

KINETIC THEORY

NEET PHYSICS ESSENTIALS

CONCEPT SUMMARY

KEY CONCEPTS | FORMULAS | RECOGNITION CUES
MISCONCEPTIONS | EXAM TRAPS | QUICK CHECKS



UNDERSTAND
THE PHYSICS



RECOGNIZE
THE PATTERN



SOLVE WITH
CONFIDENCE



Temperature
(T)

$$PV = nRT$$

SAME PHYSICS.
A HIGHER SCORE.

1. Chapter Introduction

Kinetic Theory explains the measurable properties of a gas by connecting them with the motion and energy of its molecules. It links pressure, temperature, molecular speeds, internal energy, heat capacities and mean free path.

Before choosing a formula, ask: What property is being asked about? What molecular behaviour explains it? Which quantities remain constant? Does the model fit the situation?

2. Chapter in One View

Central idea: A gas may appear still, but its molecules move randomly. The collective effect of molecular motion explains the measurable properties of the gas.

- Molecular collisions with container walls → pressure.
- Average translational kinetic energy per molecule → absolute temperature.
- Temperature and molar mass → characteristic molecular speeds.
- P , V , T and amount of gas → ideal-gas equation.
- Volume change → work done by or on the gas.
- Active degrees of freedom → internal energy and heat capacities.
- Molecular size and number density → mean free path.

3. Must-Know Concepts

- Ideal-gas model: molecular size is negligible compared with container volume; intermolecular forces are negligible between collisions; collisions are elastic.
- Random isotropic motion: in equilibrium, no direction is preferred.
- Pressure: repeated wall collisions transfer momentum and produce an average force.
- Temperature: average translational kinetic energy per molecule is proportional to absolute temperature.
- Characteristic speeds: most probable, average and RMS speeds are different measures of the molecular speed distribution.
- Ideal-gas state: $PV = nRT = NkT$.
- Work: under the “work done by gas” convention, expansion is positive and compression is negative.
- Degrees of freedom: independent active ways in which a molecule stores energy.
- Equipartition: each active quadratic energy term contributes $\frac{kT}{2}$ per molecule in the classical model.
- Heat capacities: $C_{P,m} - C_{V,m} = R$ for an ideal gas.
- Mean free path: average distance travelled between successive molecular collisions.
- Ideal-gas approximation: generally less reliable at high pressure and low temperature.

4. Formula + Meaning

4.1 Pressure from molecular motion

$$P = \left(\frac{1}{3}\right) \rho V_{rms}^2 = \left(\frac{1}{3}\right) n_0 m V_{rms}^2$$

Meaning: Connects pressure with molecular motion and gas density.

Use when: Pressure, density or RMS speed is required.

Condition: Random, isotropic molecular motion and a suitable ideal-gas model.

Trap: Pressure depends on the square of RMS speed.

4.2 Average translational kinetic energy

$$\langle K \rangle = \left(\frac{3}{2}\right) kT$$

Meaning: Average translational kinetic energy per molecule.

Use when: Comparing average molecular kinetic energies or calculating one at a given temperature.

Condition: Ideal gas in thermal equilibrium; T in kelvin.

Trap: This is an average; individual molecules do not all have equal kinetic energy.

4.3 Molecular speeds

$$v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$$

$$\bar{v} = \sqrt{\frac{8RY}{\pi M}}; v_{mp} = \sqrt{\frac{2RT}{M}}$$

Use when: Temperature and molar mass are given and a characteristic speed is requested.

Condition: Classical ideal gas in thermal equilibrium with a Maxwell speed distribution; use M in kg mol^{-1} .

$$v_{mp} < \bar{v} < v_{rms}$$

Trap: At fixed M , speed $\propto \sqrt{T}$; at fixed T , RMS speed $\propto 1/\sqrt{M}$.

4.4 Ideal-gas equation and gas laws

$$PV = nRT = NkT$$

Use when: Relating pressure, volume, temperature and amount of gas. Use kelvin and check whether the amount is fixed.

