CE 213A
Introduction to Environmental Science

L 2 : Unit 1

Energy and Review of Thermodynamics

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Schedule : LEC: mon. wed, fri 5:00 - 600; L9

Contd.

- Thermodynamics
  - Energy
  - Heat and Work
    - Forms of heat energy
  - Enthalpy
    - Endothermic vs. Exothermic Processes
    - Enthalpy of formation, Standard States
  - Entropy, Gibb's Free Energy
  - Laws of thermodynamics

What is always present but never visible?

ENERGY!

What Is Energy?

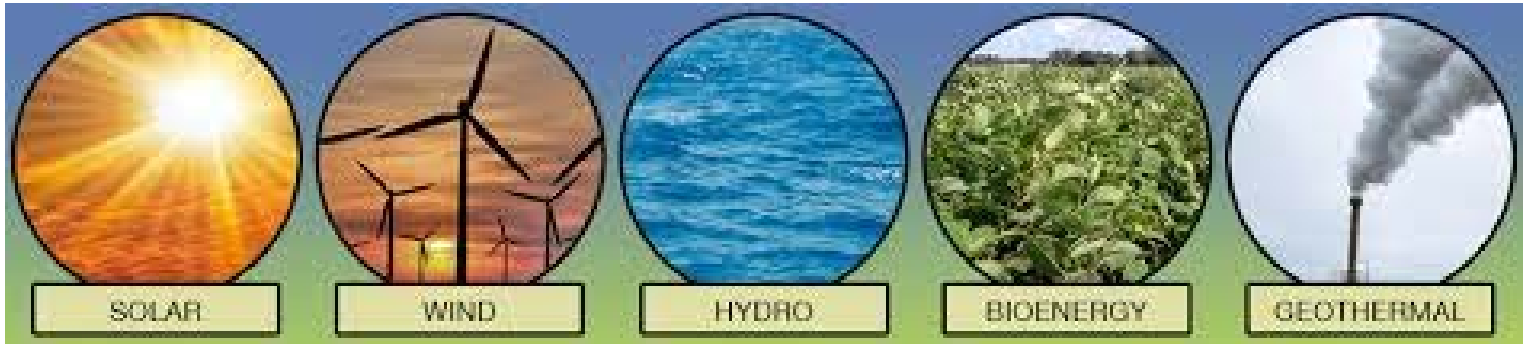
Energy is a **property of a system** that contains matter

<u>Definition:</u>

Energy is the ability to <u>transform, organize, or change</u> a system that contains matter

- SI Unit is Joule (J)

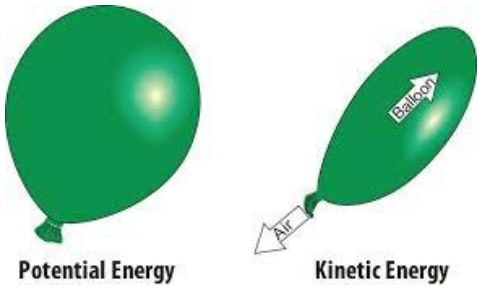
Sources

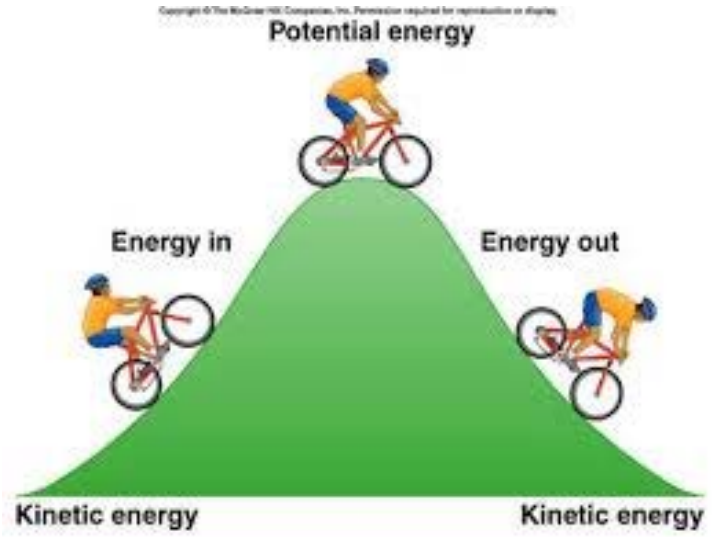


Forms/ Types of Energy

scientists have discovered ways to measure and quantify energy.

