

00:51 07/08/2025 15:00

Suppose gas in a container and its molecules moving randomly, they collide or hit's each other molecule and the wall, when they hit wall, they exert force on it, ~~that~~ That force is actually Force per unit Area = Pressure. So they exert Pressure. (Which we will calculate) ...

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REDMI 12

Physics:

Chapter: 16

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: PRESSURE EXERTED BY GAS MOLECULE:

- Molecules of gas moves randomly and consistantly inside a cotainer
- They collide elastically with each other & with container
- When gas molecules collide with the wall rebound and it's momentum changes.
- This change in momentum results in a force on wall:

$$F = \frac{\Delta P}{\Delta t} \rightarrow P = \frac{F}{A} \quad P = \frac{\Delta P}{\Delta t} \times \frac{1}{A} \quad *$$

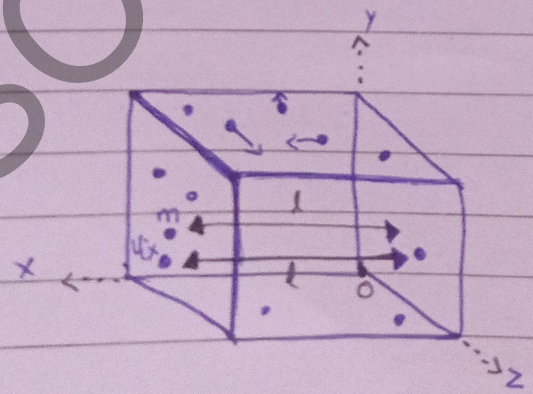
: Pressure On A Cubic Container:

Consider a cube of side 'l' containing 'N' molecules. Mass of single molecule is 'm' moving with velocity v_{ix} along x-axis, v_{iy} along y-axis & v_{iz} on z-axis.

As, Taking along x-axis;

$$P_x = \frac{F_x}{A} \rightarrow (1)$$

$$F_x = \frac{\Delta P}{\Delta t} \rightarrow (2)$$



• As, the moment of panicles, along x, y, z axis is same, So, we will take only one axis to calculate!

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along x-axis, Suppose e on
 $\Delta P = \Delta P_x$
 $\Delta P = (mv_x)$
 $\Delta P = -2$

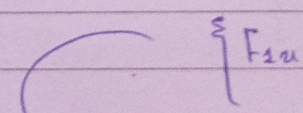
$$\Delta t = \frac{s}{v}$$

$$\therefore \Delta t = \frac{2l}{v_{ix}}$$

Putting in eqn -

$$As, \quad F_x =$$

$$F_{2x}$$



This is Force equal and oppos on the wall:

$$\therefore F_x = F_{1x} + F_{2x} + \dots$$

$$F_x = \frac{mv_{ix}^2}{l}$$

$$F_x = \frac{m}{l} \{ v_{ix}^2 \}$$

2) Multiplying and

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along x-axis, Suppose one particle,

$$\Delta P = \Delta P_f - \Delta P_i$$

$$\Delta P = (mv_{1x}) - (mv_{1x})$$

$$\therefore \Delta P = -2mv_{1x} \quad \text{--- (iii)}$$

Now,

$$\Delta t = \frac{S}{v}$$

$$\therefore \Delta t = \frac{2l}{v_{1x}} \quad \text{--- (iv)}$$

$\therefore$ Putting in eqn (iii) --- (v)

$$\text{As, } F_{1x} = \frac{-2mv_{1x} \times v_{1x}}{2l}$$

$$F_{1x} = \frac{-2mv_{1x}^2}{2l}$$

$$\left\{ F_{1x} = \frac{-m v_{1x}^2}{l} \right\} \quad \text{--- (v)}$$

This is Force exerted by wall on the molecule, is equal and opposite to force exerted by molecules on the wall:

$$F_{1x} = - \left\{ \frac{-m v_{1x}^2}{l} \right\} = \frac{m v_{1x}^2}{l}$$

$$F_{2x} = \frac{m v_{2x}^2}{l}, \quad F_{3x} = \frac{m v_{3x}^2}{l} \dots \dots F_{nx} = \frac{m v_{nx}^2}{l}$$

