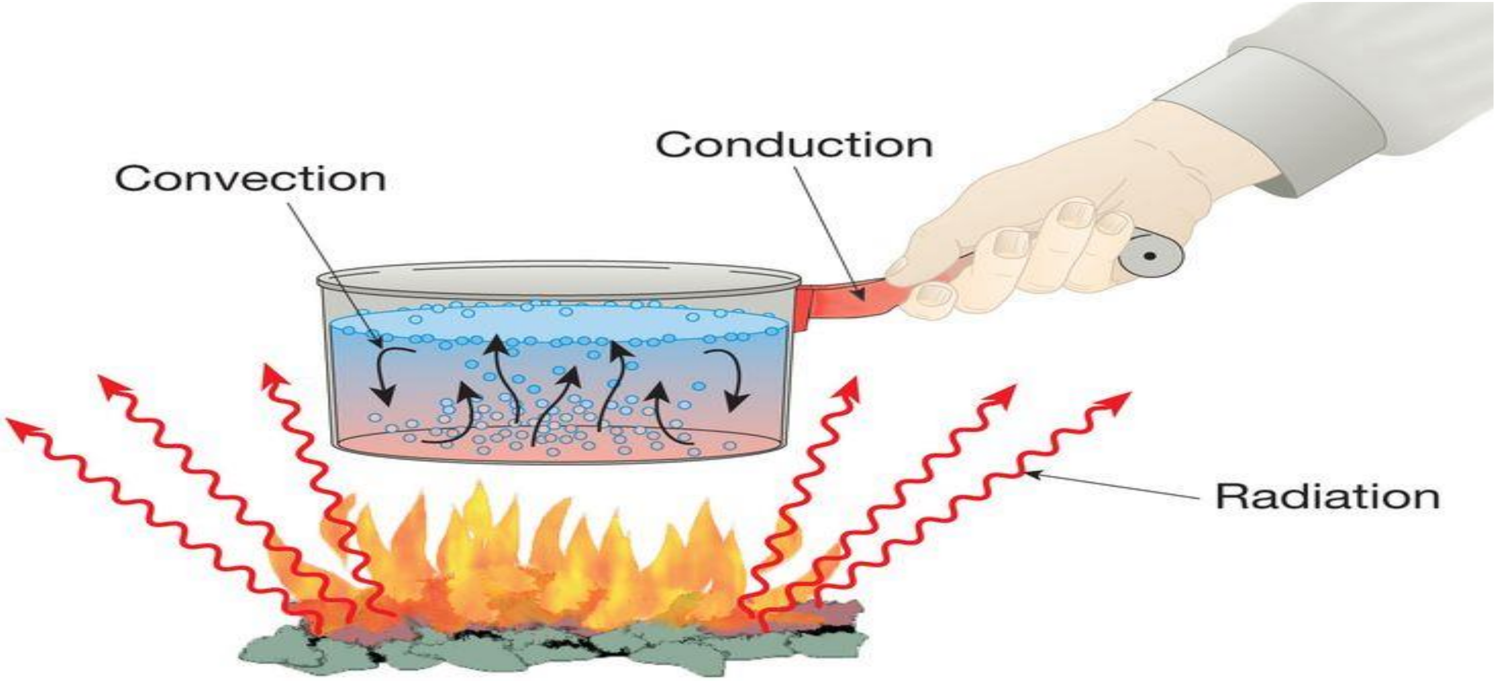
LAWS OF THERMODYNAMICS

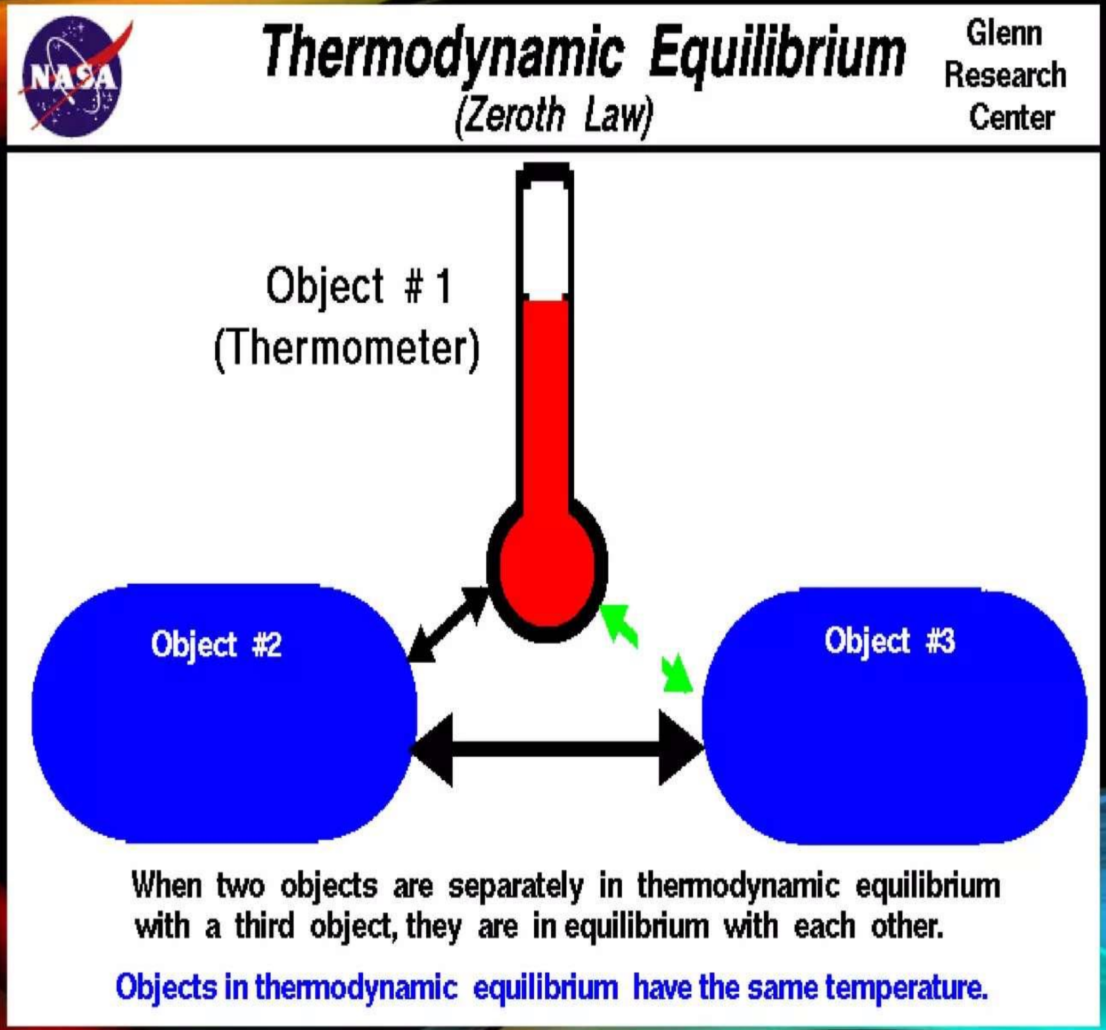


LAWS OF THERMODYNAMICS

- Zeroth Law of thermodynamics
- First law of thermodynamics
- Second law of thermodynamics
- Third law of thermodynamics

Zeroth Law of Thermodynamics

- If object A is in thermal equilibrium with object B and B is in thermal equilibrium with object C then A & C are in thermal equilibrium with each other
- if two closed system with different temperatures are come into contact then heat is transferred from high temp. to law temp.
- it is the basis for temperature measurement of a body or object.
- This law is also used for designing the thermometer.


NASA
Thermodynamic Equilibrium
(Zeroth Law)
Glenn
Research
Center
Object # 1
(Thermometer)
Object #2
Object #3
When two objects are separately in thermodynamic equilibrium
with a third object, they are in equilibrium with each other.
Objects in thermodynamic equilibrium have the same temperature.

First Law of Thermodynamics

"You Can't Win"

- Energy and matter can't be created or destroyed; only transformed from one form to another
- The energy of universe is constant
- Relation between heat supplied & work done

