# HEAT & OPTICS

| Teaching Hours | Distribution of Theory Marks | | | |
|---|---|---|---|---|
| | R Level | U Level | A Level | Total Marks |
| 12 | 03 | 05 | 06 | 14 |

## GAS LAWS

Unit IV

# COURSE OUTCOMES & LEARNING OUTCOMES

## Course Outcomes

**CO3:** Use the basic principles of heat and optics in related engineering applications.

heat transfer

## Learning Outcomes

a. Convert the given temperature in different temperature scales.

b. Describe the properties of the given good and bad conductors of heat.

c. **Relate the characteristics of the three gas laws.**

d. **Determine the relation between specific heats for given materials.**

types

e. Distinguish the phenomena of TIR for the given medium.

f. Describe light propagation in the given type of optical fibre.

# PRESSURE

$P = \frac{F}{A} \ldots \frac{N}{m^2} \ldots Pa$

**Pressure** is defined as the force the gas exerts on a given area of the container in which it is contained. The SI unit for pressure is the Pascal, Pa.

- If you've ever inflated a tire, you've probably made a pressure measurement in kilogram (force) per square inch (area).

# VOLUME

$V = L \times B \times H$

**Volume** is the three-dimensional space occupied by a gas in container. The SI unit for volume is the cubic meter, $m^3$. A more common and convenient unit is the litre, L.

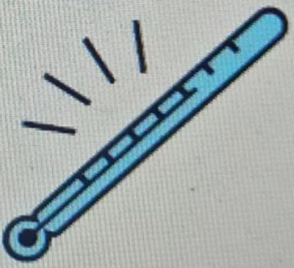
Think of a 2-litre bottle of soda to get an idea of how big a litre is.

* Heat transfer

# TEMPERATURE

**Temperature** is the measurement of heat or how fast the particles are moving. Gases, at room temperature, have a lower boiling point as compare to liquids or solids at the same temperature. **Remember**: Not all substance freeze, melt or evaporate at the same temperature.

Water will freeze at 0°C, however Alcohol will not freeze at this temperature.



# AMOUNT (MOLES)

number of mo

We already know, the SI unit for amount of substance is the mole, mol. Since we can't count molecules, we can convert measured mass (in kg) to the number of moles, n using the molecular or formula weight of the gas.

By definition, one mole of a substance contains approximately $6.022 \times 10^{23}$ particles of the substance. You can understand why we use mass and moles!

# PHYSICAL CHARACTERISTICS OF GASES

| Physical Characteristics | Typical Units |
| --- | --- |
| Volume, **V** | litres (**L**) |
| Pressure, **P** | atmosphere $P = \frac{F}{A}$ <br> (1 **atm** = $1.015 \times 10^5$ $N/m^2$) |
| Temperature, **T** | Kelvin (**K**) |
| Number of atoms or molecules, **n** | **mole** (1 mol = $6.022 \times 10^{23}$ atoms or molecules) <br> particles |

Gas laws → V, T — 2-relations keeping 3rd-constant

# BOYLE'S LAW

"Father of Modern Chemistry"
Robert Boyle
Chemist & Natural Philosopher
Listmore, Ireland
nuary 25, 1627 – December 30, 1690

At constant temperature, the pressure exerted by a fixed mass of the gas is inversely proportional to its volume.

As one goes up (↑) the other comes down (↓)

