Thermodynamics

Lecture : Introduction thermodynamics

Grade: 1th Class

Dr.Haleemah Jaber Mohmmed

2024-2023

What is thermodynamics?

- The study of thermodynamics is concerned with ways energy is stored within a body and how energy transformations, which involve heat and work, may take place.

- Approaches to studying thermodynamics
  - Macroscopic (Classical thermodynamics)
    - study large number of particles (molecules) that make up the substance in question
    - does not require knowledge of the behavior of individual molecules
  - Microscopic (Statistical thermodynamics)
    - concerned within behavior of individual particles (molecules)
    - study average behavior of large groups of individual particles

Thermodynamic

- Thermodynamics: is the branch of natural science concerned with heat and its relation to energy and work. The term of thermodynamics mean thermo and dynamics and thermodynamics have main branch called classical and statistical thermodynamic. A description of any thermodynamic system employs the four laws of thermodynamics that form an axiomatic basis. The first law specifies that energy can be exchanged between physical systems as heat and work. The second law defines the existence of a quantity called entropy, that describes the direction, thermodynamically, that a system can evolve and quantifies the state of order of a system and that can be used to quantify the useful work that can be extracted from the system.

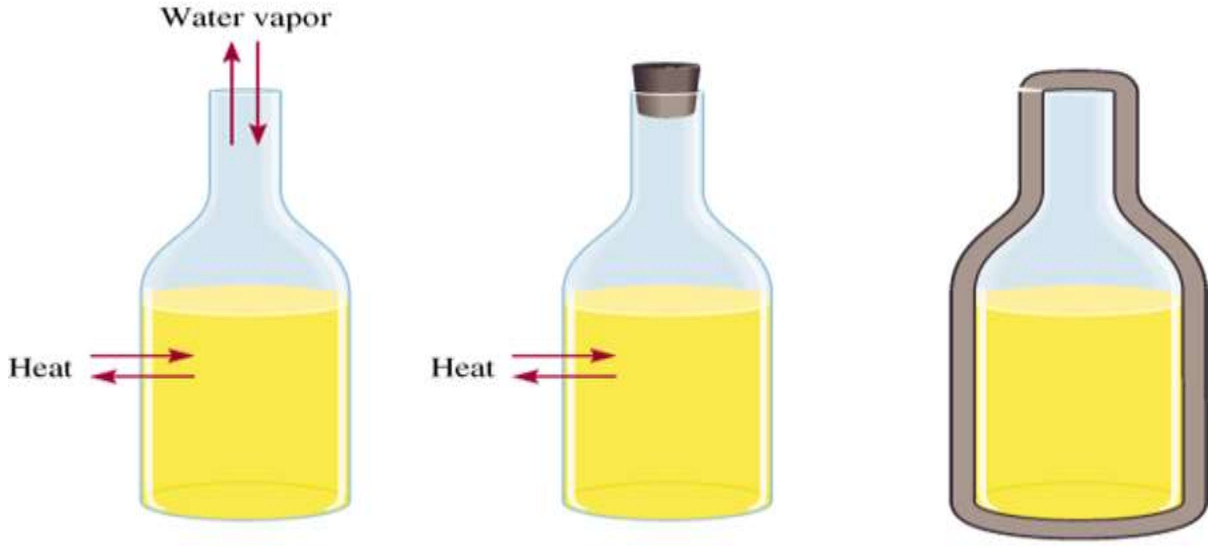
Why we study thermodynamic?

- Thermodynamic studied is useful because it help to:
- 1- Studies the more movement of heat between different objects.
- 2- it studies the change in pressure and volume of objects.
- 3- Enables one to derive relationships that quantitatively describe the nature of the conversion of energy from one into anothe