$$\Delta U = \Delta Q - \Delta W$$

ΔU =Change in Internal Energy

ΔQ =Heat given to system

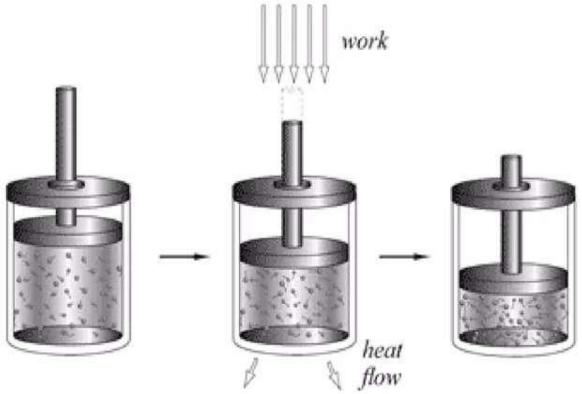
ΔW =Work done by system

The First Law of Thermodynamics

$$\Delta U = Q - W$$
$$= Q - P^{*}\Delta V$$

ΔU = internal energy change
Q = heat flow
W = macroscopic work

P^{*} = constant pressure
ΔV = volume change



Internal energy change results from the combination of heat flow and work between the system and its surroundings. In this example, the internal energy of our ideal gas system became greater (the particles are moving faster in the final state) because more energy entered the system through work than departed the system as heat flow.

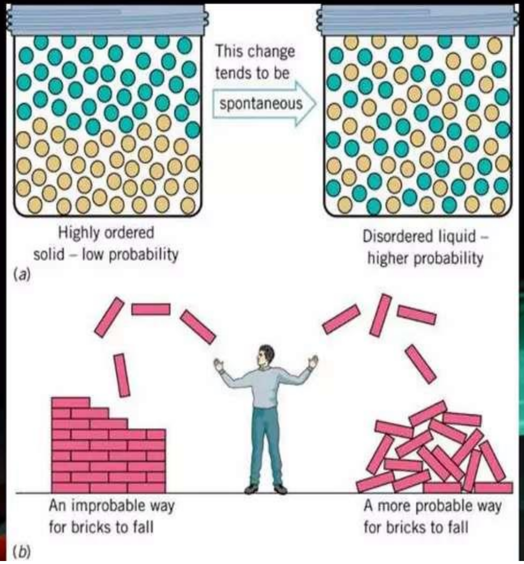
Second Law of Thermodynamics

"You Can't Break Even"

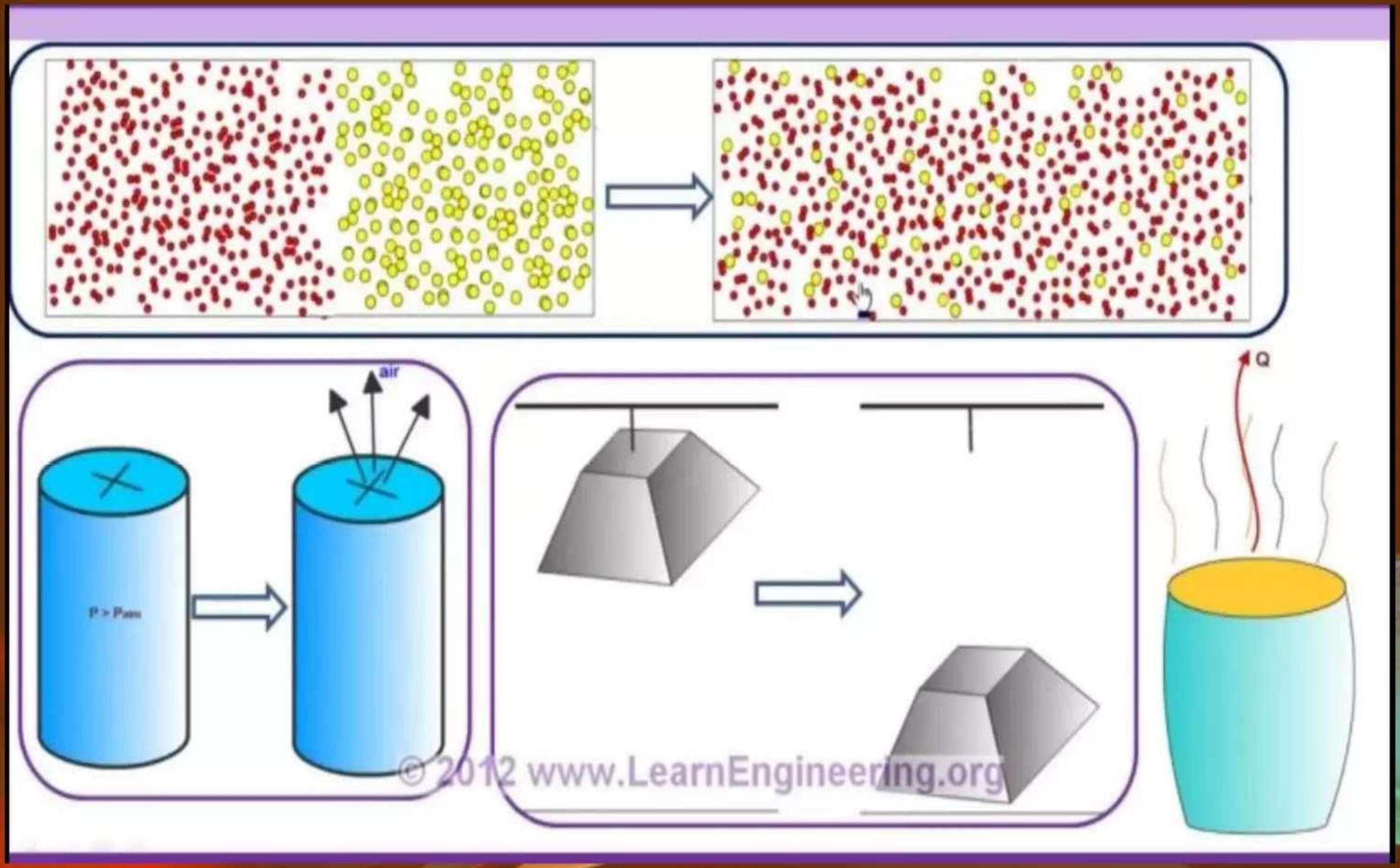
- In any spontaneous reaction the entropy of system will always increase & gibb's free energy will always decrease

