Fundamental Laws of Thermodynamics

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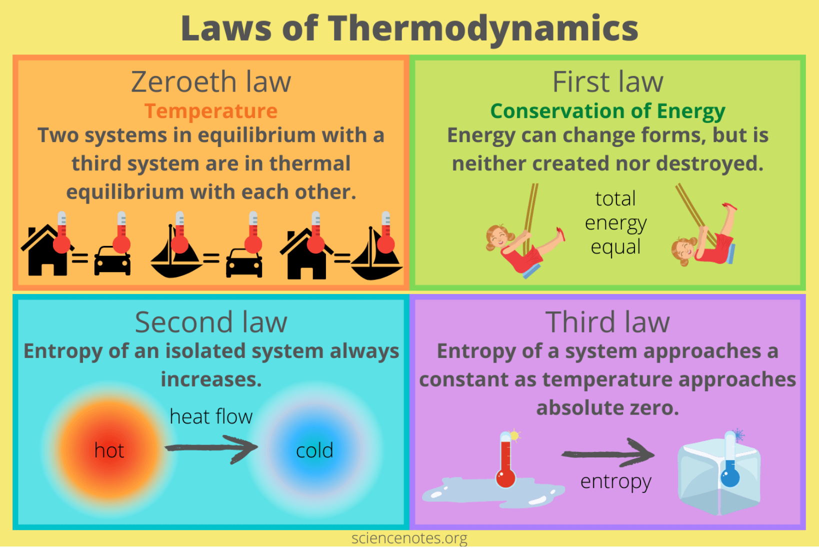
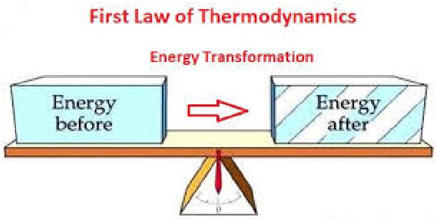
Introduction

- **Overview of thermodynamics**
  In the realm of chemistry, thermodynamics plays a pivotal role in understanding the behavior of chemical systems and reactions.
  The fundamental laws of thermodynamics provide a framework for analyzing energy transformations and the spontaneity of chemical processes.
  These laws govern the flow of heat, energy, and matter in chemical systems, shaping the directionality and feasibility of reactions.


Laws of Thermodynamics
Zeroeth law
Temperature
Two systems in equilibrium with a third system are in thermal equilibrium with each other.
First law
Conservation of Energy
Energy can change forms, but is neither created nor destroyed.
total energy equal
Second law
Entropy of an isolated system always increases.
heat flow
hot
cold
Third law
Entropy of a system approaches a constant as temperature approaches absolute zero.
entropy
sciencenotes.org

First Law of Thermodynamics

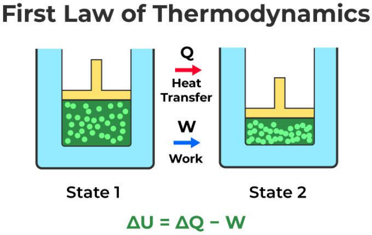
- The First Law of Thermodynamics, often referred to as the law of energy conservation, states that energy cannot be created or destroyed in an isolated system; it can only change forms.
- In simpler terms, the total energy of a closed system remains constant over time.
- Mathematically, the first law of thermodynamics can be expressed as: $\Delta U = Q - W$



Where: ΔU represents the change in internal energy of the system,
Q denotes the heat added to the system, and
W represents the work done by the system.

- This equation illustrates that any heat (Q) added to the system increases its internal energy (U), while work done by the system (W) decreases its internal energy.
- Conversely, if heat is lost from the system or work is done on the system, the internal energy decreases.

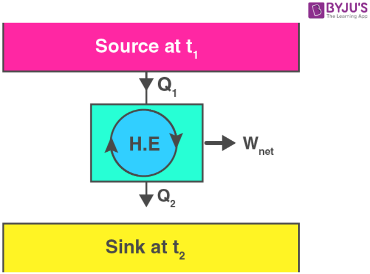
The first law of thermodynamics underscores the principle of energy conservation, providing valuable insights into the behavior of physical and chemical systems.

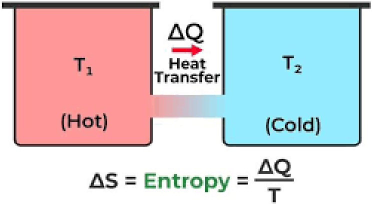


Overall, the first law of thermodynamics is a fundamental principle in physics and engineering, with broad implications across various scientific disciplines.