Introduction to thermodynamics

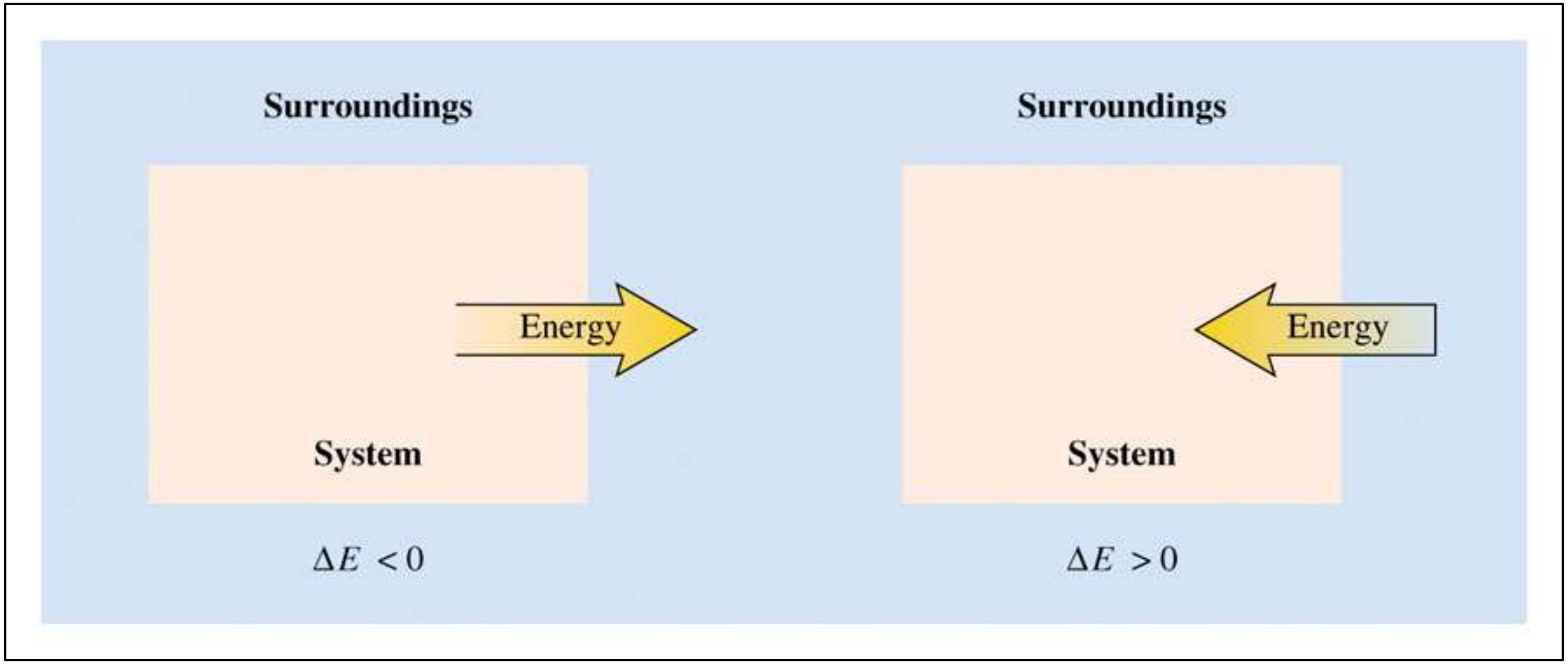
Thermochemistry is part of a broader subject called thermodynamics

The *system* is the specific part of the universe that is of interest in the study.



	open	closed	isolated
Exchange:	mass & energy	energy	nothing

Thermodynamics: Systems and Surroundings



A thermodynamic system is the part of the universe that is under consideration. A boundary separates the system from the rest of the universe, which is called the surroundings. A system can be anything that you wish it to be, for example a piston, and engine, a brick, a solution in a test tube, a cell, an electrical circuit, a planet, etc.

Thermodynamics

- “the branch of science that deals with energy levels and the transfer of energy between systems and between different states of matter”