- **Kinetic**
  - Wind
  - Electricity
  - Flowing water





- **Potential**
  - Water behind a dam
  - Gasoline in car
  - Unlit match

$$KE = \frac{1}{2}mv^2$$

$$PE = mgh$$

PE = energy in Joules

m = mass in kilograms

g = acceleration of gravity ($9.8 m/s^2$)

h = height above surface in meters

What is Matter?

- Anything that has mass and takes up space.
- Atoms, ions and molecules

- Two forms:
  - Element – distinctive building blocks of matter that make up every material substance
  - **Compound** – two or more different elements held together by **chemical bonds**

Is the law applicable under all situations?

Answer ----- NO

Case 1 – Nuclear fusion reactions violate law of conservation of mass

- Einstein's equation, $E = mc^2$, shows that *matter* and energy are two forms of the same thing. It also shows that there is a tremendous amount of energy (E) in a small *mass* (m) of *matter*. In *nuclear reactions*, *matter* changes to energy, but the total amount of *mass* and energy together *does not* change.

In *nuclear* fusion *reaction* if considered an example, energy that sun emits in its core is due to collision of hydrogen nuclei and formation of helium nuclei. Here *conservation of mass* is *not* obeyed as certain part of *mass* is converted into energy. So, *law of conservation of mass* is violated here.

Proton - proton chain reaction:

$${}_1H^1 + {}_1H^1 \xrightarrow{\text{fusion}} {}_1H^2 + {}_{+1}e^0 + \text{energy}$$

positron

$${}_1H^2 + {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^3 + \text{energy}$$

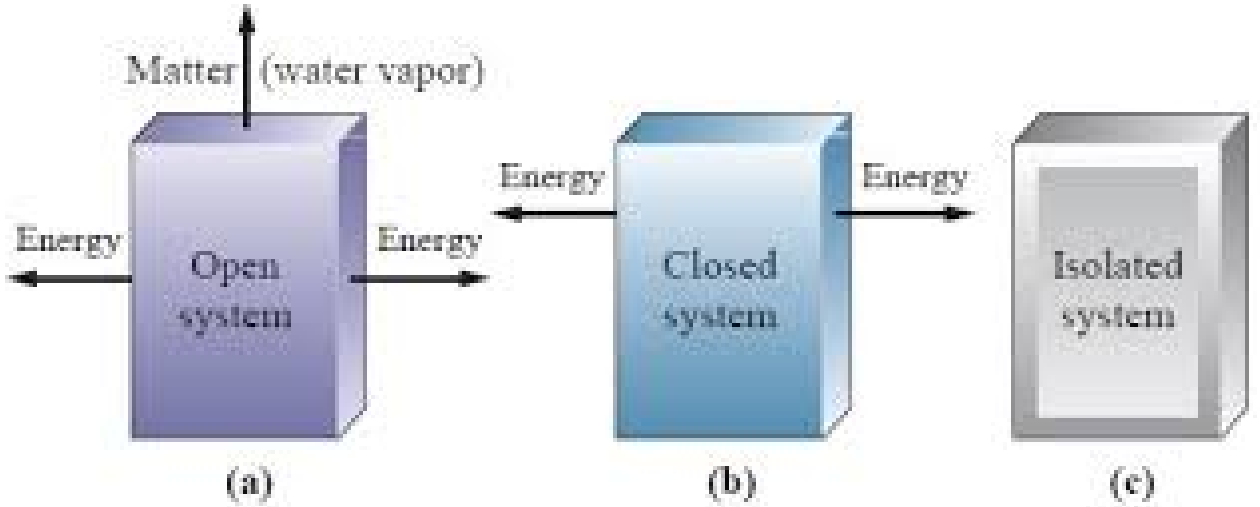
$${}_2He^3 + {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^4 + {}_{+1}e^0 + \text{energy}$$

The overall reaction, therefore, may be written as:

$$4\ {}_1H^1 \xrightarrow{\text{fusion}} {}_2He^4 + 2\ {}_{+1}e^0 + \text{energy}$$

