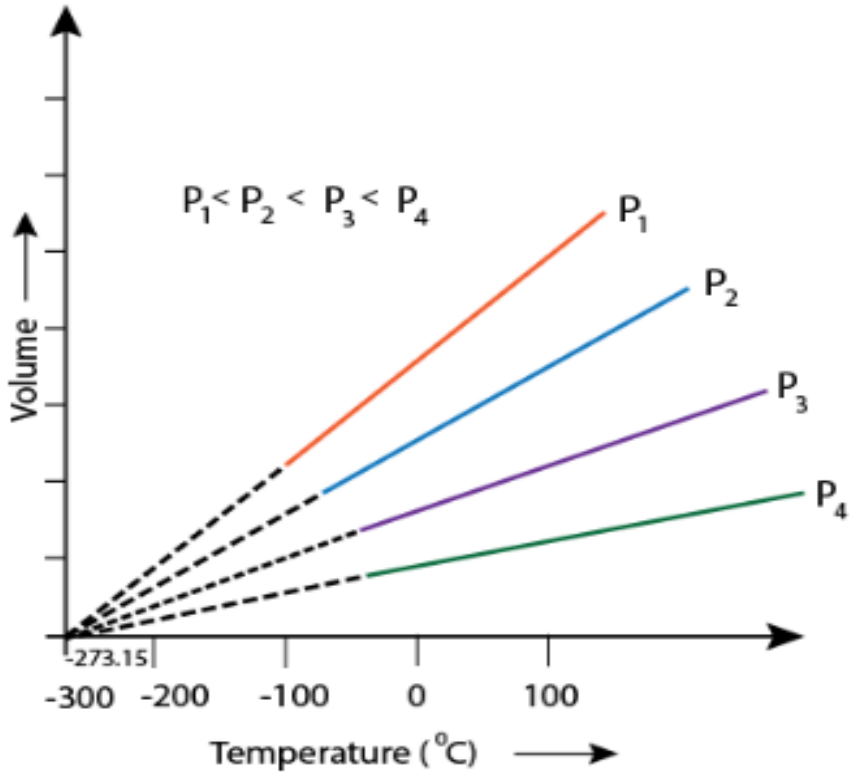
$$\frac{V_t}{V_0} = \frac{T}{T_0}$$

$$V \times T = K, \text{ a constant}$$

$$V \infty T$$

"***at constant pressure, the volume of a given amount of a gas directly proportional to its absolute temperature***".

