FREE NOTES · NCERT + JEE/NEET LEVEL

Kinetic Theory

Gas ke laws, ideal gas, kinetic theory ki assumptions, pressure ka formula, temperature ka asli matlab, rms speed, degrees of freedom, equipartition aur mean free path.

01 Gas laws
02 Ideal gas equation
03 Kinetic theory ki assumptions
04 Gas ka pressure
05 Temperature ka asli matlab
06 Molecular speeds
07 Degrees of freedom (f)
08 Law of equipartition of energy
09 Specific heats from kinetic theory
10 Mean free path
11 JEE Extra + Tricks
12 Solved numericals (R = 8.3 J/mol·K)
13 Common mistakes
14 Formula sheet
15 Practice questions
16 Quick revision: exam se pehle 5 minute

01 Gas laws

Law	Kya constant	Rishta
Boyle's law	T, mass	$P \propto 1/V$ ($PV = \text{const}$)
Charles' law	P, mass	$V \propto T$
Gay-Lussac's law	V, mass	$P \propto T$
Avogadro's law	P, T	Barabar volume me barabar molecules
Dalton's law	V, T	$P_{total} = P_1 + P_2 + \ldots$ (partial pressures)

STP pe 1 mole gas = 22.4 litre. Avogadro number $N_A = 6.02 \times 10^{23}$.

02 Ideal gas equation

$$PV = \mu R T = N k_B T$$

μ = moles, N = molecules, R = 8.314 J/mol·K, $k_B = R/N_A = 1.38 \times 10^{-23}$ J/K. Density se: $P = \rho RT/M$ (M = molar mass).

REAL GAS KAB IDEAL JAISI

Kam pressure aur zyada temperature pe. Tab molecules door-door hote hain aur unke beech ka attraction negligible.

03 Kinetic theory ki assumptions

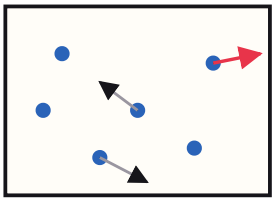
1. Gas bahut saare chhote molecules se bani hai, molecule ka apna volume negligible.
2. Molecules random motion me, har direction me, alag-alag speed se.
3. Takkar (aapas me aur deewar se) **perfectly elastic**.
4. Takkar ke alawa molecules ke beech koi force nahi.
5. Takkar ka time, do takkar ke beech ke time se bahut kam.
6. Newton ke laws lagte hain.

04 Gas ka pressure

Molecules deewar se takra ke laut-te hain, har takkar me momentum $2mv_x$ deewar ko milta hai. Lakhon takkar ka average force = pressure.

$$P = (1/3)\, n\, m\, \bar{v}^2 = (1/3)\, \rho\, v_{rms}{}^2$$

n = molecules per unit volume. Isse: $P = (2/3)\, E$, E = KE per unit volume.



Deewar se takrate molecules = pressure

05 Temperature ka asli matlab

KINETIC INTERPRETATION

Average KE per molecule = $(3/2)\, k_B\, T$

Temperature = molecules ki average translational KE ka naap. Kisi bhi gas ke liye same T pe same average KE (mass pe depend nahi). 1 mole ki KE = (3/2) RT.

Absolute zero (0 K) pe classical theory ke hisaab se molecular motion ruk jaata.

06 Molecular speeds

Speed	Formula	Ratio
RMS speed	$v_{rms} = \sqrt{(3RT/M)} = \sqrt{(3k_BT/m)}$	√3 ≈ 1.73
Average speed	$v_{avg} = \sqrt{(8RT/\pi M)}$	√(8/π) ≈ 1.60
Most probable speed	$v_{mp} = \sqrt{(2RT/M)}$	√2 ≈ 1.41

ORDER

$v_{rms} > v_{avg} > v_{mp}$. Sab $\propto \sqrt{(T/M)}$.

SHORTCUTS

- Temperature 4 guna ⇒ v_{rms} 2 guna.
- Same T pe halki gas tez: H_2 ki v_{rms} O_2 ki 4 guna (√(32/2)).
- Pressure badhao (T same) toh v_{rms} nahi badalti.
- Room temperature pe hawa ke molecules ≈ 500 m/s.

07 Degrees of freedom (f)

Molecule kitne independent tareekon se energy rakh sakta hai.

Molecule	Translational	Rotational	Total f (aam temperature)
Monoatomic (He, Ne)	3	0	3
Diatomic (O_2, N_2)	3	2	5 (zyada T pe vibration se 7)
Polyatomic non-linear (H_2O, CH_4)	3	3	6

08 Law of equipartition of energy

STATEMENT

Thermal equilibrium me har degree of freedom ko **½ k_BT** energy milti hai (vibration mode ko k_BT, kyunki KE + PE dono).

Ek molecule ki energy = $(f/2)\, k_BT$

1 mole ki internal energy $U = (f/2)\, RT$

09 Specific heats from kinetic theory

$C_v = (f/2)\,R$, $C_p = (f/2 + 1)\,R$

$$\gamma = 1 + 2/f$$

Gas	f	C_v	C_p	γ
Monoatomic	3	3R/2	5R/2	1.67
Diatomic (rigid)	5	5R/2	7R/2	1.4
Polyatomic (non-linear)	6	3R	4R	1.33

MIXTURE OF GASES

$C_{v,mix} = (n_1 C_{v1} + n_2 C_{v2})/(n_1 + n_2)$. γ_{mix} isi se nikalo, seedha γ ka average nahi.

