

UNIT 5: THERMODYNAMICS

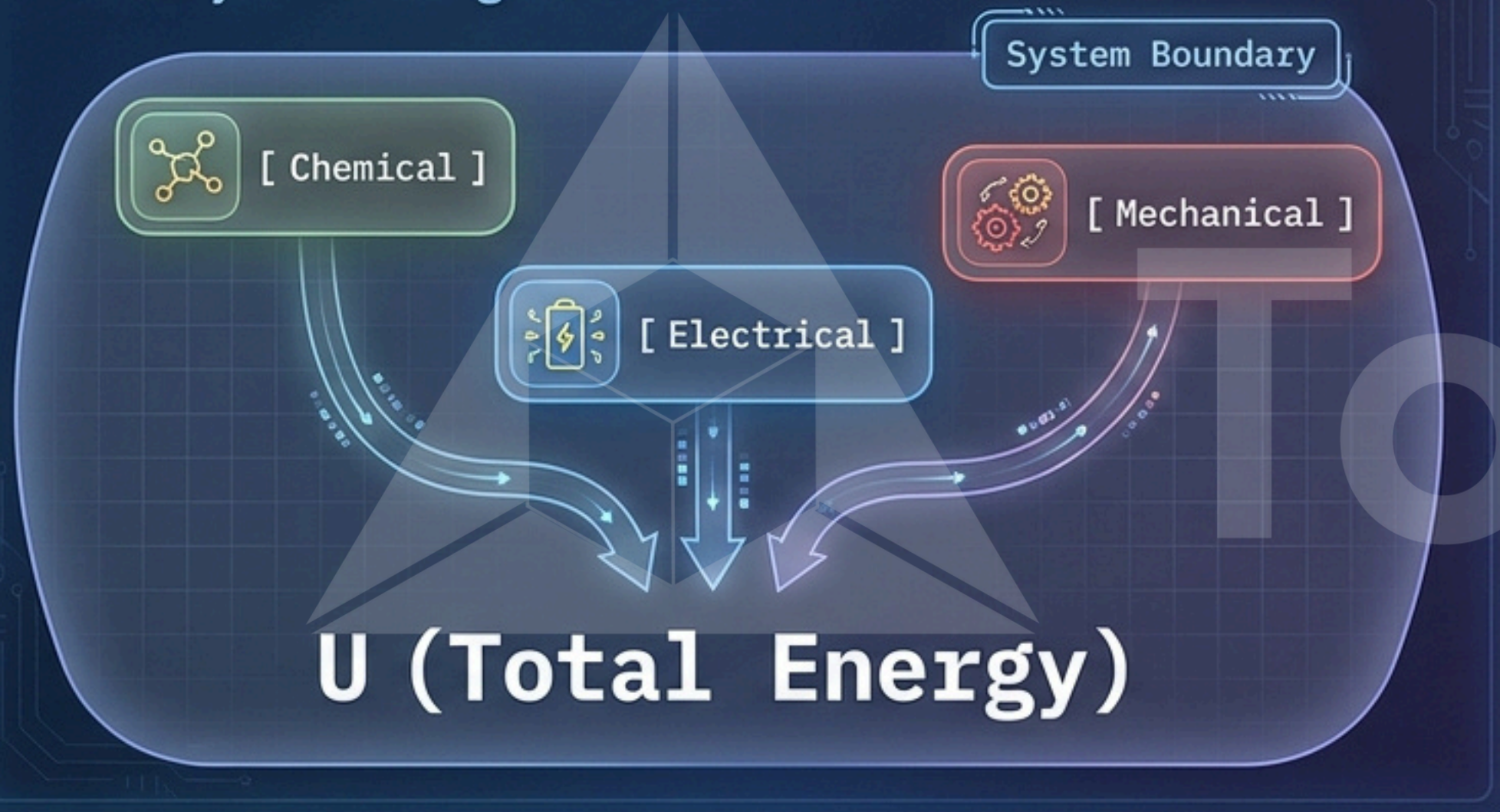
5.1.4 The Internal Energy as a State Function

Understanding the absolute sum of system energy, the levers of change, and the proof of path-independence.



What Is Internal Energy, U ?

Thermodynamic Ledger



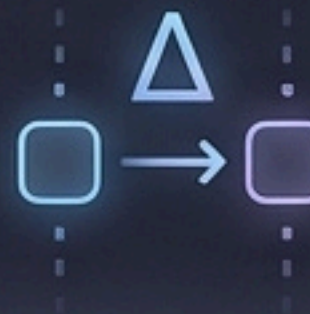
The Absolute Rule

We cannot specify an unambiguous (absolute) value for U in a particular state. It is a 'black box' metric.