VERIFICATION OF CHARLES LAW



ISOBARS – Constant pressure lines in V-T graph

GAY LUSSAC'S LAW

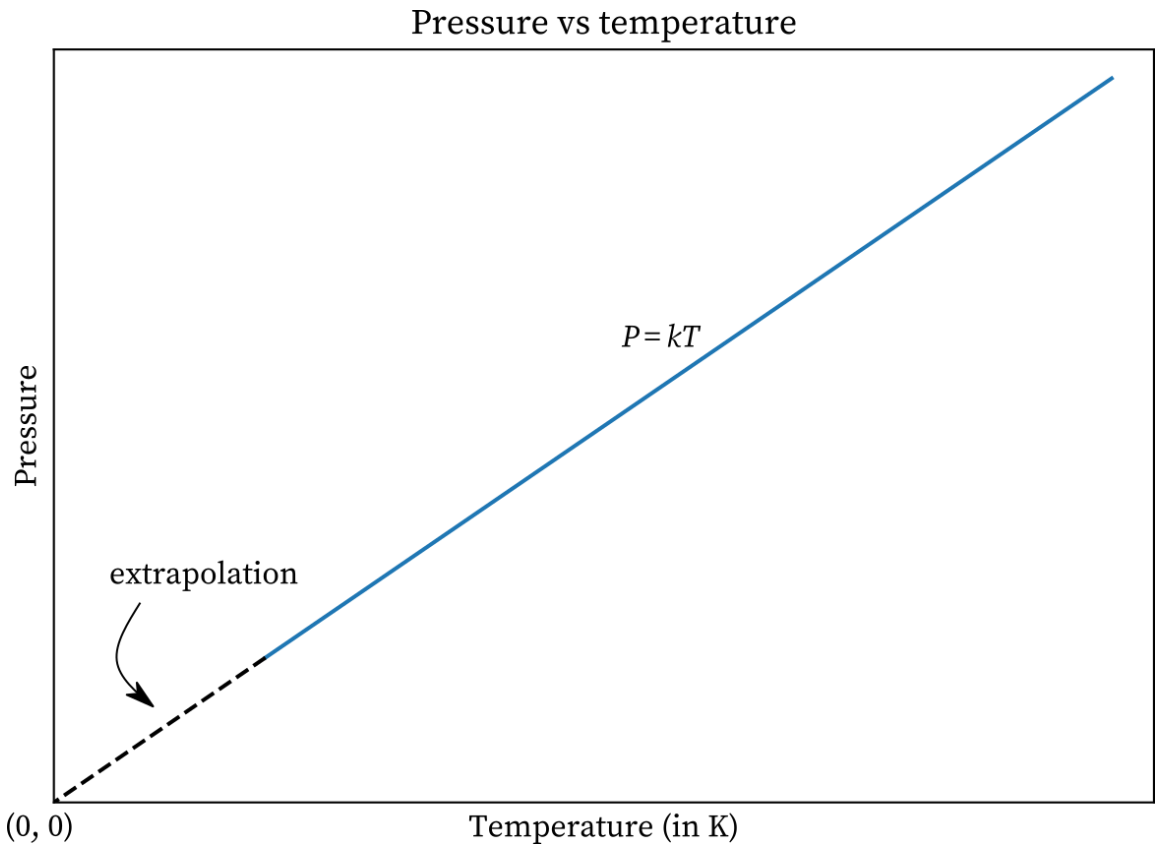
- Gay Lussac's law relates the pressure and absolute temperature of a given mass of a gas at constant volume.
- It is stated as "*at constant Volume, the pressure of given mass of a gas is directly proportional to absolute temperature*".

