

CLASS 11 PHYSICS | KINETIC THEORY

12.6.1 Monatomic Gases

Specific Heat Capacity &
Thermodynamics from First
Principles



THE PHYSICAL ACTOR

H2: The Simplest Case: The Isolated Atom

- Consists of single, unattached atoms.
- Molecules do not interact except during perfectly elastic collisions.
- Acts as a true 'point mass' in space.



Helium (He)

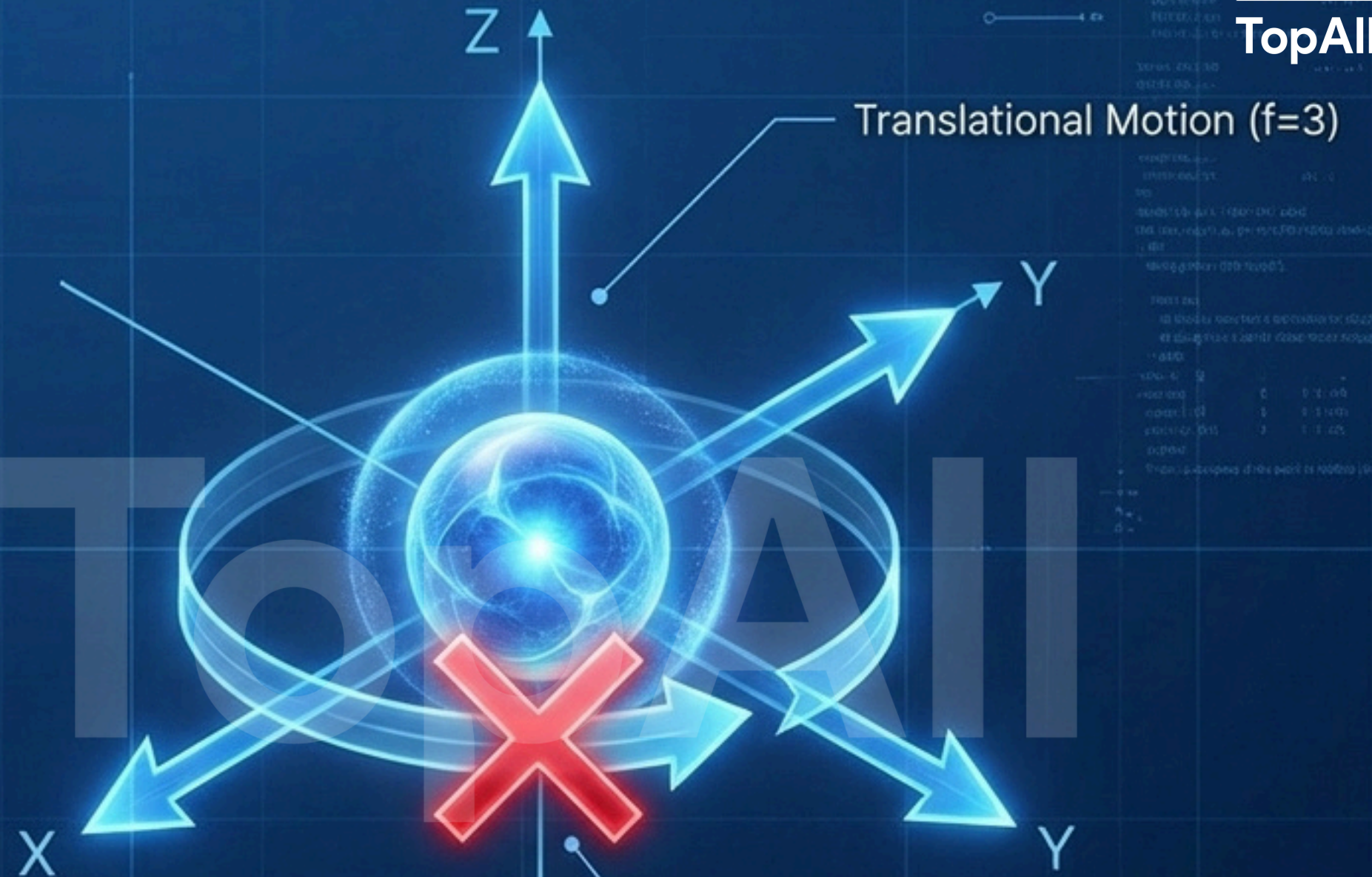
Argon (Ar)

Primary Examples

RULES OF MOTION

H2: Three Translational Degrees of Freedom

$$f = 3$$



3D Translation Engine



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$$E=mc^2$$



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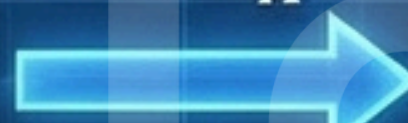


THE ENERGY STATE

H2: Calculating Total Internal Energy (U)

- By the Law of Equipartition, each degree of freedom holds $\frac{1}{2} k_B T$ energy.
- 3 degrees of freedom = $\frac{3}{2} k_B T$ per molecule.