- Entropy is a randomness of disorder

- 2nd Law of Thermodynamics states that natural systems always go from order to disorder



Order to Disorder – Entropy Increases

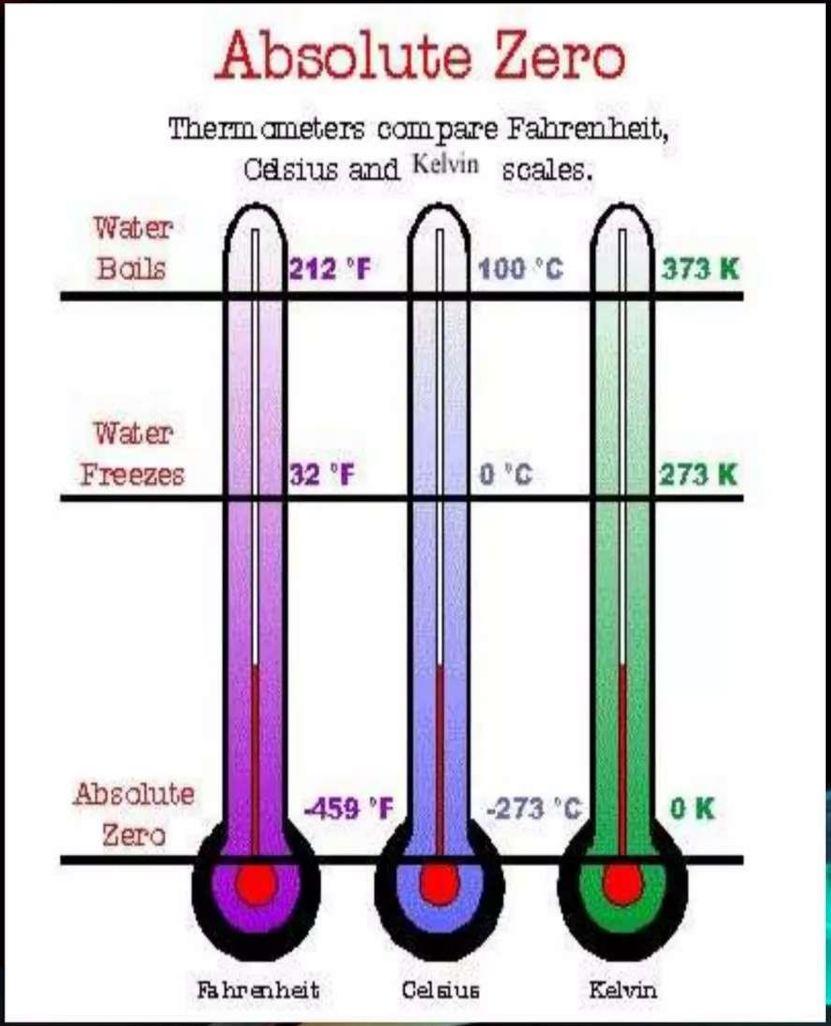


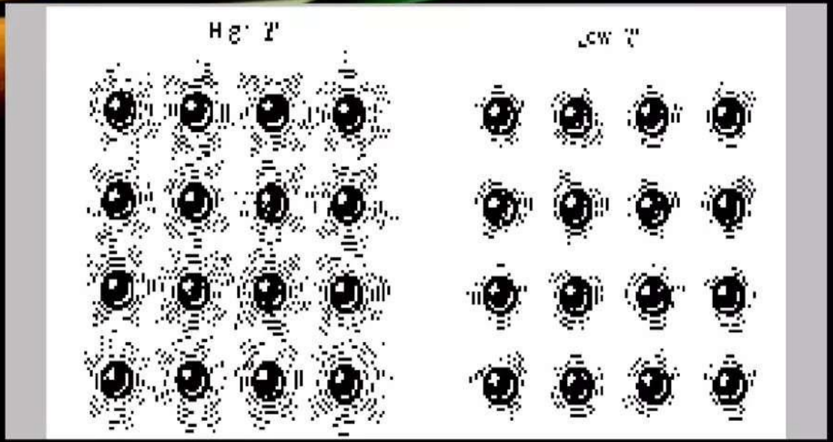
Third law of thermodynamics

"You can't get out of the game"
(because absolute zero is unattainable)

- The entropy of any crystalline material at absolute zero temperature will be zero
- The absolute zero temperature is the **reference point** for determining the entropy of a system.
- Importance of this law:

1. It helps in calculating the thermodynamic properties.
2. It explains the behavior of solids at very low temperature.

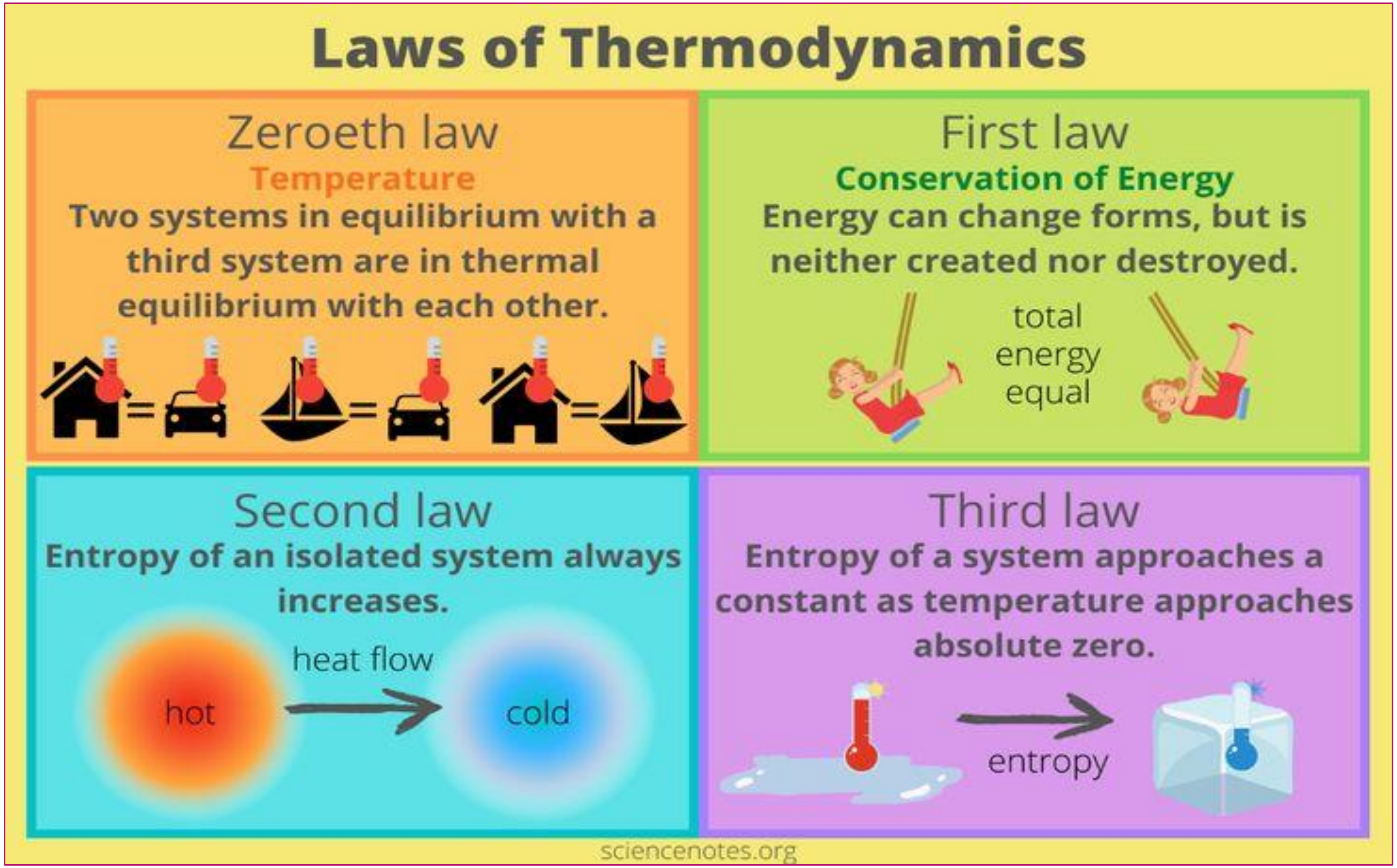

Absolute Zero
Thermometers compare Fahrenheit, Celsius and Kelvin scales.
Water Boils
212 °F
100 °C
373 K
Water Freezes
32 °F
0 °C
273 K
Absolute Zero
-459 °F
-273 °C
0 K
Fahrenheit
Celsius
Kelvin