$$\therefore F_x = F_{1x} + F_{2x} + F_{3x} + \dots \dots + F_{nx}$$

$$F_x = \frac{m v_{1x}^2}{l} + \frac{m v_{2x}^2}{l} + \frac{m v_{3x}^2}{l} + \dots \dots + \frac{m v_{nx}^2}{l}$$

$$F_x = \frac{m}{l} \left\{ v_{1x}^2 + v_{2x}^2 + v_{3x}^2 + \dots \dots + v_{nx}^2 \right\}$$

$\therefore$ Multiplying and dividing 'N' $\left[N = \text{Total no. of molecule} \right]$

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along x-axis, Suppose one particle,

$$\Delta P = \Delta P_f - \Delta P_i$$

$$\Delta P = (mv_{1x}) - (mv_{ix})$$

$$\therefore \Delta P = -2mv_{ix} \quad \text{--- (iii)}$$

Now,

$$\Delta t = \frac{S}{v}$$

$$\therefore \Delta t = \frac{2l}{v_{ix}} \quad \text{--- (iv)}$$

$\therefore$ Putting in eqn (iii) --- (v)

$$\text{As, } F_{ix} = \frac{-2mv_{ix} \times v_{ix}}{2l}$$

$$F_{ix} = \frac{-2mv_{ix}^2}{2l}$$

$$\{ F_{ix} = \frac{-m v_{ix}^2}{l} \} \quad \text{--- (v)}$$

This is Force exerted by wall on the molecule, is equal and opposite to force exerted by molecules on the wall:

$$F_{ix} = - \left\{ \frac{-m v_{ix}^2}{l} \right\} = \frac{m v_{ix}^2}{l}$$

$$F_{2x} = \frac{m v_{2x}^2}{l}, \quad F_{3x} = \frac{m v_{3x}^2}{l} \dots \dots F_{nx} = \frac{m v_{nx}^2}{l}$$

$$\therefore F_x = F_{ix} + F_{2x} + F_{3x} + \dots \dots + F_{nx}$$

$$F_x = \frac{m v_{ix}^2}{l} + \frac{m v_{2x}^2}{l} + \frac{m v_{3x}^2}{l} + \dots \dots + \frac{m v_{nx}^2}{l}$$

$$F_x = \frac{m}{l} \{ v_{ix}^2 + v_{2x}^2 + v_{3x}^2 + \dots \dots + v_{nx}^2 \}$$

$\therefore$ Multiplying and dividing 'N' $\left[\begin{array}{l} \text{Total no.} \\ \text{molecule} \end{array} \right]$

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$$F_x = \frac{mN}{l} \left\{ \frac{v_{1x}^2 + v_{2x}^2 + v_{3x}^2 + \dots + v_{Nx}^2}{N} \right\}$$

$$\left\{ F_x = \frac{mN}{l} \langle v_x^2 \rangle \right\} \text{--- (iv)}$$

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Q: Here, why mean square velocities are taken?

Ans: Bcz, they have random motion of particle, every particle don't have same velocity. So when we take average here, then we can get 'zero' answer, as some are moving in x-axis, y-axis & z-axis along positive & negative axis. So, when we add them we get answer 'zero' as by dividing by Total number 'N'. So, That's why to get zero we take ^{square} ~~velocity~~ velocity....

Now;

∴ due to random motion:-

$$\langle v^2 \rangle = \langle v_x^2 \rangle + \langle v_y^2 \rangle + \langle v_z^2 \rangle$$

$$\langle v^2 \rangle = \langle v_x^2 \rangle + \langle v_y^2 \rangle + \langle v_z^2 \rangle$$

$$\langle v^2 \rangle = 3 \langle v_x^2 \rangle$$

$$\frac{1}{3} \times \langle v^2 \rangle = \langle v_x^2 \rangle$$

So,

$$F_x = \frac{mN}{l} \times \frac{1}{3} \langle v^2 \rangle \text{--- (v)}$$

$$\frac{F}{A} = \frac{mN}{A \times l} \times \frac{1}{3} \langle v^2 \rangle$$

$$\left\{ P_z = \frac{mN}{V} \times \frac{1}{3} \langle v^2 \rangle \right\} \text{--- (vi)}$$

