

CHAPTER 12 | KINETIC THEORY

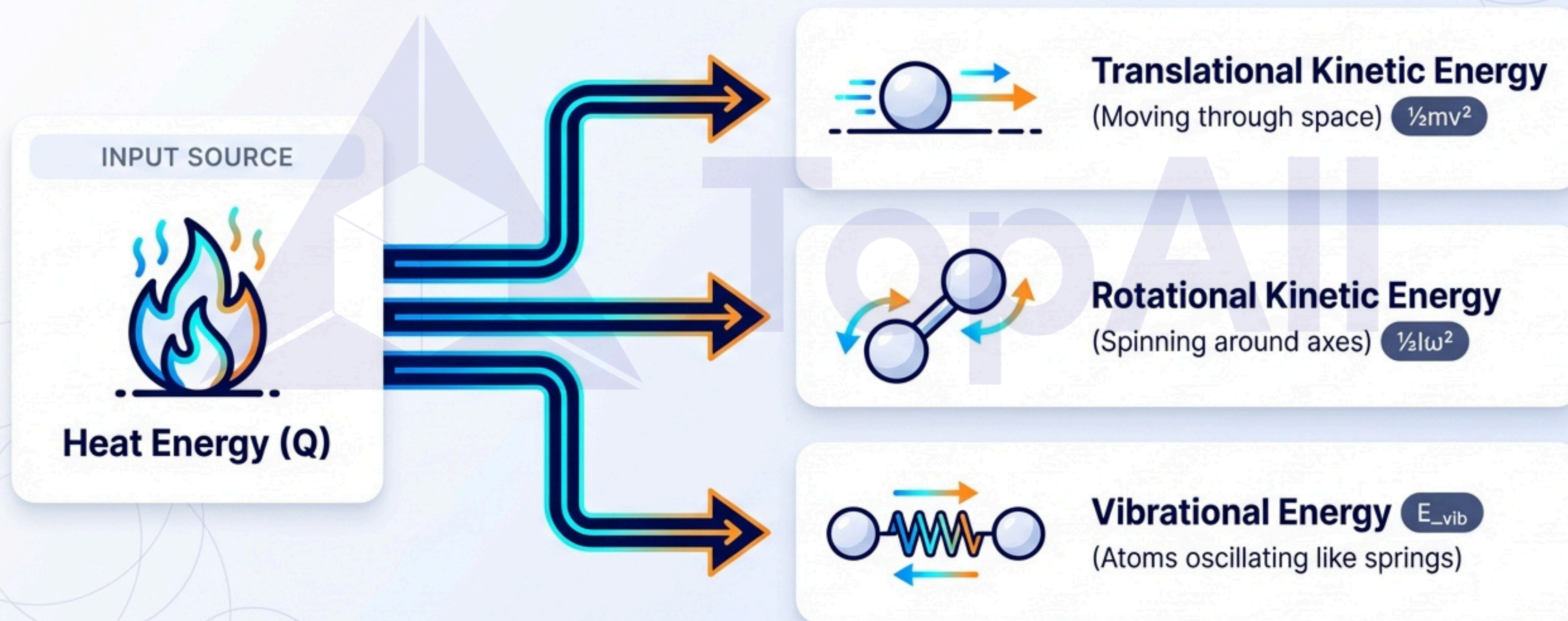
Specific Heat Capacity of Gases

Molecular energy-sharing, degrees of freedom,
and predicting thermal behavior.