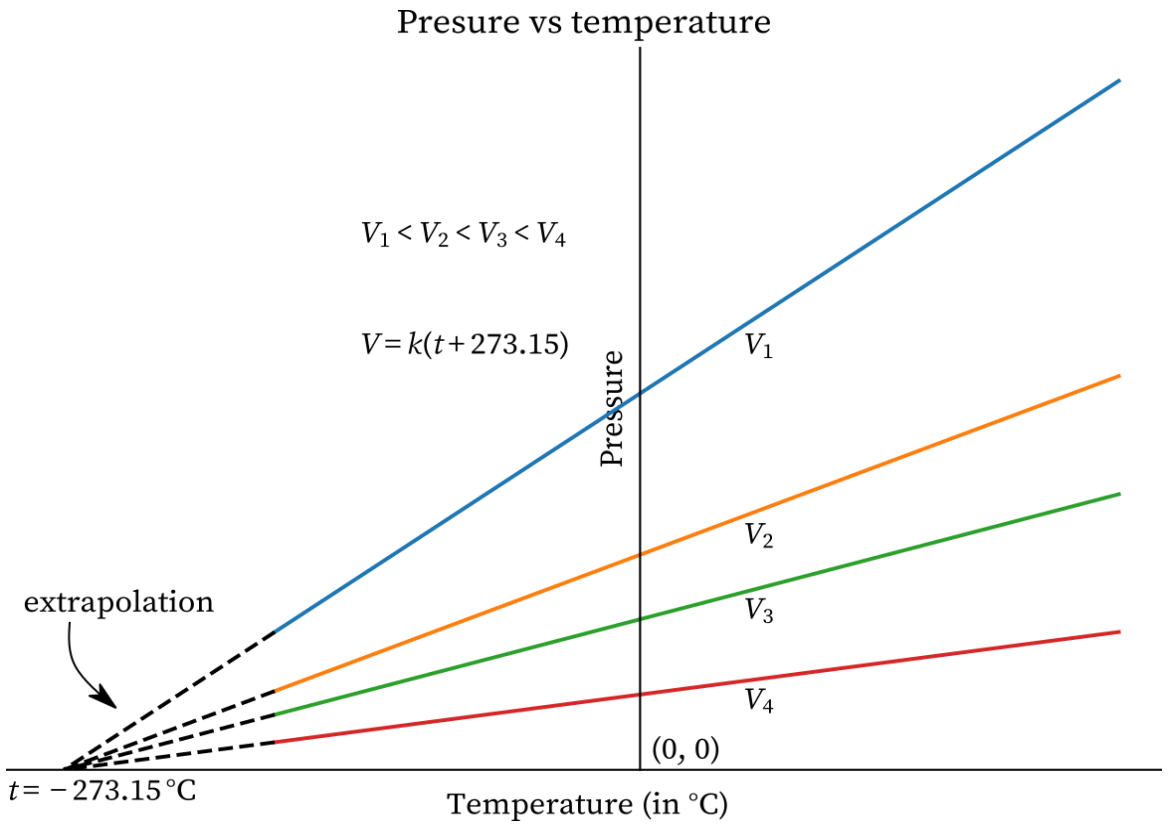
JOSEPH GAY-LUSSAC
FRENCH CHEMIST

$P \propto T$ at constant V

$$\frac{P}{T} = K, \text{ a constant}$$

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



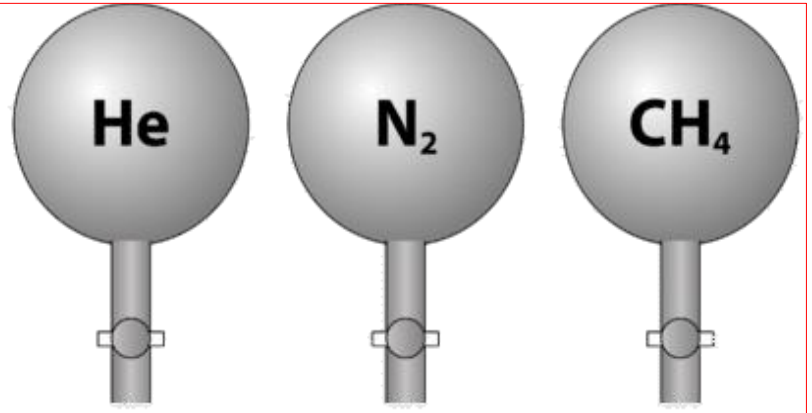


ISOCHORES – Constant volume lines in P-T graphs

AVOGRADRO'S LAW

"Equal volumes of different gases at the same temperature and pressure contain the same number of molecules."

AMEDEO AVOGADRO
ITALIAN SCIENTIST



	He	N_2	CH_4
Volume	22.4 L	22.4 L	22.4 L
Pressure	1 atm	1 atm	1 atm
Temperature	0^oC	0^oC	0^oC
Mass of gas	4.00 g	28.0 g	16.0 g
Number of gas molecules	6.02×10^{23}	6.02×10^{23}	6.02×10^{23}

$V \propto n$ (*at constant T and P*)

or $V = Kn$ (*where K is constant*)

or $V_1/n_1 = V_2/n_2 = ... = K$

1 mole of gas at 273 K and 1 atmosphere pressure occupies 22.4 Litres – The Molar Volume

IDEAL GAS EQUATION

Boyle's law, Charles law and Avogadro's law can be combined as:

According to Boyle's law, $V \propto 1/P$ at constant T & n.

According to Charle's law, $V \propto T$ at constant P & n.

According to Avogadro's law, $V \propto n$ at constant T & P

By combining the three laws we get, $V \propto nT/P$

$$V = R \times \frac{nT}{P}$$

PV = n RT

Value of universal gas constant R

PV = RT for 1 mole of a gas R = PVT

R = 8.314 Nm K^{-1} mol^{-1}

= 8.314 J K^{-1} mol^{-1}

= 8.314 x 107 erg K^{-1} mol^{-1}

= 1.987 cal. K^{-1} mol^{-1} = 2 cal. K^{-1} mol^{-1}

= 0.0821 L atm. K^{-1} mol^{-1}

AMOUNT OF THE SUBSTANCE

Amount of gas is measured in gram or kilogram.

1 kg = 10^3 g

The mass of the gas is expressed in number of moles.

Moles of gas (n) = Mass / Molar Mass