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$$\star - \left\{ P = \frac{mN}{3V} \langle v^2 \rangle \right\} - \star$$

1. Pressure In Term of Average Translation Kinetic Energy:

$$\Rightarrow P = \frac{1}{3} \frac{Nm}{V} \langle v^2 \rangle$$

$$P = \frac{2}{3} \frac{N}{V} \left\langle \frac{1}{2} mv^2 \right\rangle$$

$$P = \frac{2}{3} N_0 \langle K \cdot E \rangle$$

$$P = \text{constant} \langle K \cdot E \rangle$$

$$\star - \left\{ P \propto \langle K \cdot E \rangle \right\} - \star$$

$$\therefore K \cdot E = \frac{1}{2} mv^2$$

$$N = N_0$$

2. Pressure In Term of Density:

$$\Rightarrow P = \frac{1}{3} \frac{Nm}{V} \langle v^2 \rangle$$

$$\therefore \text{Total Mass} = Nm$$

$$\therefore \text{Total Volume} = V$$

$$\star - \left\{ P = \frac{1}{3} \rho \langle v^2 \rangle \right\} - \star$$

$$\therefore \rho = \frac{m}{V}$$

3. Interpretation of Temperature:

$$P = \frac{1}{3} \frac{Nm}{V} \langle v^2 \rangle$$

$$PV = \frac{1}{3} Nm \langle v^2 \rangle$$

$$PV = \frac{2}{3} N \left\langle \frac{1}{2} mv^2 \right\rangle$$

$$PV = \frac{2}{3} N \langle K \cdot E \rangle \quad \text{--- (1)}$$

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: General Gas Equ:

$$PV = nRT$$

$$PV = \frac{NR}{N_A} T$$

$$PV = NKT \quad \text{--- (1)}$$

: Comparing eqn (1) & (2) :-

$$\frac{2}{3} N \langle K.E \rangle = NKT$$

$$\star - \left\{ T = \frac{2}{3K} \langle K.E \rangle \right\} - \star$$

$$T = \text{constant} \langle K.E \rangle$$

$$\star - \left\{ T \propto \langle K.E \rangle \right\} - \star$$

^{Imp} Root Mean Square Velocity of Gas Molecules

► R.M.S velocity of gas molecule is the square root of velocities of all gas molecules.

► As, gas particles are moving in random direction in x, y, z axis (positive & negative axis), all have different velocities ($v_1, v_2, v_3, \dots$). Now, if we want speed of it we take average of it.

But here in R.M.S we can't take average. Buz in normal condition the +ve values cancel by -ve value, so answer is zero. As, no average, so we take square on numbers of velocities. ~~the~~ -ve values will become +ve. Then take square root to get velocity average.

$$\sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + \dots + v_n^2}{N}}$$

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→ Pressure of gas

$$P = \frac{1}{3} \frac{Nm}{V}$$

→ In term of d

$$P = \frac{1}{3} \rho$$

→ General

$$PV =$$

Derivation:

• Molecules of $v_1, v_2, v_3, \dots$

Now;

velocity =

Square of vel

Mean Square

$$\langle v^2 \rangle =$$

As, we know

$$P =$$

$$\therefore P = \frac{1}{3}$$

: Genera

$$PV$$

$$PV$$

$$PV$$

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→ Pressure of gas:

$$P = \frac{1}{3} \frac{Nm}{V} \langle V^2 \rangle \quad \text{--- (1)}$$

→ In term of density:

$$P = \frac{1}{3} \rho \langle V^2 \rangle \quad \text{--- (2)}$$

→ General gas eqn:

$$PV = nRT \quad \text{--- (3)}$$

∴ These relations will be used to derive R.M.S velocity.