Temperature

- In thermodynamics, temperature is **always** represented in Kelvins

- K = ºC + 273.15

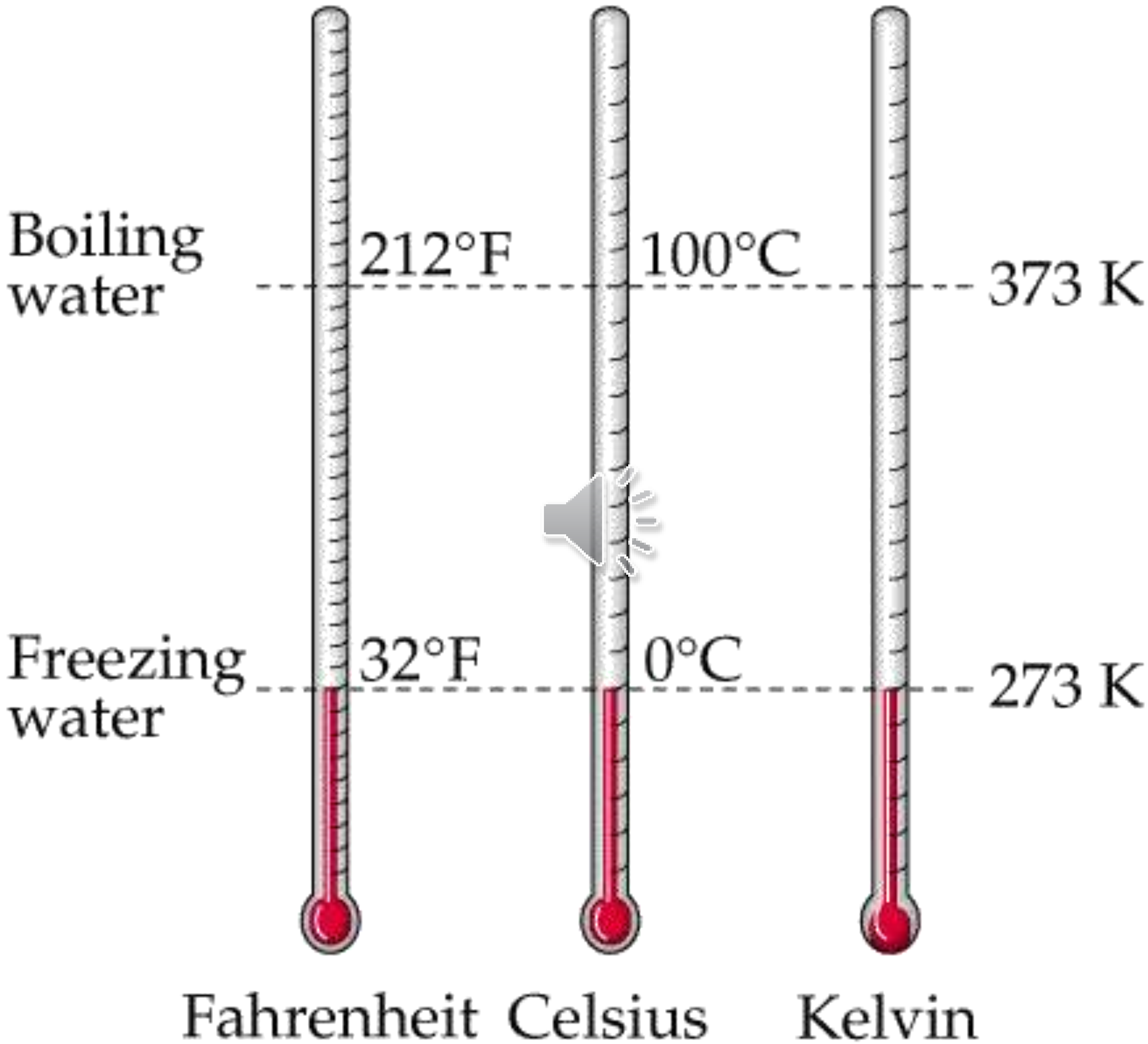
Scales

Temperature normally measured in degrees [º] using one of the following scales:

- Fahrenheit [º**F**].
- Celsius or centigrade[º**C**].
- Kelvin [ºK].

The relationships between the different temperature scales are: -

Celsius to Fahrenheit	$[°F] = [°C] \times {}^{9}/_{5} + 32$
Fahrenheit to Celsius	$[°C] = ([°F] - 32) \times {}^{5}/_{9}$
Celsius to Kelvin	$[K] = [°C] + 273$
Kelvin to Celsius	$[°C] = [K] - 273$



Boiling water
212°F
100°C
373 K
Freezing water
32°F
0°C
273 K
Fahrenheit
Celsius
Kelvin

Heat

- The origin of thermodynamics dealt with heat
- Thermo considers heat, and really ANY energy as though it were an indivisible fluid, always flowing from higher to lower energies
- Ergo → signs are + when energy flows from surroundings to the system and – when energy flows from system to surroundings

Heat (q) and Work (w)

$\Delta E = q + w$

- **q** = Heat absorbed by the system
  - ✓ If $q > 0$, heat is absorbed
  - ✓ If $q < 0$, heat is given off
- **w** = Work done on the system

- Increase the energy of a system by heating it ($q>0$) or by doing work on it ($w>0$).