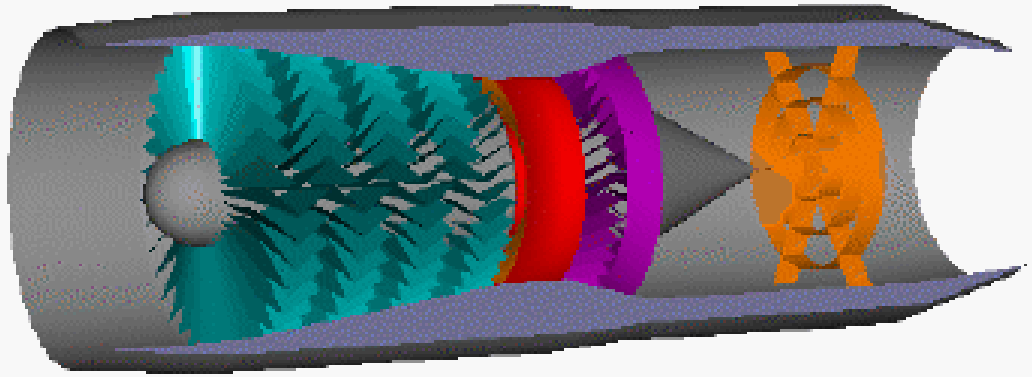
Case 2 – Open system

In special relativity, the conservation of mass *does not apply* if the system is open and energy escapes.



What is Thermodynamics?

Glenn Research Center



Thermodynamics is the study of the effects of work, heat, and energy on a system. Thermodynamics is only concerned with large scale observations.

Zeroth Law: Thermodynamic Equilibrium and Temperature

First Law: Work, Heat, and Energy

Second Law: Entropy

Definitions

- **Energy (E):**
  - Energy is the ability to transform, organize, or change a system that contains matter
    - SI Unit is Joule (J)
- **Heat (H):**
  - Form of energy which passes from one body to another solely as a result of a difference in temperature.
    - SI Unit of Heat is the calorie (cal) or Joule (J)
- **Work (W):**
  - It is the quantity of energy transferred from one system to another without an accompanying transfer of entropy.
    - SI Unit is Joule (J) (calorie (cal) in CGS system)

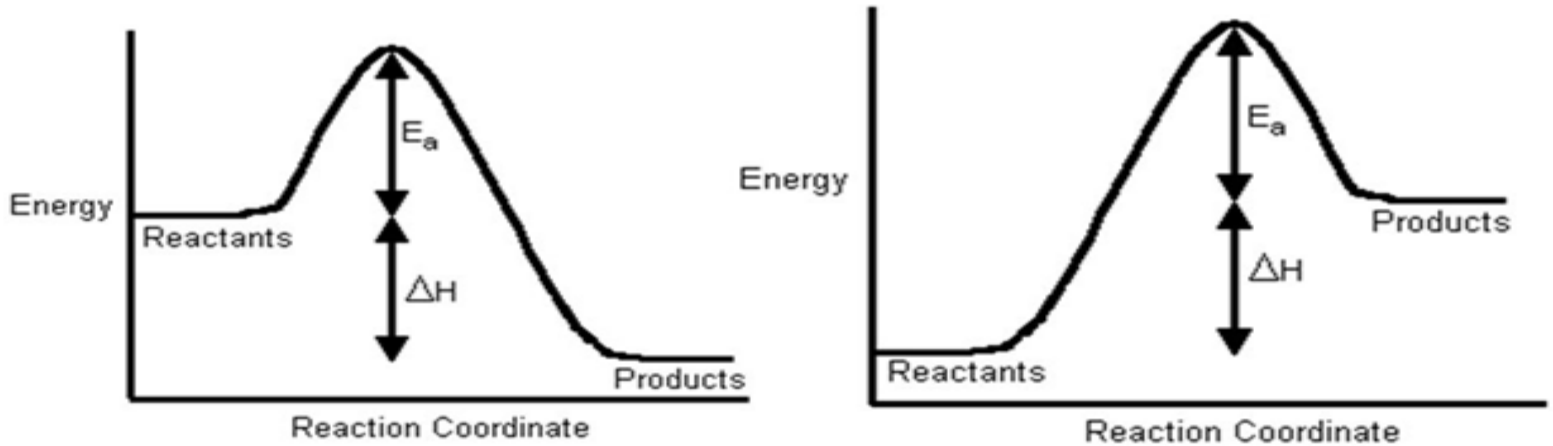
- **Entropy (S):**
  - Entropy is a measure of the degree of randomness or disorder in the system, Generally denoted as ‘S’. SI Unit is (J/K)

- **Enthalpy**
  - Enthalpy is the amount of heat content used or released in a system at constant pressure. It is usually expressed as the change in enthalpy.
  - The change in enthalpy is related to a change in internal energy and a change in the volume , which is multiplied by the constant pressure of the system

- **Free Energy**
  - Free energy is the enthalpy of the system minus the product of the temperature times the entropy of the system.
  - Often referred to as ***Gibb’s Free Energy G***.