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Derivation: R.M.S ⇒ 'S.M.R'

- Molecules of gas move with different velocity, $v_1, v_2, v_3, \dots, v_n$. Number of velocity As 'N'.

Now;

$$\text{velocity} = v_1, v_2, v_3, \dots, v_n$$

$$\text{Square of velocity} = v_1^2, v_2^2, v_3^2, \dots, v_n^2$$

Mean Square velocity =

$$\langle V^2 \rangle = \frac{v_1^2 + v_2^2 + v_3^2 + v_4^2 + \dots + v_n^2}{N}$$

As, we know pressure of gas:

$$P = \frac{1}{3} \frac{Nm}{V} \langle V^2 \rangle$$

$$\therefore P = \frac{1}{3} \frac{Nm}{V} \langle V^2 \rangle \quad \text{--- (4)}$$

∴ General gas eqn =

$$PV = nRT$$

$$PV = \frac{nRT}{N_A}$$

$$PV = NKT \quad \text{--- (5)}$$

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

$$\therefore K = \frac{R}{N_A} \text{ [constant]}$$

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∴ Comparing eqn (iv) with eqn (v) :-

$$\therefore \frac{1}{3} Nm \langle v^2 \rangle = NKT$$

$$\langle v^2 \rangle = \frac{3KT}{m}$$

∴ Taking square root on b/s :-

$$\sqrt{\langle v^2 \rangle} = \sqrt{\frac{3KT}{m}}$$

$$\therefore \left\{ V_{rms} = \sqrt{\frac{3KT}{m}} \right\} \xrightarrow{V_i} \therefore \left[\frac{3K}{m} = \text{constant} \right]$$

Here,

$$V_{rms} = \text{constant} \sqrt{T}$$

$$V_{rms} \propto \sqrt{T}$$

→ Root Mean Square velocity.

Hence,

∴ Putting $R = R/N_A$ in eqn (vi)

$$V_{rms} = \sqrt{\frac{3RT}{mN_A}}$$

$$\therefore M = mN_A$$

→ molar mass

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$V_{rms} = \text{constant} \frac{1}{\sqrt{M}}$$

$$V_{rms} \propto \frac{1}{\sqrt{M}}$$

$$\sqrt{M}$$

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∴ Pressure in

$$P = \frac{1}{3}$$

$$P = \frac{1}{3}$$

$$P = \frac{1}{3}$$

∴ Taking sq

$$\sqrt{\langle v^2 \rangle}$$

$$V_{rms}$$

$$V_{rms}$$

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∴ Pressure in Term of Density:

$$P = \frac{1}{3} \frac{Nm}{V} \langle v^2 \rangle$$

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

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

∴ Taking Square root on b/s:-

$$\sqrt{\langle v^2 \rangle} = \sqrt{\frac{3P}{\rho}}$$

$$\{ v_{rms} = \sqrt{\frac{3P}{\rho}} \}$$

$$v_{rms} = \sqrt{\frac{3kT}{Nm}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{\rho}}$$

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Modification Of The IDEAL gas Model to Discuss behaviour of NON-IDEAL gas:-

Imp (short)

:- Ideal gas Vs Non-Ideal gas:-

: IDEAL GAS:

- > It is theoretical model (supposed) of gas that help to understand the behaviour of real gas.
- > It obey all gas laws perfectly.
- > $PV = nRT$ — ①

: Assumptions of Ideal gas:

- Gas molecules are very small and volume is negligible.
- No force of attraction b/w molecules of the gas.
- Collision of molecules is perfectly elastic.
- Molecules are in constant random motion.

: Real GAS:

- > Real gas is an actual gas found in nature.

: Deviation From Ideal gas:

- Molecules of real gas are like rigid spheres & they have volume.
- Inter molecular forces are present b/w molecules.
- Collision is not perfectly elastic.
- Under certain conditions, by low Temp & high pressure, we can't neglect volume of Real gas.

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When Real Gas don't obey Ideal gas:-

* High Pressure: As, the molecules become closer, there volume ~~can't~~ ^{repulsion} forms a big particles, so we can't neglect their volume.