The Measurable Reality

We can only measure the changes in internal energy as the system moves from one state to another.



$$[\Delta U = U_{\text{final}} - U_{\text{initial}}]$$

How U Can Change

Heat (q)



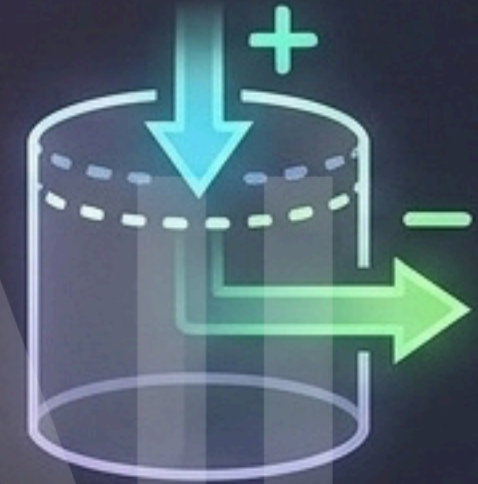
Energy transfer resulting from a temperature difference between the system and surroundings.

Work (w)



Energy transfer via mechanical (e.g., volume change) or electrical forces.

Matter Transfer



Physical mass entering or leaving the system (occurs in Open Systems).

In an isolated system, none of these three transfers occur. Therefore, $\Delta U = 0$.



You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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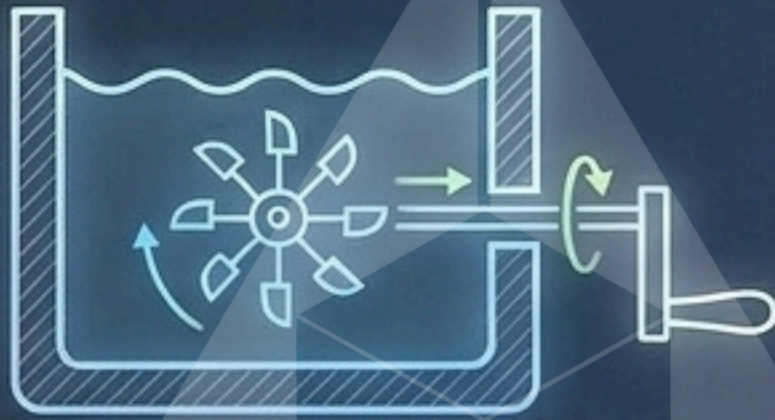
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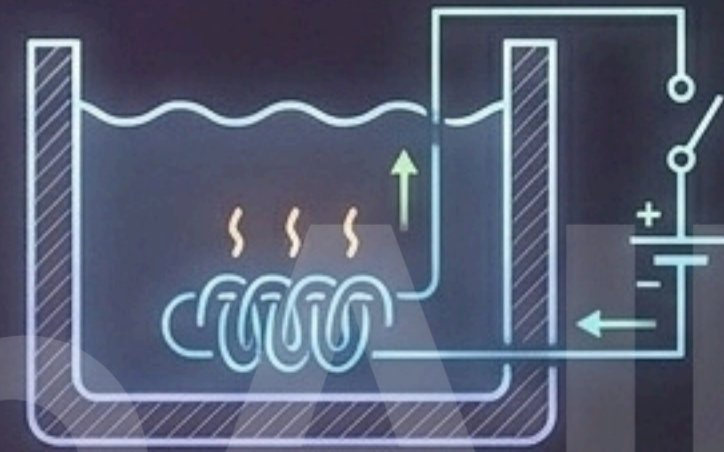
The Path-Independence Insight

Path A (Mechanical)



- **Input:** Rotating small paddles (churning water).
- **Work Done:** Exactly 1 kJ mechanical work.

Path B (Electrical)



- **Input:** Using an electrical immersion rod.
- **Work Done:** Exactly 1 kJ electrical work.

Result

Same final state. $\Delta T = T_B - T_A$ is identical.

Same Initial State + Same Amount of Work = Same Final State (regardless of how the work was done).

Adiabatic Work (w_{ad}) & Sign Conventions

Adiabatic Dashboard

Adiabatic Wall (No Heat Transfer: $q = 0$)



If $q = 0$, the only way to change U is via work. Therefore: $\Delta U = w_{ad}$

IUPAC Sign Convention Ruleset

[+w]

Work is done **ON** the system.
Internal energy U increases.



[-w]

Work is done **BY** the system.
Internal energy U decreases.



(Follows modern IUPAC standards for chemical thermodynamics)

U is a State Function

The Mountain/Path Metaphor



State Functions (Path-Independent):
Depend ONLY on initial & final states. **Variables:** U, T, V, p

Path Functions (Route-Dependent):
Depend on how the change is carried out. **Variables:** q, w

$$[\Delta U = U_2 - U_1]$$



You've Learned the Theory.

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