1 Molecule:
 $\frac{3}{2} k_B T$

$\times N_A$

(Avogadro's Number)

Equation (12.27)

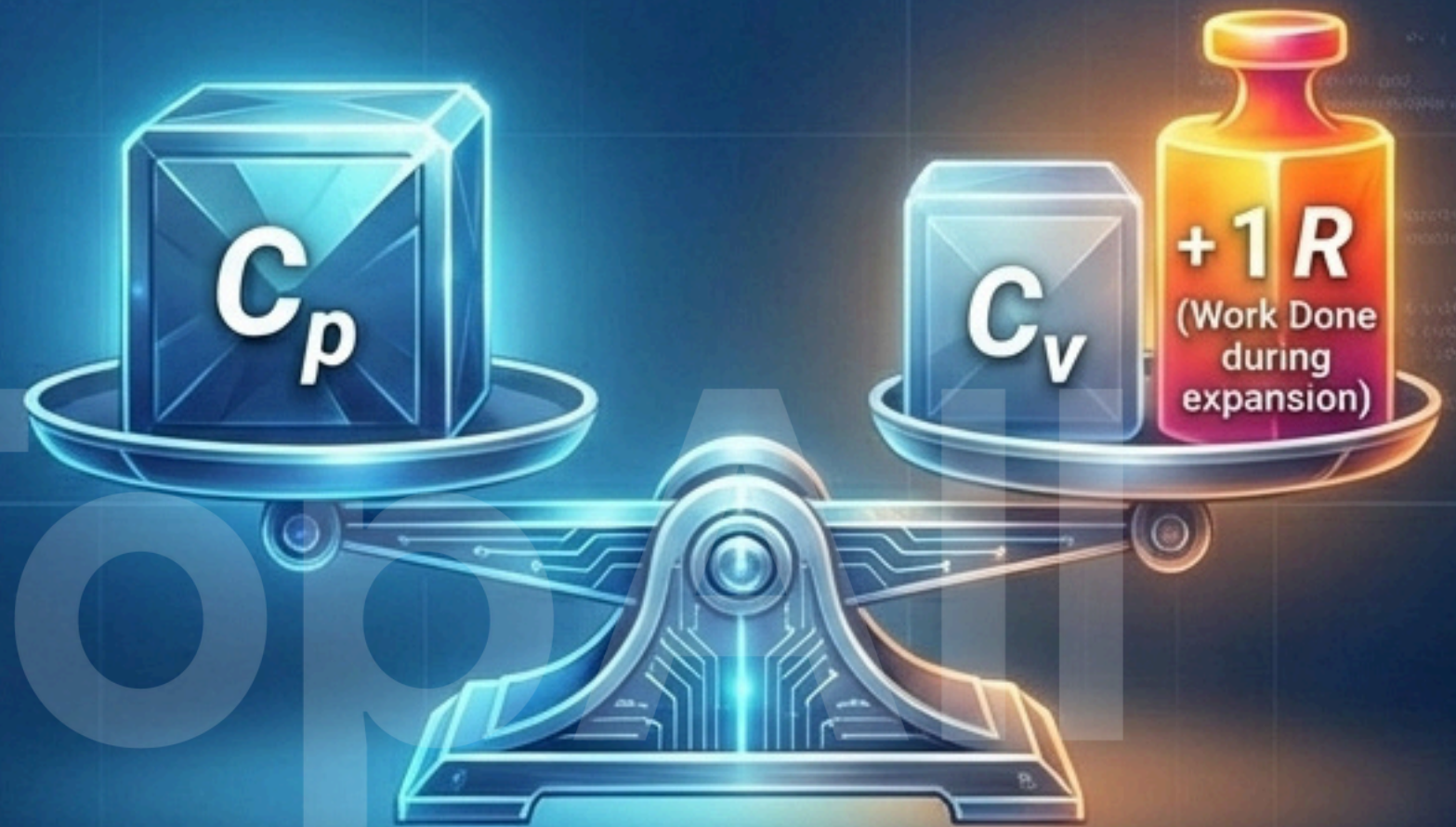
$$U = \frac{3}{2} k_B T \times N_A = \frac{3}{2} RT$$

Multiply by Avogadro's number to find the energy for one full mole.

THERMODYNAMIC RESPONSE

H2: Specific Heat Capacities: C_v and C_p

Constant Volume (C_v)	Constant Pressure (C_p)
Energy goes ONLY to internal heat.	Energy goes to heat PLUS expansion work.
$C_v = \frac{dU}{dT} = \frac{3}{2}R$	$C_p = \frac{5}{2}R$



Mayer's Relation:

$$C_p - C_v = R$$

EXAM TIP | KEY CONSTANTS



H2: The Adiabatic Index (γ)

γ (gamma) dictates how a gas behaves during sudden adiabatic changes.

$$\gamma = \frac{C_p}{C_v} = \frac{\frac{5}{2}R}{\frac{3}{2}R} \rightarrow \frac{5}{3}$$

$\gamma \approx 1.67$ for all ideal monatomic gases.

KEY TAKEAWAYS

Monatomic Gases: The Cheat Sheet



Motion

 3 Translational Degrees of Freedom ($f=3$)

Specific Heats

$$\text{Flame icon } C_v = \frac{3}{2} R \quad | \quad \text{Flame icon } C_p = \frac{5}{2} R$$

Energy

Total Internal Energy:

 $U = \frac{3}{2} RT$

Ratio

γ Adiabatic Index: $\gamma = \frac{5}{3}$

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