If P is the pressure and V is the volume at constant temperature, then

$T = \text{constant}$

$$\boxed{P \propto \frac{1}{V} \text{ or } PV = \text{constant}}$$

$$P \propto \frac{1}{V} \Rightarrow P = \frac{\text{constant}}{V}$$

$$\Rightarrow PV = \text{constant}$$

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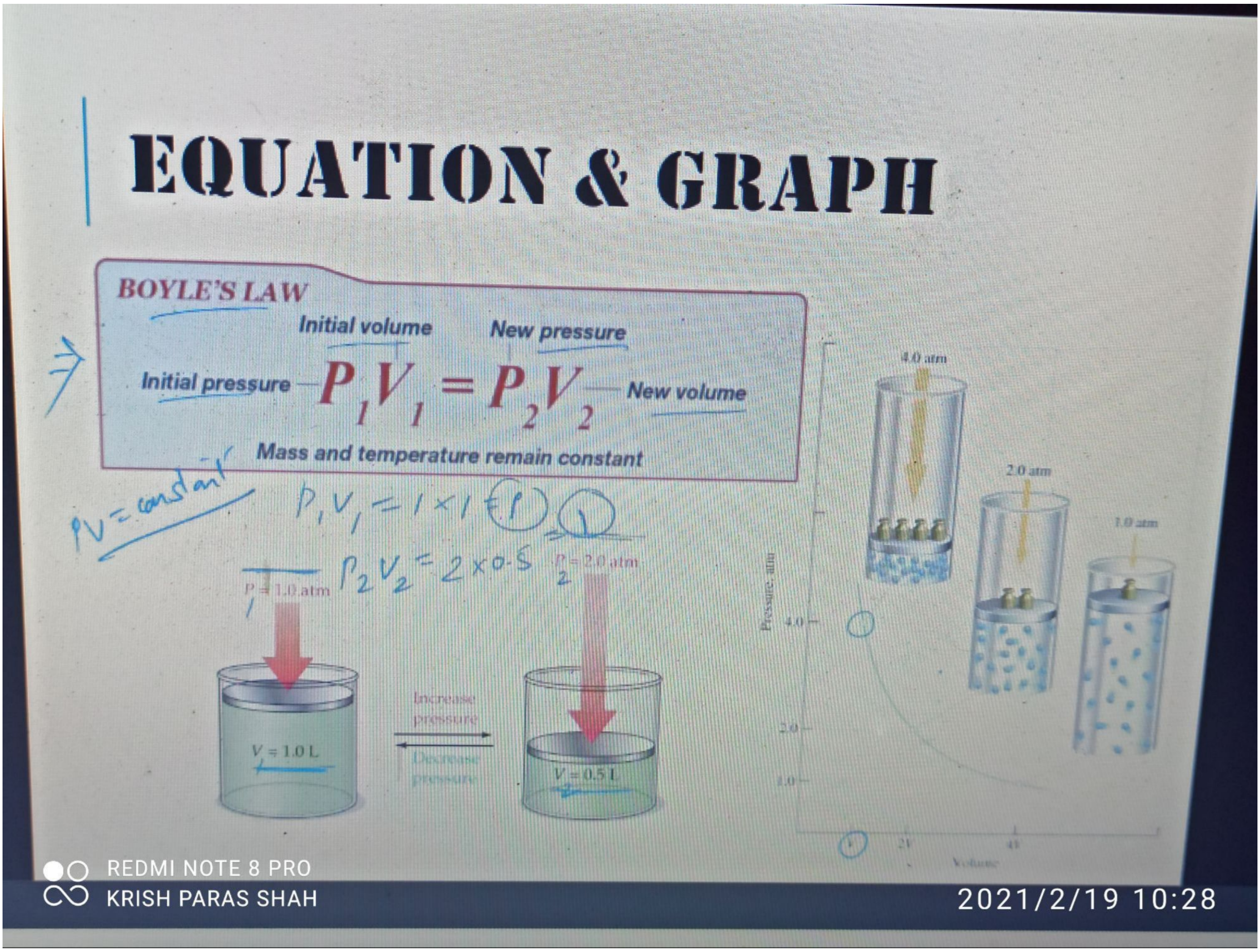
Case

$$P \propto \frac{1}{V} \text{ or } \boxed{PV = \text{constant}}$$

In general if $V_1$, $V_2$ and $V_3$ are volumes at pressures $P_1$, $P_2$ and $P_3$ respectively at constant temperature of a given mass of a gas, we have

