First Law of Thermodynamics

Introduction

The First Law of Thermodynamics is a fundamental principle in chemical engineering and physics. It states that energy cannot be created or destroyed, only transformed from one form to another. This law forms the basis for energy balances in chemical processes and is essential for understanding how systems exchange energy with their surroundings.

Key Concepts

- State and Path Functions
- Energy Conservation
- Internal Energy
- Work and Heat
- Closed and Open Systems
- Reversible and Irreversible Processes

Definitions

- **Internal Energy (U):** The total energy contained within a system. Energy stored in molecular motion, configuration, and position.
- **Heat (Q):** Energy transferred into/from a system due to a temperature difference.
- **Work (W):** Energy transferred when a force moves an object.
- **System:** The part of the universe being studied.
- **Surroundings:** Everything outside the system.
- **Reversible Process:** A process that can be reversed without leaving any effect on the surroundings.
- **State Function:** A property that depends only on the current state of a system, not on the path taken.
- **Path Function:** A property that depends on the specific path taken. Examples: work, heat.

State and Path Functions

State functions depend only on the current state of a system, not on the path taken. Examples include internal energy, enthalpy, and entropy. Changes in state functions are independent of the process path. Path functions depend on the specific path. Examples: work, heat.

Energy Conservation

The First Law is the law of energy conservation: energy cannot be created or destroyed, only transferred or transformed. The total energy in the universe must stay constant.

$$\Delta U = Q + W$$

where ΔU is the change in internal energy, Q is the heat transfer, and W is the work done by or on the system.

Internal Energy

Internal energy (U) is the total energy contained within a system, including kinetic and potential energy of molecules, chemical bonds, and intermolecular forces. Think of each molecule having a tiny bit of energy from motion, position, or interactions. Adding them all up gives the system's internal energy.

Work and Heat

Work (W) and heat (Q) are two ways energy can be transferred between a system and its surroundings. Work is energy transfer due to force acting over a distance, while heat is energy transfer due to temperature difference.

Both are path functions: their values depend on the process path.

- In UT ChE convention: Work done **by** the system $\rightarrow$ negative. Work done **on** the system $\rightarrow$ positive.
- Heat added to the system $\rightarrow$ positive. Heat removed $\rightarrow$ negative.

Closed and Open Systems

A closed system does not exchange matter with its surroundings, only energy. An open system can exchange both matter and energy. The First Law is applied differently depending on the type of system.

Misconception: If a system exchanges energy, it must be open. *Correction:* Closed systems can exchange energy but not matter.

Reversible and Irreversible Processes

Reversible processes are idealized processes that occur infinitely slowly, keeping the system in equilibrium. They simplify calculations and can sometimes be approximated in real systems, but no real process is perfectly reversible. Irreversible processes are real-world processes with losses due to friction, turbulence, etc.

Recap

The First Law of Thermodynamics is a cornerstone of energy analysis in chemical engineering. It ensures all energy changes are accounted for and helps engineers design efficient processes. A solid understanding of these concepts is essential for applying the First Law correctly.