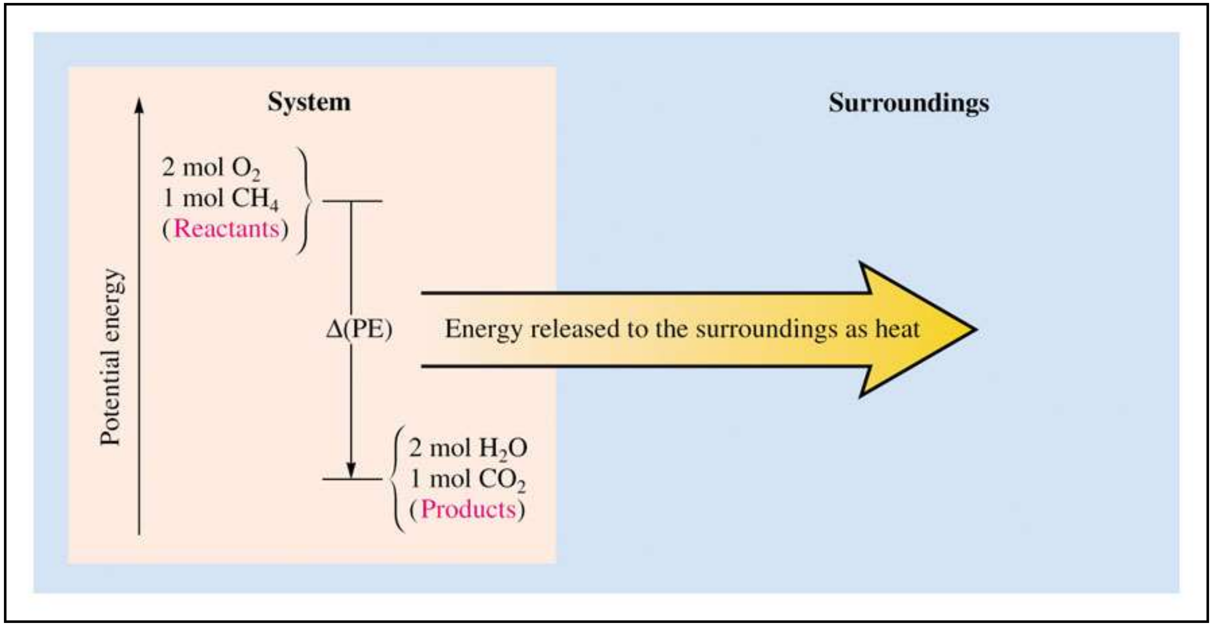
Work

- **w** = Force x distance
  = (Pressure x area) x distance
  = pressure x **$\Delta V = P\Delta V$**

Work is Pressure-Volume work (P-V)

Exothermic reactions release energy to surroundings (by heating the surroundings)

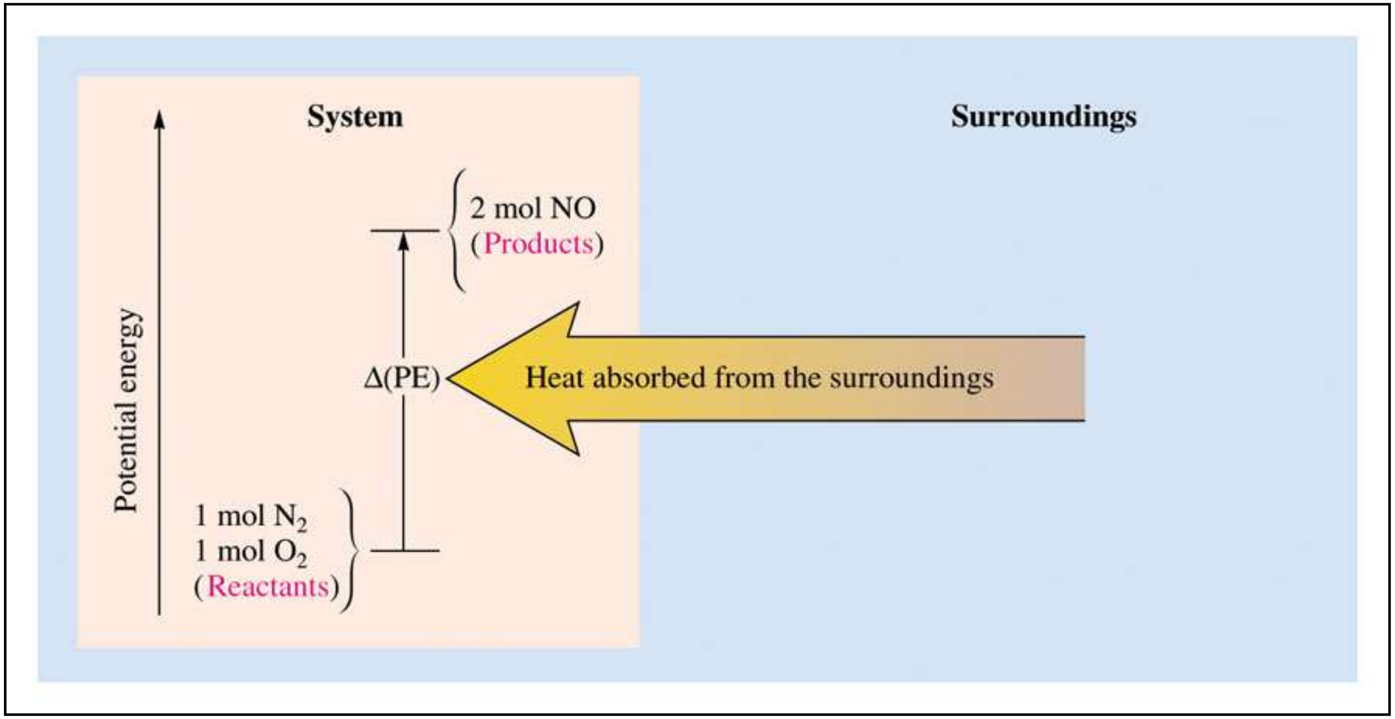
$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (g)$ **+ heat**



In an **exo**thermic process, the energy stored in chemical bonds/molecular interactions is converted to thermal energy (random kinetic energy).

