

# Chemical Thermodynamics (Energy & Spontaneity)

## 1. Core Definitions

Thermodynamics examines the flow of heat and energy during chemical transformations.

- **System:** The specific chemical reaction or region being studied.
- **Surroundings:** Everything outside the system (the rest of the universe).
- **State Functions:** Properties that depend only on the current state of the system, not how it got there (e.g., Enthalpy, Entropy, Temperature).

## 2. The First Law & Enthalpy (H)

The First Law of Thermodynamics states that energy cannot be created or destroyed, only transformed. In chemistry, we track this using **Enthalpy (H)**, which is the total heat content of a system at constant pressure.

### Heat of Reaction ( $\Delta H$ )

$$\Delta H = H_{\text{products}} - H_{\text{reactants}}$$

- **Exothermic Reactions ( $-\Delta H$ ):** The system releases heat energy to the surroundings. The products have lower energy than the reactants, making them inherently more stable. (e.g., Combustion).
- **Endothermic Reactions ( $+\Delta H$ ):** The system absorbs heat from the surroundings. The products have higher energy than the reactants. (e.g., Photosynthesis).

## 3. The Second Law & Entropy (S)

The Second Law states that any spontaneous process increases the total entropy (disorder) of the universe. **Entropy (S)** is a measure of molecular randomness or the number of microstates available to a system.

- $+\Delta S$  (**Increasing Disorder**): Occurs when a solid melts into a liquid, a liquid evaporates into a gas, or a solid dissolves in a solvent.
- $-\Delta S$  (**Decreasing Disorder**): Occurs when gas molecules condense into a liquid or compress into a smaller volume.

#### 4. Gibbs Free Energy (G) & Spontaneity

To determine if a reaction will occur naturally without continuous external intervention (spontaneity), we use the Gibbs Free Energy equation:

$$\Delta G = \Delta H - T\Delta S$$

- $\Delta G < 0$  (**Negative**): The reaction is **spontaneous** (exergonic).
- $\Delta G > 0$  (**Positive**): The reaction is **non-spontaneous** (endergonic).
- $\Delta G = 0$ : The system is at **equilibrium**.

#### Spontaneity Matrix

$\Delta H$	$\Delta S$	Spontaneity Outcome
Negative (Exo)	Positive (+Disorder)	Always spontaneous at all temperatures ( $\Delta G$ is always negative)

Positive (Endo)	Negative (-Disorder)	Never spontaneous at any temperature ( $\Delta G$ is always positive)
Negative (Exo)	Negative (-Disorder)	Spontaneous only at <b>low</b> temperatures
Positive (Endo)	Positive (+Disorder)	Spontaneous only at <b>high</b> temperatures