Fixed amount: $P_1 V_1 / T_1 = P_2 V_2 / T_2$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Process	Constant Quantities	Relation
Isothermal	T , amount of gas	$P_1 V_1 = P_2 V_2$
Isobaric	P , amount of gas	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Isochoric	V , amount of gas	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Trap: Identify what remains constant before selecting a gas law. Never substitute Celsius directly.

4.5 Work during expansion and compression

$$W_{BY} = \int P \, dV \quad ; \quad \text{constant pressure: } W_{BY} = P(V_2 - V_1)$$

Meaning: Work done by the gas; on a P–V graph it is the signed area under the process curve.

Sign: Expansion $\rightarrow$ positive; compression $\rightarrow$ negative; constant volume $\rightarrow$ zero. Work done on the gas is $W_{on} = -W_{BY}$.

Condition: The integral uses boundary pressure; for a quasi-static equilibrium process, gas pressure can represent it.

Trap: Read whether the question asks for work by the gas or on the gas.

4.6 Degrees of freedom, internal energy and heat capacities

$$U = \left(\frac{f}{2}\right) nRT \quad ; \quad \Delta U = \left(\frac{f}{2}\right) nR\Delta T$$

Model (stated approximation)	f	$C_{v,m}$	$C_{p,m}$	γ
Monatomic; translation only	3	$\frac{3R}{2}$	$\frac{5R}{2}$	$\frac{5}{3}$
Linear diatomic; vibration neglected	5	$\frac{5R}{2}$	$\frac{7R}{2}$	$\frac{7}{5}$
Non-linear; vibration neglected	6	$3R$	$4R$	$\frac{4}{3}$

Use when: The active degrees of freedom are known and remain fixed over the temperature range.

$$C_{V,m} = \left(\frac{f}{2}\right) R; \quad C_{P,m} = C_{V,m} + R; \quad \gamma = \frac{C_{P,m}}{C_{V,m}}$$

Why $C_{P,m} > C_{V,m}$: At constant pressure, some supplied heat is associated with expansion work.

Trap: Mayer's relation $C_{P,m} - C_{V,m} = R$ is molar. For total heat capacities of n moles, the difference is nR . Do not assume $f = 5$ for every diatomic gas at every temperature.

4.7 Mean free path and number density

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n_0}; \quad n_0 = \frac{N}{V}$$

$$P = n_0 kT \Rightarrow \lambda = \frac{kT}{\sqrt{2}\pi d^2 P}$$

Meaning: λ is the average distance between collisions; d is collision diameter and n_0 is molecules per unit volume.

Use when: A dilute hard-sphere model is suitable and the required molecular data are known.

Trap: n in $PV = nRT$ means moles; n_0 means molecular number density in m^{-3} .

5. Formula Selection Guide

SEE THIS	THINK THIS	USE THIS
Pressure and RMS speed/density	Kinetic-theory pressure	$P = \frac{\rho v_{\text{rms}}^2}{3}$
Average energy per molecule	Temperature–energy link	$\langle K \rangle = \frac{3}{2} kT$
Temperature and molar mass	Molecular speed	$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$
Fixed amount, two gas states	Combined gas law	$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
Rigid sealed container	Constant volume	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
Constant-pressure volume change	Boundary work	$W_{by} = P\Delta V$
Monatomic ideal gas	$f = 3$	$U = \frac{3}{2} nRT$
Diatomic; vibration neglected	$f = 5$	$C_{v,m} = \frac{5R}{2}; C_{p,m} = \frac{7R}{2}$
Molecular diameter and number density	Hard-sphere collisions	$\lambda = \frac{1}{\sqrt{2} n d^2 n_0}$
Number of molecules	Moles to particles	$N = nN_a$

6. When to Use / When Not to Use

Ideal-gas equation

- Use when: The gas is treated as ideal and state variables are related.
- Do not use blindly when: High pressure or low temperature may make real-gas effects important.