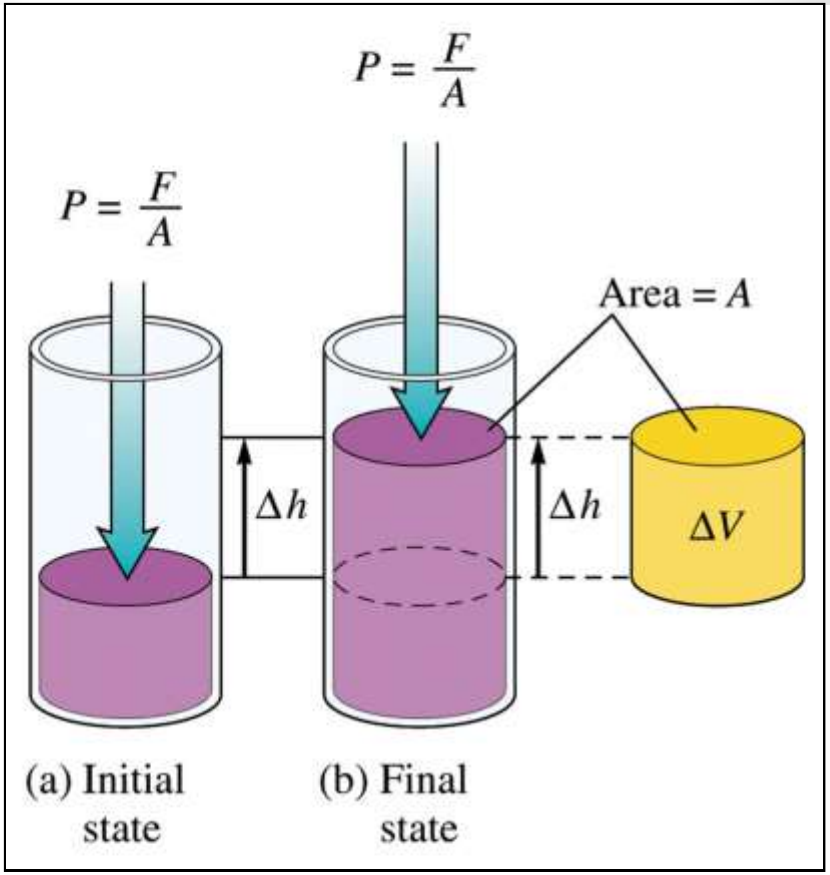
Endothermic reactions absorb energy

$N_2\ (g) + O_2\ (g)$ **+ Energy (heat)** $\rightarrow 2\ NO\ (g)$



An endothermic reaction consumes heat and stores energy in the chemical bonds/molecular interactions of the products.

