

Internal Energy & First Law of Thermodynamics | JEE

The fundamental equation governing energy transfer in chemical systems.



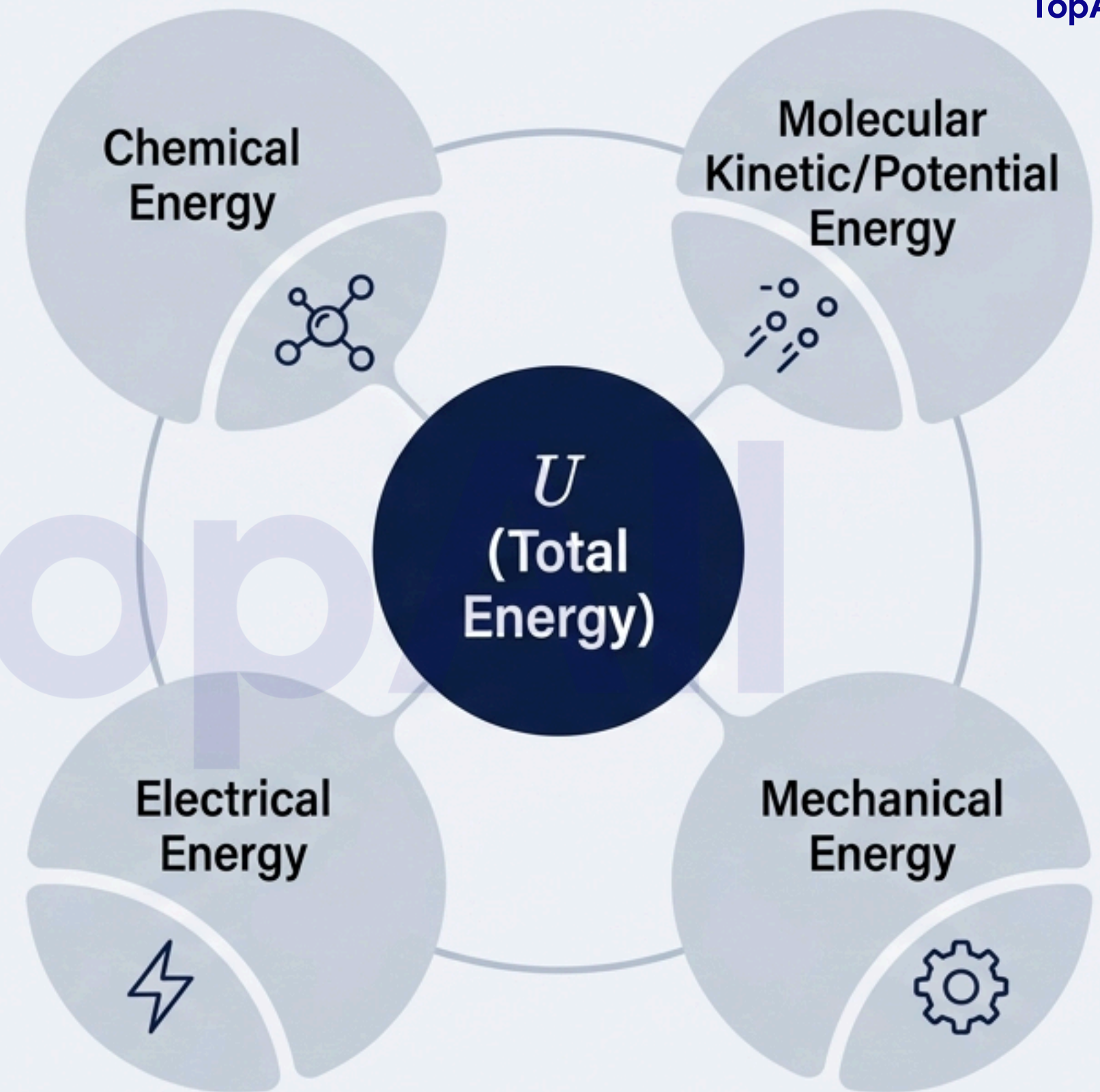
$$\Delta U = q + w$$

What is Internal Energy (U)?

- The total energy associated with a thermodynamic system.
- Sum of all microscopic forms of energy (we cannot measure its absolute value).
- We only measure the change:

$$\Delta U = U_{final} - U_{initial}$$

STATE FUNCTION: U depends only on the current state of the system (p, V, T). It does **not** depend on the path taken to reach that state.



The Two Pathways of Energy Transfer

Path Functions: q & w depend on how the change is carried out.

How do we change a system's internal energy? Through q and w .

HEAT (q)

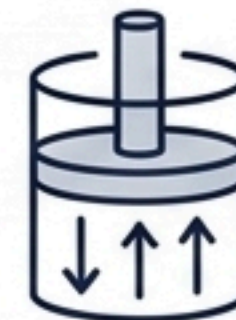


Energy transfer driven by a temperature difference between system and surroundings.