Equipartition and heat capacities

- Use when: The active degrees of freedom are specified and the classical model is appropriate.
- Do not use blindly when: The active rotational or vibrational modes change with temperature.

Mean free path

- Use when: The dilute hard-sphere model is suitable.
- Do not use blindly when: Real-gas effects make that model unsuitable.

Gas laws

- Use when: The amount of gas and the fixed process variables are identified.
- Do not use blindly when: The amount changes or the process condition does not match.

7. Common Misconceptions

- Wrong: A stationary-looking gas has stationary molecules. → Correct: Molecules move randomly. → Why: Bulk motion differs from molecular motion.

- Wrong: Pressure is simply caused by molecular weight. → Correct: Pressure comes from momentum transfer at wall collisions.
- Wrong: All molecules have the same speed. → Correct: Speeds follow a distribution.
- Wrong: $\text{RMS speed} \propto T$. → Correct: At fixed molar mass, $\text{RMS speed} \propto \sqrt{T}$.
- Wrong: A rigid container cannot receive heat. → Correct: Its volume and boundary work are zero, but heat may enter.
- Wrong: $C_p = C_v$ for an ideal gas. → Correct: $C_{pm} - C_{vm} = R$.
- Wrong: Mean free path is molecular diameter. → Correct: It is an average travel distance between collisions.

8. Exam Traps

- Using Celsius instead of kelvin.
- Forgetting to square RMS speed in the pressure relation.
- Assuming speed doubles when absolute temperature doubles.
- Choosing a gas law before checking the fixed quantities.
- Reporting work done by the gas when work on the gas is requested.
- Mixing molar and total heat capacities.
- Using $f = 5$ without checking the stated molecular model.
- Confusing moles n with number density n_0 .
- Applying ideal-gas or hard-sphere formulas without checking model validity.

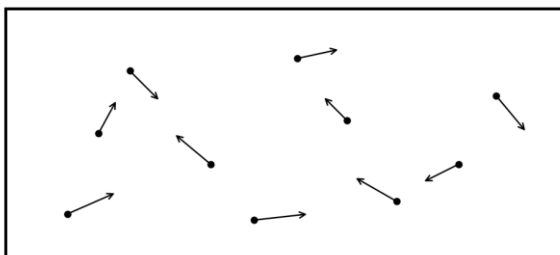
9. See This → Think This

- Pressure asked → Molecular momentum transfer to walls.
- Same temperature → Same average translational kinetic energy per molecule for ideal gases.
- Temperature doubles → Average translational kinetic energy doubles; RMS speed multiplies by $\sqrt{2}$.
- Same T , different gases → Smaller molar mass gives greater RMS speed.
- Rigid sealed container → P/T remains constant for fixed amount.
- Constant-pressure compression → $W_{BY} = P\Delta V$ is negative.
- Diatomic, vibration neglected → Use $f = 5$ in the stated model.
- Mean free path at fixed T and $d \rightarrow \lambda \propto 1/P$.
- Number of molecules → $N = nN_a$.

10. Key Diagrams / Graphs

Molecular motion and pressure

Notice: Molecules move randomly and strike the walls. Exam use:
Link collisions and momentum transfer with pressure.