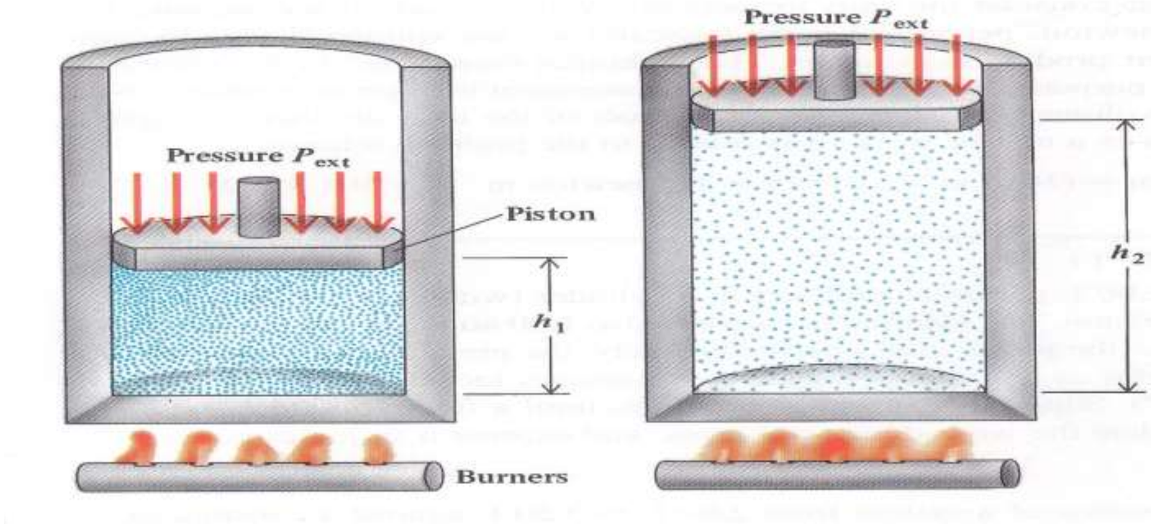
Work



$w = F \times \Delta h$ $\qquad P = F/A$

$P \times A \times \Delta h$ $\qquad \Delta V = A\,\Delta h$

$W = P\,\Delta V$



- Force exerted by heating = P_1A
  - Where P_1 is the pressure inside the vessel
  - Where A is the Area of the piston

$$P_{ext} = P_1 \text{ if balanced}$$

$$w = F \times d = F \times \Delta h = P \times A \times \Delta h$$

$$\Delta V = A\,\Delta h$$

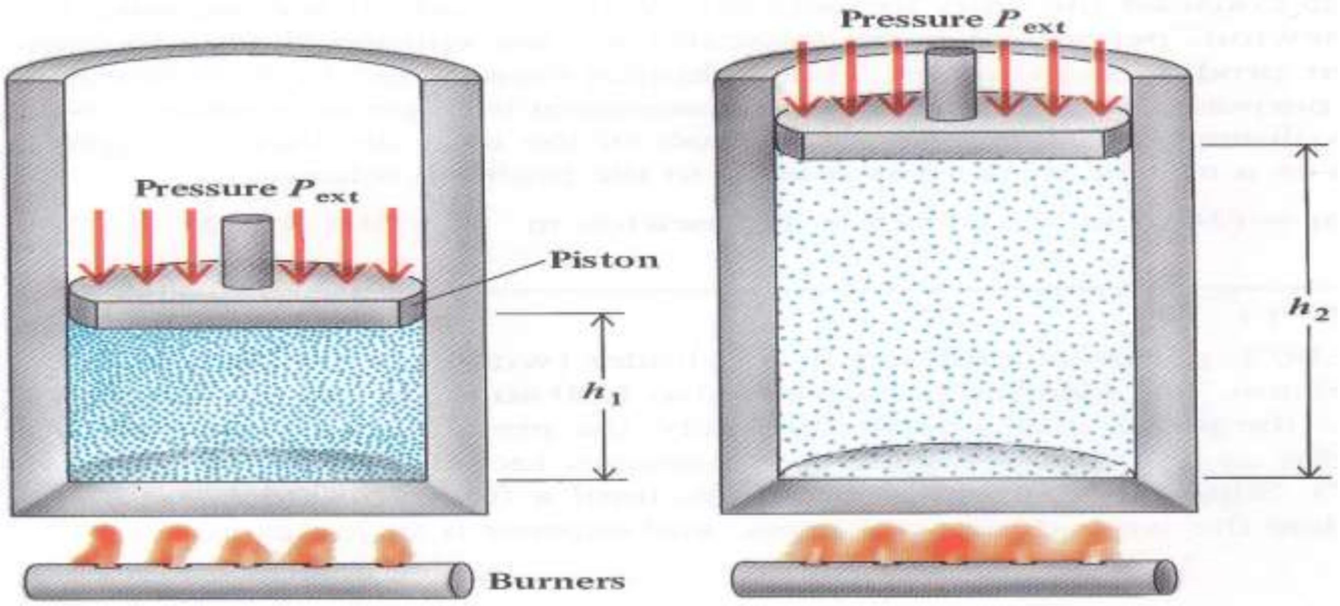
$$w = -P_{ext}\,\Delta V$$

– Units are atm·L or L atm

– **Where 1 L atm = 101.3 Joules**

ratio of Gas law constants

$$= \frac{\frac{8.3145\ \text{J}}{\text{K mol}}}{\frac{0.08206\text{L atm}}{\text{K mol}}} = \frac{101.3\text{J}}{\text{L atm}}$$



- Expansion (w<0)
  - The system does work on the surroundings.

- Compression (w>0)
  - The surroundings do work on the system.

-Energy

- : Energy is defined as the capability to produce an effect. It is important to note that energy can be stored within a system and can be transferred (as heat, for example) from one system to another. In thermodynamic the energy is the amount of work that a thermodynamic system can perform

Energy

- Energy is the capacity to do work.