NEET / JEE Prep Essential

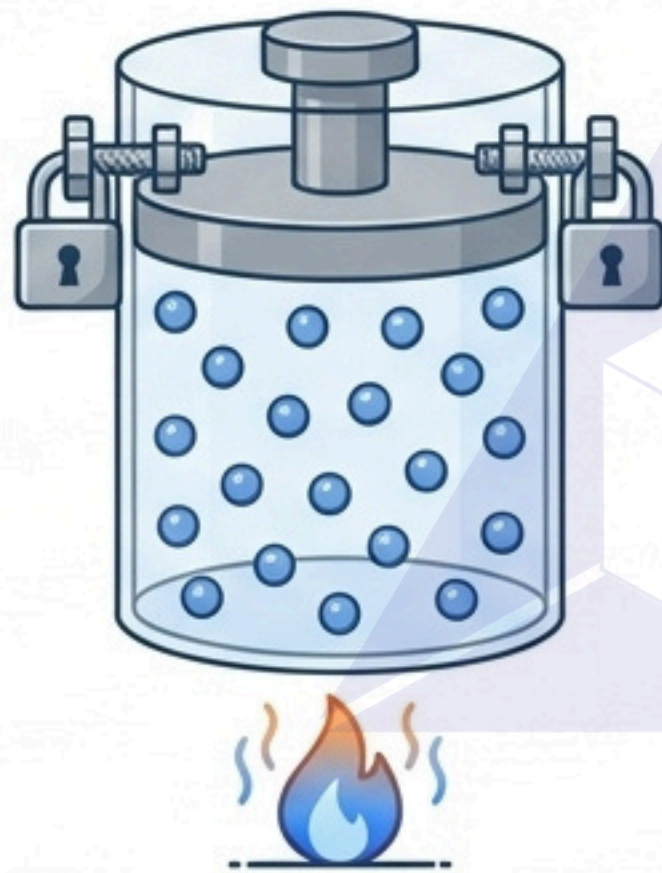
Where can the heat go?

Specific heat capacity depends entirely on molecular energy-sharing. The more ways a molecule can move, the more heat it "hides" without raising its overall temperature.



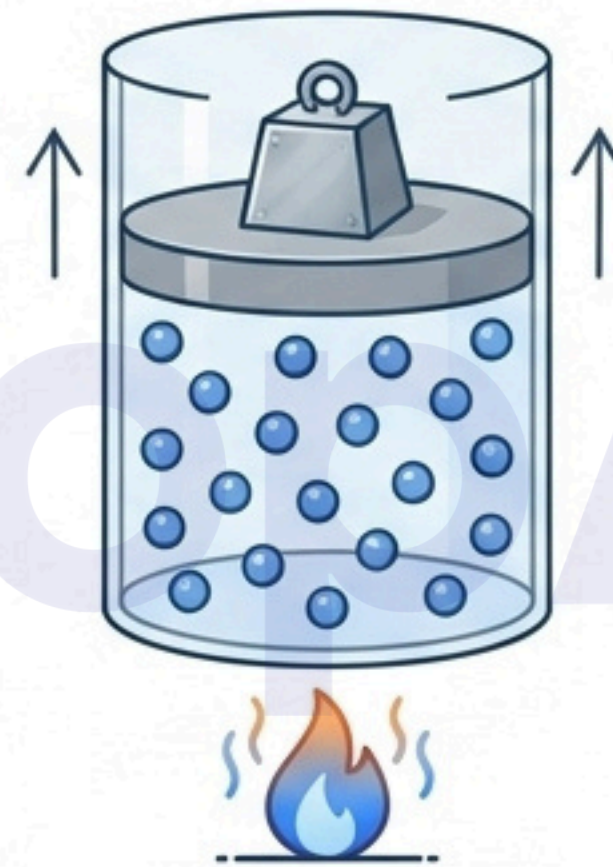
Cv vs Cp Comparison

Cv - Constant Volume



- Gas cannot expand ($W = 0$).
- All added heat increases internal energy (U).

Cp - Constant Pressure



- Gas expands and does work against surroundings.
- Requires extra heat to do work + raise temperature.

Formula Focus — Mayer's Relation: $C_p - C_v = R$

(Where R is the universal gas constant)