What is Enthalpy?

- ΔH, heat energy
- ENDOthermic: heat is taken in by the reactants
- EXOthermic: heat is released as a product



$$\Delta H^{o}_{rxn} = \Delta H^{o}_{f(products)} - \Delta H^{o}_{f(reactants)}$$

Gibbs free energy *G*

- The *Gibbs free energy* of a system at any moment in time is defined as the enthalpy of the system minus the product of the temperature times the entropy of the system.

$$G = H - TS$$

- The *Gibbs free energy* of the system is a state function because it is defined in terms of thermodynamic properties that are state functions.

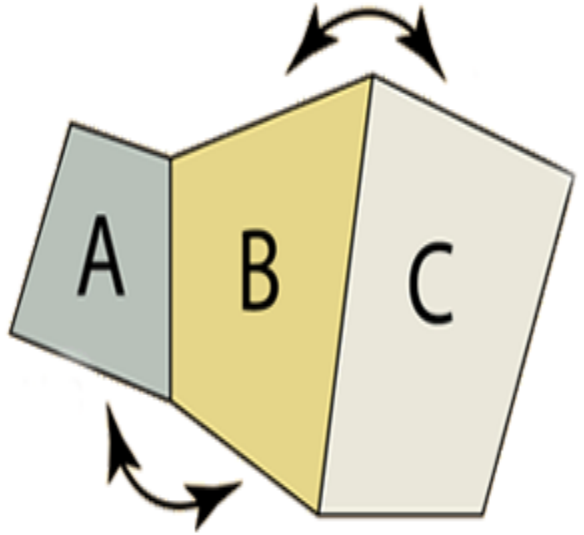
Laws of thermodynamics

Zeroth law of Thermodynamics

- Base for all temperature measurement.
- Thermal equilibrium is the key word for zeroth law

Definition:

When a body A is in **thermal equilibrium** with a body B, and also separately with a body C, then B and C will be in thermal equilibrium with each other.



Keyword - Thermal Equilibrium

Law of Conservation of Energy

First law of thermodynamics

The **first law**, **also known** as **Law** of Conservation of Energy, states that energy cannot be created or destroyed in an isolated system.

The change in internal energy of a system is equal to the heat added to the system minus the work done by the system.

$$\Delta U = Q - W$$

Change in internal energy

Heat added to the system

Work done by the system

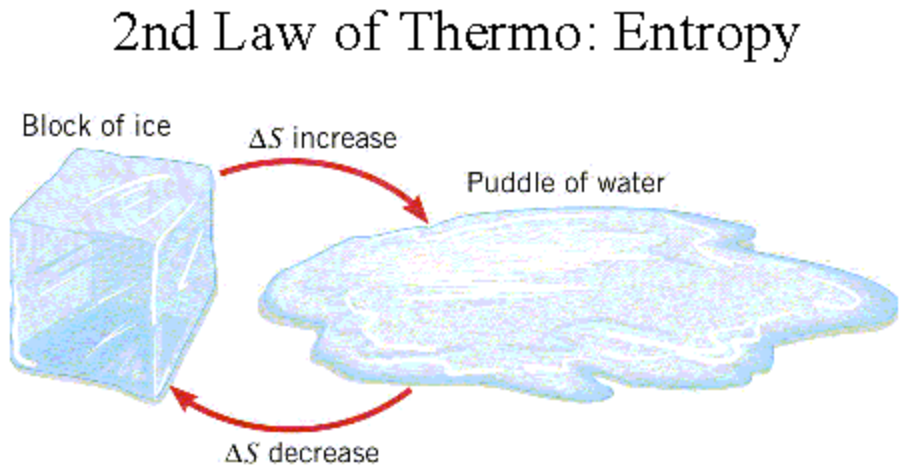
Heat Capacity

- Molar **heat capacity** is a measure of the amount of **heat** necessary to raise the temperature of one mole of a pure substance by one degree K.

- **Specific heat capacity** is a measure of the amount of **heat** necessary to raise the temperature of one gram of a pure substance by one degree K.

Second law of thermodynamics

- The Second Law of Thermodynamics states that the state of **entropy of the entire universe**, as an isolated system, **will always increase over time**.
- The second law also states that the changes in the entropy in the universe can never be negative.



Third law of thermodynamics

- The *Third Law of Thermodynamics* is concerned with the limiting behavior of systems as the temperature approaches absolute zero.

- The *Third Law* states, "**The entropy of a perfect crystal is zero when the temperature of the crystal is equal to absolute zero (0 K).**"