Case 1 Case 2 Case 3

$$P_1V_1 = P_2V_2 = P_3V_3 = \text{constant}$$


EQUATION & GRAPH
BOYLE'S LAW
Initial volume
New pressure
Initial pressure
$P_1V_1 = P_2V_2$
New volume
Mass and temperature remain constant
PV = constant
$P_1V_1 = 1 \times 1 = 1$
$P_2V_2 = 2 \times 0.5 = 1$
$P_1$ = 1.0 atm
$P_2$ = 2.0 atm
Increase pressure
Decrease pressure
V = 1.0 L
V = 0.5 L
4.0 atm
2.0 atm
1.0 atm
Pressure, atm
4.0
2.0
1.0
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2021/2/19 10:28

# CHARLE'S LAW

P V T

Jacques-Alexandre Charles
Mathematician, Physicist, Inventor
Beaugency, France
November 12, 1746 – April 7, 1823

At constant pressure, the volume of a fixed mass of a gas is directly proportional to the absolute temperature. (K)

As one goes up (↑) the other also goes up (↑)

If V is the volume and T is the temperature at constant pressure, then

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

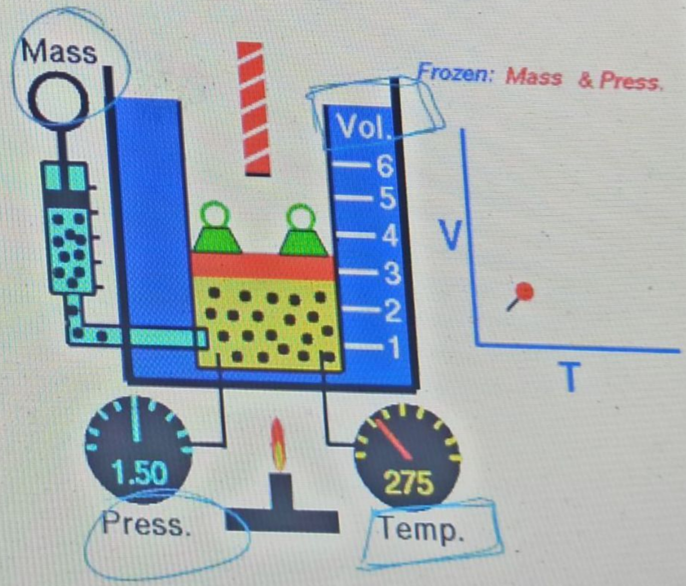
In general if $V_1$, $V_2$ and $V_3$ are volumes at temperatures $T_1$, $T_2$ and $T_3$ respectively at constant pressure of a given mass of a gas, we have