- **Energy** is a **state property**, which means it depends on the initial and final state, not the path between them.

$$\Delta E = E_{final} - E_{initial}$$

$$\Delta E_{rxn} = E_{products} - E_{reactants}$$

The nature of energy and types of energy

Energy is : *the capacity to do work*

Work " directed energy change resulting from a process "

work = **force** **x** **distance**

Types of energy : . *Radiant energy*

- *Thermal energy*
- *Chemical energy*
- *Nuclear energy*
- *Potential energy*
- *Kinetic energy*

Types of energy

- *Radiant energy* comes from the sun and is earth's primary energy source
- *Thermal energy* is the energy associated with the random motion of atoms and molecules
- *Chemical energy* is the energy stored within the bonds of chemical substances
- *Nuclear energy* is the energy stored within the collection of neutrons and protons in the atom
- *Potential energy* is the energy available by virtue of an object's position
- *Kinetic energy* consists of various types of molecular motion and the movement of electrons within molecules.

Enthalpy

- Heat is a means by which **energy is transferred.**
- For processes carried out at constant pressure, the heat absorbed equals a change in **Enthalpy,** Δ**H**.

$$q_p = \Delta H$$ Enthalpy Change

(p denotes constant pressure)

- **Enthalpy** is a **state property**, which means it depends on its initial and final state, not the path between them.

$$\Delta H = H_{final} - H_{initial}$$

$$\Delta H_{rxn} = H_{products} - H_{reactants}$$

Enthalpy

- $\Delta E = q + w = \Delta H + w$ (at constant P)

- If a chemical reaction occurs in solution with no PV work (no change in V), then w=0 and **$\Delta E = \Delta H$.**

- ΔH for a reaction may be either positive (absorbs heat from surroundings) or negative (disperses heat to the surroundings).

- For a gas phase reaction, where **ΔV** is allowed, then **$\Delta E \neq \Delta H$.**

Phase Changes

Phase changes (are not chemical reactions) but involve enthalpy changes

Melt ice: $H_2O(s) \rightarrow H_2O(l)$ ΔH_{fusion}= + 6 kJ at 0C

ΔH_{fusion} is positive means endothermic (add heat)

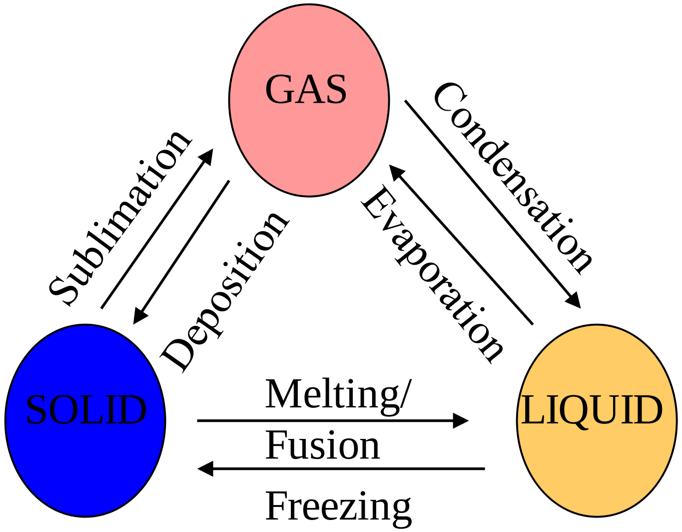
if reversed

$H_2O(l) \rightarrow H_2O(s)$ ΔH_{freeze}= – 6 kJ

$$\Delta H_{freeze} = -\Delta H_{fusion}$$

$$\Delta H_{vaporization} = -\Delta H_{condensation}$$

$$\Delta H_{sublimation} = -\Delta H_{deposition}$$



Thermodynamics Equilibrium

Q: Define thermodynamic equilibrium system

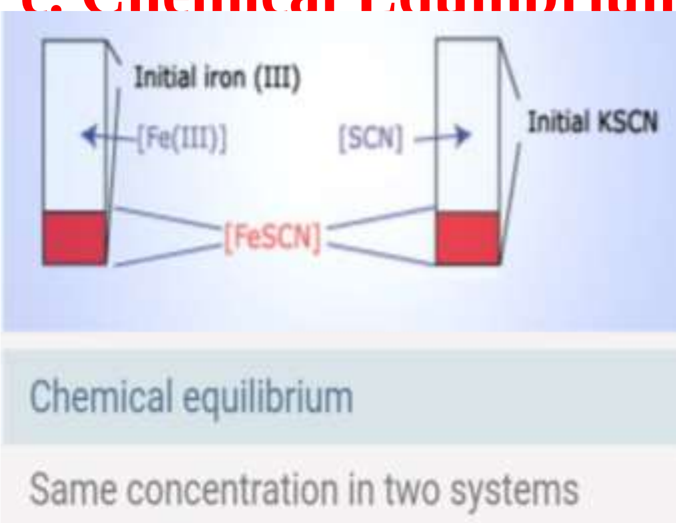
Thermodynamics Equilibrium

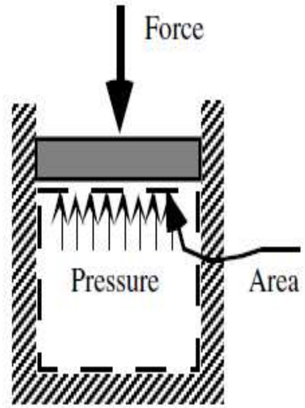
A system is said to be in thermodynamic equilibrium if it maintains