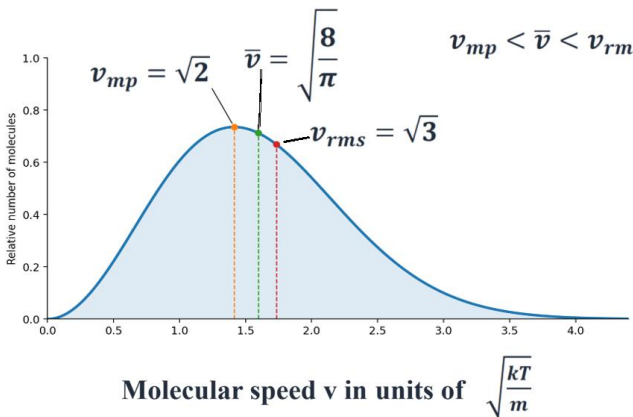


Random molecular motion; wall collisions transfer momentum

Characteristic molecular speeds

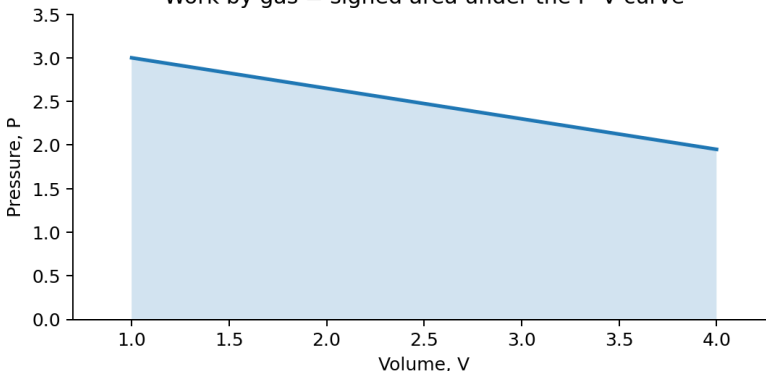
Notice: $v_{mp} < \bar{v} < v_{rms}$. Exam use: Distinguish the most probable, average and RMS speeds; these are not the speeds of every molecule.

Maxwell Speed Distribution: Three Characteristic Speeds



P–V graph and work: Notice: The signed area under the curve represents work by the gas. Exam use: Identify direction and sign before calculating.

Work by gas = signed area under the P–V curve



Exam use: Read the signed area under the process curve.

Expansion gives positive work by the gas; compression gives negative work.

11. Quick Checks

- Q: What microscopic event produces gas pressure? → Wall collisions transfer momentum.
- Q: Which temperature scale is required? → Kelvin.
- Q: If T doubles, what happens to average translational kinetic energy? → It doubles.
- Q: If T doubles at fixed molar mass, what happens to RMS speed? → It increases by $\sqrt{2}$.
- Q: At the same T , which gas has greater RMS speed? → The gas with smaller molar mass.
- Q: What remains constant in a rigid sealed container? → Volume and amount of gas.
- Q: What is the sign of work by the gas during compression? → Negative.
- Q: What is $C_{p,m} - C_{v,m}$ for an ideal gas? → R .
- Q: What is f for a monatomic gas in the translation-only model? → 3.
- Q: What does mean free path measure? → Average distance between successive collisions.
- Q: What is the difference between n and n_0 ? → Moles versus molecules per unit volume.
- Q: When is the ideal-gas approximation less reliable? → Generally at high pressure and low temperature.

12. Mini Exam Reasoning

Clue: Gas is heated in a rigid sealed container. → Situation:

Isochoric change. → Model: Fixed amount and volume. →

Relation: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ → Check: Use kelvin.

Clue: Two gases have the same temperature but different molar

masses. → Situation: Molecular speed comparison. → Model:

RMS speed. → Relation: $v_{rms} \propto \frac{1}{\sqrt{M}}$. → Check: Compare square roots of molar masses.

Clue: Gas is compressed at constant pressure. → Situation:

Boundary work. → Relation: $W_{BY} = P(V_2 - V_1)$. → Check: $V_2 < V_1$, so work by gas is negative.

Clue: Diatomic gas, vibration neglected. → Model: $f = 5$. →

Relation: $C_{V,m} = \frac{5R}{2}$; $C_{P,m} = \frac{7R}{2}$ → Check: Keep molar heat capacities distinct from total capacities.