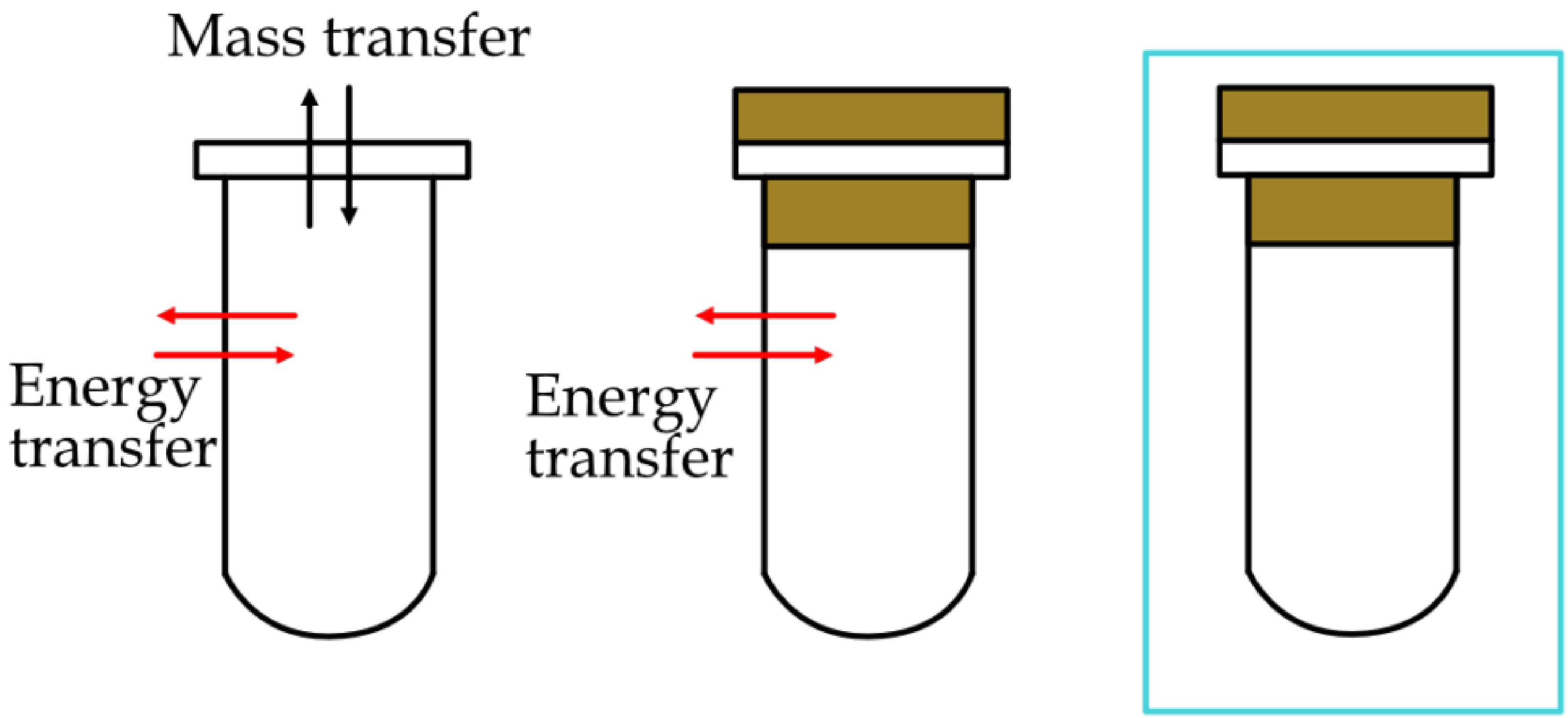
ICE Lattice CLOSE TO ABSOLUTE 0

- In the crystalline form, water molecules still have some entropy. There is enough thermal energy left to cause them to vibrate within the general area of their lattice sites. At any instance, the water molecules would be near, but probably not exactly at, their lattice positions. If we cool the solid further, thermal energy decreases and the water molecules spend less time away from their lattice positions. As you approach absolute zero, energy and entropy decrease. The ice will be in a state of absolutely minimal energy and molecular movement. At absolute zero the entropy will be zero.

- Statement of the Third Law of Thermodynamics: *At absolute zero, the entropy of a pure crystal is zero.*


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

Parameter	Symbol	Unit
Pressure	p	$Pa = N\, m^{-2}$
Temperature	T	K
Specific volume or	$v = \frac{V}{m} = \frac{1}{\rho}$	$m^3\, kg^{-1}$
Density	$\rho = \frac{m}{V} = \frac{1}{v}$	$kg\, m^{-3}$



Open System

Closed System

Isolated System

Thermodynamics Cycle

A thermodynamic cycle is a series of thermodynamic actions that, when carried out repeatedly, leave the system in the same state as when it was first created. Thermodynamic cycles are used to explain how heat engines, which convert heat into work, operate. The thermodynamic cycle is a closed cycle that has many changes due to temperature, pressure, and volume, but whose end and initial states are equal. This cycle is important because it allows the piston in the engine to move continuously and the fluid working in the refrigerator to expand/compress.

Types of Thermodynamic Cycles

There are various types of cycles in thermodynamics, and some of those important cycles are listed as follows:

- Carnot Cycle
- Rankine Cycle
- Otto Cycle
- Diesel Cycle