# WHAT DOES CHARLE'S LAW MEAN?

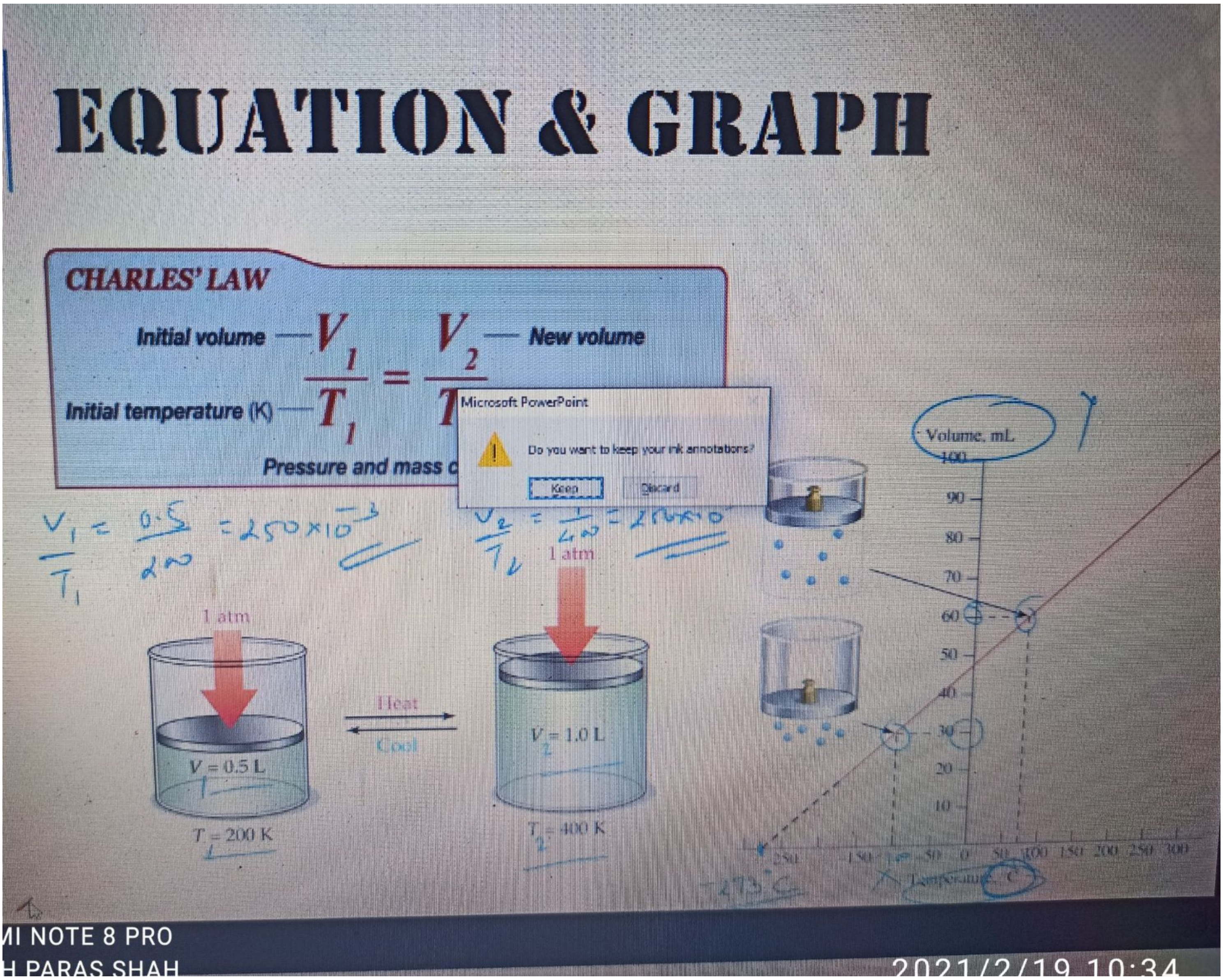
Suppose you have that same cylinder with a piston at the top allowing **volume** to change, and a heating/cooling element allowing for changing **temperature**.

The force on the piston head is constant to maintain **pressure**, and the cylinder is enclosed by a fixed **amount** of gas.

An increase in **temperature** results in increased **volume**.




→ As the temperature increases, the volume increases. Conversely, when the temperature decreases, volume decreases.


EQUATION & GRAPH
CHARLES' LAW
Initial volume
New volume
Initial temperature (K)
Pressure and mass c
Microsoft PowerPoint
Do you want to keep your ink annotations?
Keep
Discard
1 atm
1 atm
Heat
Cool
V = 0.5 L
T = 200 K
V2 = 1.0 L
T2 = 400 K
Volume, mL
Temperature (°C)
-273°C
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# GAY LUSSAC'S LAW

P (V) T

**Joseph-Louis Gay-Lussac**
Experimentalist
Limoges, France
*December 6, 1778 – May 9, 1850*

At constant volume, the pressure of a fixed mass of a gas is directly proportional to the absolute temperature.