* Low Temp: As, the molecules are far away, many no. of particles. So here we neglect its any little difference in volume.

Microscopic Properties:-

- These are properties related to individual particles of gas.
- Velocity of single molecule.
- Position of molecules.
- Energy of molecules.
- These properties can't be calculated directly.
- Not observable.

Macroscopic Properties:-

- These are properties of substance that you can see.
- Measure or feel without knowing about individual particles.
- Temp. Pressure. Density. Volume etc.....

: COMPARISON:

When Real gas obey Ideal gas:-

1. Real gas can obey / behave as Ideal gas with low pressure & high Temp, but Intermolecular forces are weak in this case.
- Low Pressure, Gas particles are far apart, so their own volume is negligible. At High Temp particles move fast. so attractive forces b/w them are negligible.

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- No ideal gas exists in real life.
- Temp of ideal gas is given by $T = \frac{m}{k} \langle v^2 \rangle$, is defined by motion of molecules which is microscopic property.
- There is a relation b/w macroscopic & microscopic properties which give rise to a branch of physics called statistical mechanics.
- Ideal gas governs macroscopic properties. $PV = nRT$

⇒ VAN DER WAAL EQU:-

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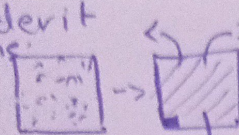
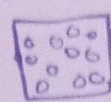
- This is modified version of ideal gas eqn.
- But, ideal gas eqn $PV = nRT$ — (1)
- It's not valid at high ~~Temp~~ pressure & low Temp due to faulty assumptions.

∴ FAULTY Assumption's:-

- 1- Volume of molecule is negligible.
 - 2- No intermolecular forces is present b/w molecules.
- ∴ Pressure & Volume are affected by the assumptions.

Q: Why we use it?

Ans: As, the Ideal gas eqn $PV = nRT$, to understand it's behaviour it should be on high Temp, low P. If it's not this then, we can understand $PV = nRT$. Then van der waal came with formulas in which we can use wide range of Temp & Pressure & still can understand ideal gas eqn.

we consider it Full Volume. As, P.V.  V for gas mole But  $\rightarrow$  less space $\rightarrow$ have Volume $(V-nb)$ significant V . In real

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: Volume Correction:

- Van Deer Waal state that gas molecules are like hard molecules are like hard spheres with definite volume. 
- At high pressure when gas is compressed the actual volume of gas can't be neglected. $\rightarrow P \uparrow$ 
- So, space available for motion of molecules of gas will be slightly lesser. 

Now;

$$\rightarrow V_{\text{container}} = V_{\text{free}} + V_{\text{molecules}}$$

$$\rightarrow V_{\text{free}} = V_{\text{container}} - V_{\text{molecules}}$$

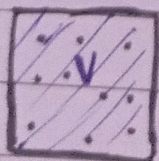
$$\therefore \text{Volume of 1 mole molecules} = b$$

$$\therefore \text{Volume of } n \text{ moles molecules} = nb$$

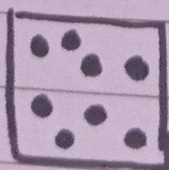
$$V_{\text{free}} = V - nb \quad \text{--- (1)}$$

$$\therefore n = 1 \text{ for 1 mole.}$$

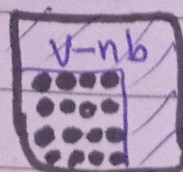
$$\therefore V_{\text{free}} = (V - b) \quad \text{--- (2)}$$



Ideal Gas



Real gas



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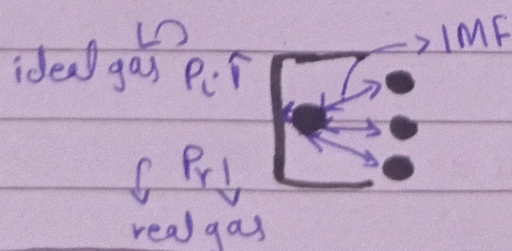
: PRESSURE CORECTION:

- In real gas molecules of gas attracts each other at low Temp.
- Inside container interaction b/w gas molecules cancel each other.
- Particles near the wall of container have net inward forces.