Solids: har atom 3 direction me vibrate, har vibration ki energy $k_B T \Rightarrow C = 3R$ (Dulong-Petit). **Paani:** C ≈ 9R (bahut zyada).

10 Mean free path

Do lagaataar takkar ke beech molecule jitni average doori seedha chalta hai.

$$\lambda = 1 / (\sqrt{2}\,\pi\,n\,d^2) = k_B T / (\sqrt{2}\,\pi\,d^2\,P)$$

n = number density, d = molecule ka diameter. Density ya pressure badhe ⇒ λ ghatta. Hawa me STP pe λ ≈ 0.1 µm (molecule ke size se ~500 guna).

Isliye perfume ki khushboo turant nahi failti, dheere-dheere: molecules tez hain par baar-baar takrate hain.

11 JEE Extra + Tricks

JEE LEVEL

- Speeds: $v_{rms} = \sqrt{(3RT/M)}$, $v_{avg} = \sqrt{(8RT/\pi M)}$, $v_{mp} = \sqrt{(2RT/M)}$; ratio ≈ 1.73 : 1.60 : 1.41 (rms > avg > mp).
- Degrees of freedom f: monatomic 3, diatomic 5 (zyada T pe vibration se 7); $\gamma = 1 + 2/f \Rightarrow$ 5/3, 7/5, 4/3.
- Gases ka mixture: $C_{v,mix} = (n_1C_{v1} + n_2C_{v2})/(n_1 + n_2)$.
- Mean free path $\lambda = 1/(\sqrt{2}\,\pi\, d^2\, n) = kT/(\sqrt{2}\,\pi\, d^2\, P)$.
- Pressure $P = \frac{1}{3}\rho v_{rms}^2$; ek molecule ka average KE = (3/2)kT, gas ke type se independent.

12 Solved numericals (R = 8.3 J/mol·K)

Q1. 300 K pe O_2 (M = 0.032 kg/mol) ki v_{rms}?
v = √(3 × 8.3 × 300/0.032) = √233437 ≈ 483 m/s. **Ans: ≈ 483 m/s**

Q2. Kis temperature pe O_2 ki v_{rms}, 27 °C pe H_2 ke barabar hogi?
T/M same ⇒ T_{O_2} = 300 × 32/2 = 4800 K. **Ans: 4800 K**

Q3. 27 °C pe ek molecule ki average translational KE? ($k_B = 1.38 \times 10^{-23}$)
KE = 1.5 × 1.38 × 10^{-23} × 300 ≈ 6.2 × 10^{-21} J. **Ans: ≈ 6.2 × 10^{-21} J**

Q4. 2 mol He aur 1 mol O_2 ka mixture. γ_{mix}?
C_v = (2 × 1.5R + 1 × 2.5R)/3 = 5.5R/3. $C_p = C_v + R$ = 8.5R/3. γ = 8.5/5.5 ≈ 1.55. **Ans: ≈ 1.55**

Q5. Cylinder me 2 atm, 300 K pe gas. Temperature 600 K, volume same. Pressure?
P ∝ T ⇒ 4 atm. **Ans: 4 atm**

13 Common mistakes

- v_{rms} me M ko grams/mol me daalna. kg/mol me lo (O_2 = 0.032).
- Temperature °C me lena. Kelvin.
- Mixture ka γ seedha average kar dena.
- Average KE ko gas ke mass pe depend maan lena (sirf T pe).
- Diatomic me vibration ki degrees bhi aam temperature pe gin lena.

14 Formula sheet

Ideal gas	$PV = \mu RT = Nk_BT$
Pressure	$P = \frac{1}{3}\rho v_{rms}^2 = \frac{2}{3}E$
Average KE	$(3/2)k_BT$ per molecule
Speeds	$\sqrt{(3RT/M)}$, $\sqrt{(8RT/\pi M)}$, $\sqrt{(2RT/M)}$
Equipartition	$\frac{1}{2}k_BT$ per degree of freedom
Internal energy	$U = (f/2)\mu RT$
Specific heats	$C_v = fR/2$, $\gamma = 1 + 2/f$
Mean free path	$\lambda = 1/(\sqrt{2}\,\pi nd^2)$

15 Practice questions

1. Temperature 27 °C se 927 °C. v_{rms} kitni guna?
2. Diatomic gas ki 1 mole internal energy 300 K pe?
3. Gas ka γ = 1.4. Degrees of freedom?
4. Pressure 2 guna (T same). Mean free path?

ANSWERS

1) T 300 → 1200 K ⇒ 2 guna · 2) (5/2) × 8.3 × 300 ≈ 6.2 kJ · 3) 1.4 = 1 + 2/f ⇒ f = 5 · 4) Aadha

16 Quick revision: exam se pehle 5 minute

GAS LAWS

- $PV = \mu RT$; real gas ideal at low P, high T.
- Boyle, Charles, Gay-Lussac, Dalton.
- $k_B = R/N_A$.

KINETIC THEORY

- $P = \frac{1}{3}\rho v^2_{rms}$.
- $KE = (3/2)k_BT$, mass pe nahi.
- $v_{rms} > v_{avg} > v_{mp}$, $\propto \sqrt{(T/M)}$.

EQUIPARTITION

- f: mono 3, di 5, poly 6.
- $\frac{1}{2}k_BT$ per degree.
- $\gamma = 1 + 2/f$.

OTHERS

- Solid $C = 3R$.
- $\lambda = 1/(\sqrt{2}\,\pi n d^2)$.
- Mixture: C_v ka weighted average.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.