Heat **IN** (Absorbed) $\rightarrow q > 0$

Heat **OUT** (Released) $\rightarrow q < 0$

WORK (w)



Energy transfer achieved through macroscopic mechanical or electrical means (e.g., pressure-volume changes).

Work **ON** system (Compression) $\rightarrow w > 0$

Work **BY** system (Expansion) $\rightarrow w < 0$



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$$E=mc^2$$



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The First Law of Thermodynamics

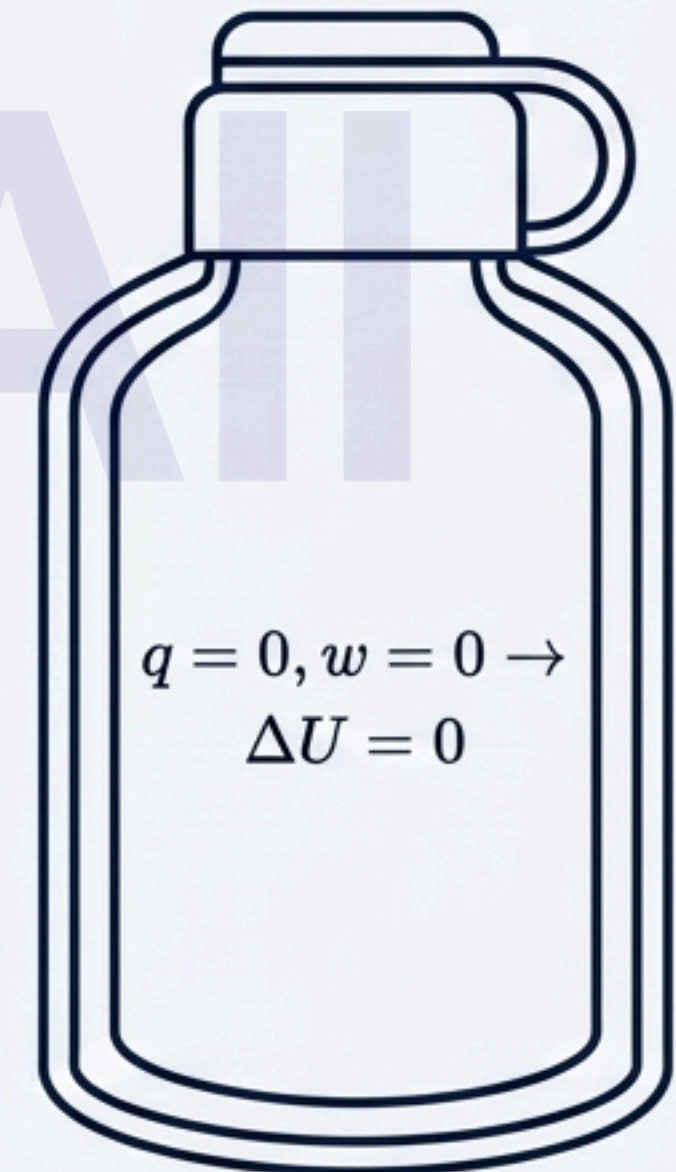
The energy of an isolated system is constant.

(Energy can neither be created nor destroyed, only transferred as heat or work.)

$$\Delta U = q + w$$

- ΔU = Change in internal energy (State Function)
- q = Heat added to the system (Path Function)
- w = Work done on the system (Path Function)

While q and w vary depending on the path, their sum ($q + w$) is identical for any given initial and final state.



Special Cases of the First Law

How $\Delta U = q + w$ adapts to specific system constraints.

Condition	Physical Meaning	First Law Result
Adiabatic Process	Thermally insulated walls. No heat exchange.	$q = 0 \rightarrow \Delta U = w_{\text{ad}}$
Constant Volume (Isochoric)	Rigid closed container. No mechanical work possible ($\Delta V = 0$).	$w = 0 \rightarrow \Delta U = q_V$
Isolated System	Perfectly sealed & insulated. No heat or matter/work exchange.	$q = 0, w = 0 \rightarrow \Delta U = 0$

Beware the Sign Convention Trap

! CHEMISTRY vs PHYSICS CONVENTION

In Chemistry (IUPAC), the perspective is always from the System's point of view.

- System is compressed (surroundings give energy) → Work ON system = Positive (+)
- System expands (spends its own energy) → Work BY system = Negative (-)

(Note: Physics uses the surroundings' viewpoint. Do not mix them up!)

✗ Common Misconception

Adiabatic means constant temperature.

✓ Correct Concept

Adiabatic means $q = 0$ (no heat transfer). The temperature will change if work is done ($w \neq 0$). Isothermal means $\Delta T = 0$.

Concept Summary

State vs Path

- State Functions:
 U, p, V, T
- Path Functions: q, w

$$\Delta U = q + w$$

Sign Logic

- Energy entering system
→ POSITIVE (+)
- Energy leaving system
→ NEGATIVE (-)

Adiabatic: $\Delta U = w$

Isochoric (Constant V): $\Delta U = q_V$



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