CHAPTER-12: KINETIC THEORY OF GASES

Part–1: Ideal Gas • Kinetic Theory • Gas Pressure • RMS Speed

1. Ideal Gas

An ideal gas is a hypothetical gas which obeys the gas laws at all temperatures and pressures.

Ideal Gas Equation

$$\boxed{PV = nRT}$$

Where

- P = Pressure
- V = Volume
- n = Number of moles
- R = Universal Gas Constant
- T = Absolute Temperature (Kelvin)

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2. Assumptions of Kinetic Theory

- Gas consists of a large number of molecules.
- Molecules are point masses.
- Molecules move randomly in all directions.
- Collisions are perfectly elastic.
- Molecular volume is negligible compared to the container volume.
- No intermolecular force acts except during collisions.

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3. Pressure of an Ideal Gas

From Kinetic Theory,

$$\boxed{P = \frac{1}{3}\rho c_{\text{rms}}^2}$$

Where

- ρ = Density of gas
- c_{rms} = Root Mean Square Speed

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4. Kinetic Energy of One Molecule

$$\boxed{KE = \frac{1}{2}mv^2}$$

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5. Average Translational Kinetic Energy

$$\boxed{\frac{3}{2}kT}$$

Where

- k = Boltzmann Constant

$$\boxed{k = 1.38 \times 10^{-23} J/K}$$

6. Total Kinetic Energy of n Moles

$$\boxed{KE = \frac{3}{2} nRT}$$

7. Root Mean Square (RMS) Speed

$$\boxed{c_{\text{rms}} = \sqrt{\frac{3RT}{M}}}$$

Where

- M = Molar Mass (kg/mol)

8. Relation with Pressure

$$\boxed{c_{\text{rms}} = \sqrt{\frac{3P}{\rho}}}$$

9. Most Probable Speed

$$\boxed{c_p = \sqrt{\frac{2RT}{M}}}$$

10. Average Speed

$$\boxed{c_{avg} = \sqrt{\frac{8RT}{\pi M}}}$$

11. Relation Among Speeds

$$\boxed{c_p < c_{avg} < c_{rms}}$$

Important Constants

Universal Gas Constant

$$\boxed{R = 8.314 J\, mol^{-1} K^{-1}}$$

Boltzmann Constant

$$\boxed{k = 1.38 \times 10^{-23} J/K}$$

Exam Tips

- RMS Speed greater than **Average Speed**
- RMS Speed increases upon increasing the temperature
- Kinetic Energy depends only on **Absolute Temperature (Kelvin)**

Part–2: Degrees of Freedom • Equipartition of Energy • Specific Heat

12. Degrees of Freedom (f)

The number of independent ways in which a molecule can possess energy is called **Degrees of Freedom**.

Monoatomic Gas

$$\boxed{f = 3}$$

(Only Translational at all temperature)

Diatomic Gas (Ordinary Temperature)

$$\boxed{f = 5}$$

(3 Translational + 2 Rotational)

Diatomic Gas (High Temperature)

$$\boxed{f = 7}$$

(3 Translational + 2 Rotational + 2 Vibrational)

Polyatomic Gas

$$\boxed{f = 6}$$

or more (depending on molecular structure and temperature)

13. Law of Equipartition of Energy

According to this law,
Each degree of freedom contributes an average energy of

$$\boxed{\frac{1}{2}kT}$$

per molecule.

14. Total Average Energy per Molecule

$$\boxed{E = \frac{f}{2}kT}$$

15. Total Internal Energy of n Moles

$$\boxed{U = \frac{f}{2} nRT}$$

16. Molar Specific Heat at Constant Volume

$$\boxed{C_V = \frac{f}{2} R}$$

17. Molar Specific Heat at Constant Pressure

$$\boxed{C_P = C_V + R}$$

or

$$\boxed{C_P = \frac{f+2}{2} R}$$

18. Ratio of Specific Heats

$$\boxed{\gamma = \frac{C_P}{C_V}}$$

Monoatomic Gas

$$\boxed{\gamma = \frac{5}{3} = 1.67}$$

Diatomic Gas

$$\boxed{\gamma = \frac{7}{5} = 1.40}$$

19. Mean Free Path

Average distance travelled by a molecule between two successive collisions.

$$\boxed{\lambda = \frac{1}{\sqrt{2}\, \pi d^2 n}}$$

Where

- d = Molecular Diameter
- n = Number Density

20. Avogadro Number

$$\boxed{N_A = 6.022 \times 10^{23} mol^{-1}}$$

21. Universal Gas Constant Relation

$$\boxed{R = N_A k}$$