Second Law of Thermodynamics

- The Second Law of Thermodynamics states that in any natural thermodynamic process, the total entropy of a closed system always increases over time, or remains constant in ideal cases.
  - Entropy is a measure of the disorder or randomness of a system, and the second law suggests that natural processes tend to move towards
- Mathematically, the second law of thermodynamics is often expressed in various forms, such as the Clausius statement or the Kelvin-Planck statement.


BYJU'S
The Learning App
Source at t_1
Q_1
H.E
W_{net}
Q_2
Sink at t_2


T_1
(Hot)
ΔQ
Heat
Transfer
T_2
(Cold)
ΔS = Entropy = $\frac{\Delta Q}{T}$

Clausius Statement

- The Clausius statement asserts that heat cannot spontaneously flow from a colder body to a hotter one,

Kelvin-Planck Statement

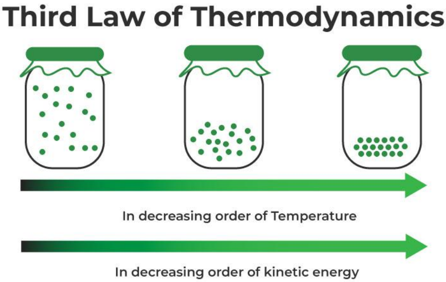
- Kelvin-Planck statement states that it is impossible to construct a device that operates in a cycle and produces no effect other than the extraction of heat from a hot reservoir and the performance of an equivalent amount of work.

Examples of Second Law of Thermodynamics:

- Heat Flow: Heat naturally flows from a higher temperature object to a lower temperature object. This is why ice melts when placed in a warmer environment.
- Refrigerators work by transferring heat from inside the refrigerator (lower temperature) to the surrounding environment (higher temperature). This process requires energy input and is in accordance with the second law.
- Carnot Efficiency: The maximum efficiency of a heat engine operating between two temperature reservoirs is given by the Carnot efficiency, which is based on the second law of thermodynamics. No real heat engine can exceed this efficiency.

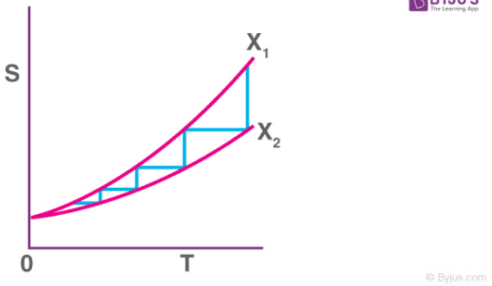
Third Law of Thermodynamics

- The Third Law of Thermodynamics states that as the temperature of a system approaches absolute zero (0 Kelvin), the entropy of the system approaches a minimum or constant value.
- This law implies that it is impossible to reach absolute zero through any finite number of processes and that all processes cease as the temperature approaches absolute zero.
- The Third Law of Thermodynamics has significant implications in the study of material properties at very low temperatures, such as superconductivity and quantum mechanics.
- It also helps to define the concept of absolute entropy, providing a reference point for entropy calculations.


Third Law of Thermodynamics
In decreasing order of Temperature
In decreasing order of kinetic energy

Examples of Third Law of Thermodynamics:

- Absolute Zero: Scientists use the Third Law to study materials at extremely low temperatures, close to absolute zero. For example, in cryogenics research, where temperatures near absolute zero are used to study the behavior of materials, such as superconductors and quantum fluids..
- Preservation of Food: Freezing food items preserves them by slowing down the rate of chemical reactions and microbial growth. While not reaching absolute zero, the principles of the Third Law are at play as the temperature decreases, reducing the entropy and slowing down molecular motion, thereby extending the shelf life of the food.



Supporting Equation:

- $S - S_o = K_B \ln\Omega$

Conclusion

- In conclusion, the fundamental laws of thermodynamics form the cornerstone of our understanding of energy and its transformations.
- From
  - First Law's conservation of energy principle
  - Second Law's directionality of processes
  - Third Law's insights into absolute zero and entropy

  these laws govern the behavior of systems at the macroscopic and microscopic levels.
- Through this presentation, we have explored the significance of these laws in various fields, including physics, chemistry, engineering, and beyond.
- Understanding these principles enables us to manipulate energy effectively, driving innovations across science and technology.

References

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- MIT OpenCourseWare - Thermodynamics
- Byjus