◆ How Intermolecular forces effect's Pressure in Real gas?

⇒ As, at low Temp, when a gas molecules is at low Temp, the distance ~~blw~~ ~~the~~ ~~molecules~~ ~~become~~ become lesser & the Intermolecular forces become stronger. It effects Pressure, as when a particles hit's wall of container, the other particles attracts towards them, so that particle hit's but not that fast or strongly due to strong intermolecular forces, by this the Pressure decreases.

⇒ In Ideal gas Pressure is increased, as when that particle hit's the wall, there is other particles to attract it towards them, so hit's fast & strongly with weak I.M.F. $\therefore P \uparrow$.



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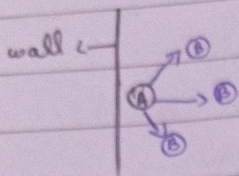
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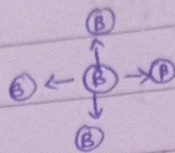
> if the central molecule increase OR if the other attractive molecules increase. In both 2 case, will decrease Pressure & force of hitting wall.

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Force direction
→

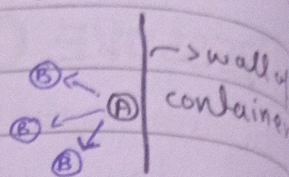


Onward Pull



Balanced

← F



Inward Pull

A = Molecules near walls of container.

B = Molecules in the center.

▲ Real Gas

- Because a molecule going towards wall is attracted by other molecules.
- So,

$$P_r < P_i$$

$$P_r = P_i - P' - \text{m}$$

∴ The decrease in Pressure depends on: -

- $P' \propto$ concentration of A-type molecules and B-type molecules.

$$P' \propto (A \times B)$$

$$P' \propto \left(\frac{n}{V}\right) \times \left(\frac{n}{V}\right)$$

$$P' \propto \left(\frac{n^2}{V^2}\right)$$

$$P' = a \frac{n^2}{V^2}$$

∴ a = constant

∴ Eqn (i) becomes:

$$P_r = P_i - a \frac{n^2}{V^2}$$

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$$\left(P + a \frac{n^2}{V^2}\right)$$

∴ for 1 m

$$\left(P + \frac{a}{V^2}\right)$$

Hence,

This can be

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$$P + a \frac{n^2}{V^2} = P_i \quad \text{--- (iv)}$$

Putting value of eq $PV = nRT$ from eq (i) ~~Eq (iv)~~

$$PV = nRT$$

$$\left(P + a \frac{n^2}{V^2} \right) (V - nb) = nRT$$

$\therefore$ for 1 mole : $n=1$

$$\boxed{\left(P + \frac{a}{V^2} \right) (V - b) = RT} \quad \text{--- ****}$$

Hence,

This eqn is designed for real gas but can be used for ideal gas too....!

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!!! Main Concept Question !!!

- Q1. What do you mean by elastic collision of gas molecules?
- Q2. Why pressure equally distributed on all faces?
($P_x = P_y = P_z$)?
- Q3. Why do we consider mean square velocity?
- Q4. State a relation b/w pressure & K.E?
- Q5. How temperature is related to the average K.E of molecules?
- Q6. Why is $\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle$?
- Q7. Derive relation b/w pressure & density?
- Q8. If we increase number of molecules of gas, what effect it had on pressure?
- Q9. Root Mean Square velocity of a gas increase with temperature. Justify?
- Q10. What is physical significance of R.M.S value of velocity of a gas?
- Q11. Why we take R.M.S value of velocity of molecules of gas?
- Q12. Why do real gases deviate from ideal behaviour?
- Q13. When do real gases obey the ideal gas behaviour?
- Q14. What are the limitations of ideal gas?
- Q15. When the Ideal Gas Law works? & when fail?
- Q16. Difference b/w Ideal & Non Ideal gas?
- Q17. Why does pressure of real gas is less than produced by ideal gas?
- Q18. What do you mean by microscope & macroscopic properties of gas?

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