13. One-Minute Recall

- Pressure → momentum transfer to container walls.
- $\langle K \rangle = 3kT/2$ → average translational kinetic energy per molecule.
- $v_{rms} = \sqrt{\frac{3RT}{M}}$ → T in kelvin; M in kg/mol.
- $v_{mp} < \bar{v} < v_{rms}$
- $PV = nRT = NkT$.
- Fixed amount: isothermal $PV = \text{constant}$; isobaric $V/T = \text{constant}$; isochoric $P/T = \text{constant}$.

- Work by gas: expansion positive; compression negative;

$$W_{\text{on}} = -W_{\text{BY}}.$$

- $U = \left(\frac{f}{2}\right) nRT$ when f remains fixed.
- $C_{V,m} = \frac{fR}{2}$; $C_{P,m} = C_{V,m} + R$
- At fixed T and d , mean free path $\lambda \propto 1/P$.
- $N = nN_a$; $n_0 = N/V$; $P = n_0kT$.
- Ideal-gas model is less reliable at high pressure and low temperature.

14. Formula Map

Topic

Formula / Reminder

Kinetic-theory pressure

$$P = \frac{\rho v_{\text{rms}}^2}{3} = \frac{n_0 m v_{\text{rms}}^2}{3}$$

Average translational kinetic energy

$$\langle K \rangle = \frac{3}{2} kT$$

RMS speed

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

Average speed

$$\bar{v} = \sqrt{\frac{8RT}{\pi M}}$$

Most probable speed

$$v_{\text{mp}} = \sqrt{\frac{2RT}{M}}$$

Ideal gas law

$$PV = nRT = NkT$$

Topic

Formula / Reminder

Moles and molecules

$$N = nN_a; R = N_a k$$

Fixed-amount state
comparison

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Work by gas

$$W_{by} = \int P \, dV; \text{constant } P: P(V_2 - V_1)$$

Internal energy

$$U = \frac{f}{2} nRT; \Delta U = \frac{f}{2} nR\Delta T$$

Molar heat capacities

$$C_{v,m} = \frac{fR}{2}; C_{p,m} = C_{v,m} + R$$

Heat-capacity ratio

$$\gamma = \frac{C_{p,m}}{C_{v,m}} = \frac{f+2}{f} \quad (\text{for fixed } f)$$

Mean free path

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n_0} = \frac{kT}{\sqrt{2}\pi d^2 P}$$

Number density

$$n_0 = \frac{N}{V}; P = n_0 kT$$

Symbols and Constants

Symbol Meaning

SI Unit

 P Absolute pressure

Pa

 V Volume m^3 T Absolute temperature

K

Symbol	Meaning	SI Unit
n	Amount of gas	mol
N	Number of molecules	—
N_a	Avogadro constant	mol ⁻¹
R	Universal gas constant	J mol ⁻¹ K ⁻¹
k	Boltzmann constant	J K ⁻¹
M	Molar mass	kg mol ⁻¹
m	Mass of one molecule	kg
ρ	Mass density	kg m ⁻³
v_{rms}	RMS speed	m s ⁻¹
f	Active degrees of freedom	—
$C_{v,m}, C_{p,m}$	Molar heat capacities	J mol ⁻¹ K ⁻¹
λ	Mean free path	m
d	Collision diameter	m
n_0	Molecular number density	m ⁻³

15. Final Revision Checklist

- I can explain how molecular collisions produce gas pressure.
- I can relate average translational kinetic energy to kelvin temperature.
- I can distinguish average, most probable and RMS speeds.

- I can select a gas law from the fixed conditions.
- I can determine the sign of work from expansion or compression.
- I can identify active degrees of freedom before using heat-capacity formulas.
- I can distinguish molar from total heat capacity.
- I can use the mean-free-path formula with the correct number density.
- I can state when the ideal-gas approximation may be unreliable.

Go Deeper with the Complete Concept Book

This website concept summary supports rapid understanding, formula selection and revision. The complete NEET Physics Essentials Concept Book provides fuller concept development, detailed derivations, microquestions, solved examples and integrated problem-solving.

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