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$$E=mc^2$$



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Key Highlights

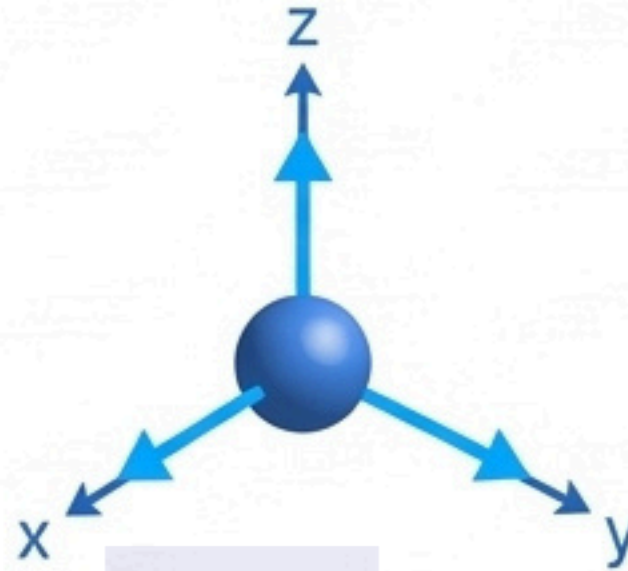
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Counting the "Energy Buckets" (f)

Monatomic Gases (e.g., He, Ar)

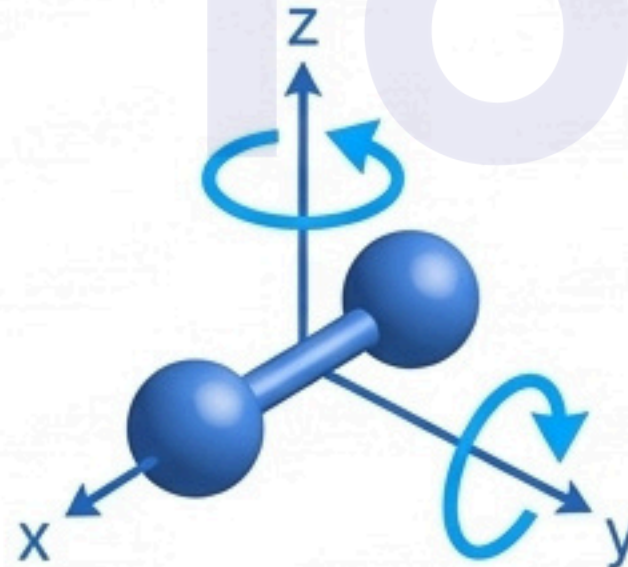
Can only move through space
(Translation).



**f = 3 degrees
of freedom**

Rigid Diatomic Gases (e.g., O₂, N₂)

Can move through space (3) + spin
around two independent axes (2).



**f = 5 degrees
of freedom**

EXAM TIP: By the Law of Equipartition, every degree of freedom gets $\frac{1}{2} k_B T$ of energy!

Calculating Specific Heat from Theory

GAS TYPE	Cv (Internal Energy)	Cp (Cv + R)	$\gamma = C_p / C_v$
Monatomic (f=3)	$\frac{3}{2} R$	$\frac{5}{2} R$	$\frac{5}{3}$ (~1.67)
Rigid Diatomic (f=5)	$\frac{5}{2} R$	$\frac{7}{2} R$	$\frac{7}{5}$ (1.40)

General Rule: For any ideal gas with f degrees of freedom, $C_v = (f/2)R$.

Does reality match the math?

Theory vs. Experiment

Gas	Predicted Cv	Observed Cv
He (Monatomic)	Predicted: 12.5	Observed: 12.5 (Perfect Match) ✓
Ar (Monatomic)	Predicted: 12.5	Observed: 12.5 (Perfect Match) ✓
O2 (Diatomic)	Predicted: 20.8	Observed: 20.8 (Perfect Match) ✓
Cl2 (Diatomic)	Predicted: 20.8	Observed: 24.1 (Discrepancy)

At ordinary temperatures, the rigid rotator model works beautifully.

Why do some vary?

Gases like Cl₂ or complex polyatomic molecules have "non-rigid" bonds. They activate extra vibrational modes, absorbing more heat than predicted by translation and rotation alone.

Key Takeaways



- **Specific heat** is determined by how molecules share energy across their degrees of freedom.
- **Cp is always greater than Cv** because constant pressure expansion requires extra work ($C_p - C_v = R$).
- **Monatomic gases have 3 degrees of freedom**; Diatomic gases have 5 (ignoring vibration).
- The **Law of Equipartition accurately predicts specific heats**, though high-temperature vibrational modes can cause real-world variations.

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