As one goes up (↑) the other also goes up (↑)

If P is the pressure and T is the temperature at constant volume, then

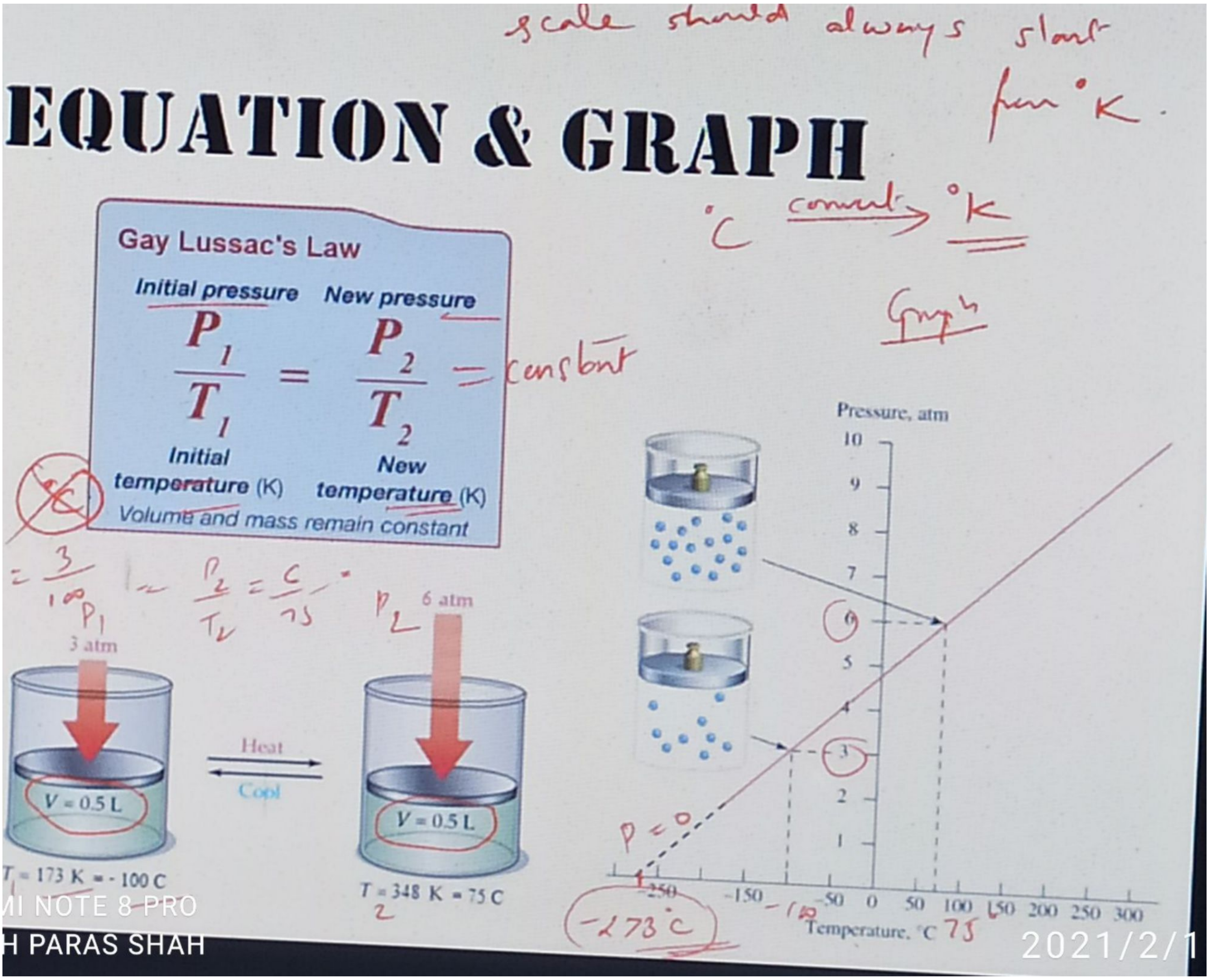
$$\boxed{P \propto T \text{ or } \frac{P}{T} = \text{constant}}$$

In general if $P_1$, $P_2$ and $P_3$ are the pressure at temperature $T_1$, $T_2$ and $T_3$ respectively at constant volume of a given mass of a gas, we have

case 1 case 2 case 3

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \frac{P_3}{T_3} = \text{constant}$$