- Brayton Cycle
- Stirling Cycle

Carnot Cycle

•**Purpose**: Idealized cycle for maximum efficiency.

•**Processes**:

- Isothermal expansion (heat absorption at high temperature)
- Adiabatic expansion
- Isothermal compression (heat rejection at low temperature)
- Adiabatic compression

Otto Cycle

•**Purpose**: Models spark-ignition internal combustion engines (e.g., gasoline engines).

•**Processes**:

- Adiabatic compression
- Constant-volume heat addition
- Adiabatic expansion
- Constant-volume heat rejection

Diesel Cycle

•**Purpose**: Models compression-ignition engines (e.g., diesel engines).
•**Processes**:

- Adiabatic compression
- Constant-pressure heat addition
- Adiabatic expansion
- Constant-volume heat rejection

Brayton Cycle

Purpose: Models gas turbines (e.g., jet engines).
Processes:

Isentropic compression
Constant-pressure heat addition
Isentropic expansion
Constant-pressure heat rejection

Rankine Cycle

- **Purpose**: Models steam power plants.
- **Processes**:
  - Isentropic compression (pump)
  - Constant-pressure heat addition (boiler)
  - Isentropic expansion (turbine)
  - Constant-pressure heat rejection (condenser)

Refrigeration Cycle (Reverse Rankine)

Purpose: Models cooling devices (e.g., refrigerators and air conditioners).

Processes:

Isentropic compression
Constant-pressure heat rejection
Isenthalpic expansion (throttling)
Constant-pressure heat absorption

Stirling Cycle

•**Purpose**: Models external combustion engines (e.g., Stirling engines).

•**Processes**:

- Isothermal expansion
- Isovolumetric (constant-volume) heat transfer
- Isothermal compression
- Isovolumetric heat transfer.

Ericsson Cycle

Purpose: A variation of the Stirling cycle with constant-pressure processes.

Processes:

Isothermal expansion
Constant-pressure heat addition
Isothermal compression
Constant-pressure heat rejection