E has left the meeting


scale should always start from °K.
EQUATION & GRAPH
°C convert °K
Graph
Gay Lussac's Law
Initial pressure
New pressure
$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{constant}$$
Initial temperature (K)
New temperature (K)
Volume and mass remain constant
3 atm
6 atm
Heat
Cool
V = 0.5 L
V = 0.5 L
T = 173 K = - 100 C
T = 348 K = 75 C
Pressure, atm
Temperature, °C
P = 0
-273 °C
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has occupies same pressure and volume at NTP

normal temp pressure

# UNIVERSAL GAS CONSTANT (R)

$PV = KT$

For **one gram mole** of a gas the general gas equation is given as **PV = RT** (where R is universal gas constant)

***R*** is called ***universal gas constant*** because value of R is same for all gases (R = 8314.91 J/°K-kg-mole).

The reason is that one gram molecule of any gas occupies same volume under normal temperature pressure (NTP) condition.

$PV = RT$

$$\left[\begin{array}{l} P \propto \frac{1}{V} \\ P \propto T \end{array}\right] \rightarrow P \propto \frac{T}{V} \Rightarrow PV \propto T$$

$$V \propto T$$

$$\boxed{PV = KT}$$

# UNIVERSAL GAS CONSTANT (R)

**Unit of R:** We know PV = RT, $\therefore\ \frac{PV}{T} = R$

$$\therefore\quad R = \frac{P \times V}{T} = \frac{\left(\frac{N}{m^2}\right) \times \left(\frac{m^3}{kg \times mole}\right)}{{}^\circ K} = \frac{N.m}{{}^\circ K.kg.mole} = \frac{J}{{}^\circ K.kg.mole}$$

Now for ***n moles*** of a gas, the gas equation is given as ***PV = nRT*** is called **molar gas equation**.

# SPECIFIC HEAT

**Specific heat of substance (c):** The specific heat of substance is defined as the quantity of heat required to raise the temperature of unit mass of substance through 1°C (or 1°K). Specific heat is denoted by symbol 'c'.

If Q is the quantity of heat supplied to a substance of having mass m and specific heat c and θ is the rise temperature of the substance, then the heat absorbed by the substance is given as

Heat absorbed = mass × specific heat × rise in temperature.

$$\therefore \quad Q = m \times c \times \theta$$

$$\therefore \quad c = \frac{Q}{m \times \theta}$$

**Unit of specific heat (c):** As we know, $c = \frac{Q}{m\theta} = \frac{J}{kg°K}$ or $\frac{J}{kg°C}$

# SPECIFIC HEAT

Practically & theoretically it is noted that if a gas is heated at constant pressure its volume changes and vice-versa, hence there are two specific heats of a gas.

They are specific heat of a gas at constant volume ($c_v$) and specific heat of a gas at constant pressure ($c_p$)

c - sp heat
Q

1) **Specific heat at constant volume ($c_v$):** The quantity of heat required to increase the temperature of unit mass of gas by 1°K or 1°C, at *constant volume* is called specific heat of gas at constant volume ($c_v$).

2) **Specific heat at constant pressure ($c_p$):** The quantity of heat required to increase the temperature of unit mass of gas by 1°K or 1°C, at *constant pressure* is called specific heat of gas at constant pressure ($c_p$).

# RATIO OF SPECIFIC HEAT

**Ratio of specific heats:** For a particular gas, $C_v$ and $C_p$ is always constant. Also $C_p$ is greater than $C_v$.

$$\therefore \frac{C_p}{C_v} = constant = \gamma \qquad (\gamma = adiabatic\ constant)$$

$$\therefore C_p > C_v \qquad \therefore \gamma > 1$$

Value of $\gamma$ = 1.66 for monoatomic gases

$\frac{C_p}{C_V}$

= 1.41 for diatomic gases

= 1.31 for triatomic gases