a. **Thermal Equilibrium (Equality of Temperature)**

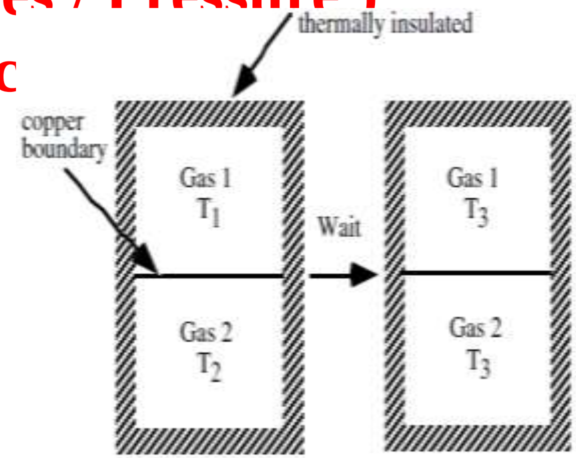
b. Mechanical Equilibrium (Equality of Forces / Pressure)

c. Chemical Equilibrium (... ic





mechanical equilibrium
(force balances pressure times area)



thermal equilibrium
(same temperature)

Thermodynamics Equilibrium types

Between the system and surroundings, if there is no difference in

▪ Pressure	→	Mechanical equilibrium
▪ Potential	→	Electrical equilibrium
▪ Concentration of species	→	Species equilibrium
▪ Temperature	→	Thermal equilibrium

No interactions between them occur.
They are said to be in equilibrium.

Thermodynamic equilibrium implies all those together.
A system in thermodynamic equilibrium does not deliver anything.

Definition Of Temperature and Zeroth Law Of Thermodynamics

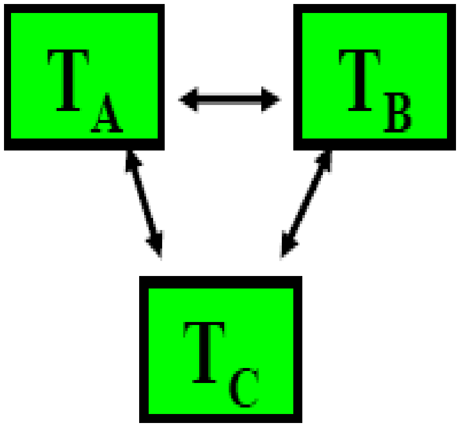
- **Temperature** is a property of a system which determines the degree of hotness.
- Obviously, it is a relative term.

Example g: A hot cup of coffee is at a higher temperature than a block of ice. On the other hand, ***ice is hotter than liquid hydrogen.***

- Two systems are said to be equal in temperature, when there is no change in their respective observable properties when they are brought together. In other words, "when two systems are at the same temperature they are in thermal equilibrium" (They will not exchange heat).

Zeroth Law

If two systems (say A and B) are in therm… equilibrium with a third system (say C) separately (that is A and C are in thermal equilibrium; B and C are in thermal equilibrium) th… in thermal equilibrium them… and B will be in thermal equilil…



Q: State Zeroth law of thermodynamics.

A… B are in thermal equilibrium with a third body C separately, then the two bodies A and B shall also be in thermal equilibrium with each other

Explanation of Zeroth Law

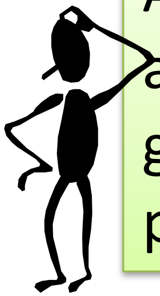
- Let us say T_A,T_B and T_C are the temperatures of A, respectively.
- A and c are in thermal equilibrium. $T_a = t_c$
- B and C are in thermal equilibrium. $T_b = t_c$

Consequence of of '0'th law

- A and B will also be in 29$T_A=T_B$
- Looks very logical
- All temperature measurements are based on this LAW.

Q: How Zeroth law of thermodynamics is applied in thermometry?

hermal equilibrium with a third system separately then two systems are also in thermal equilibrium with each other It provide the basis for the measurement of temperature of a system.



A sample of nitrogen gas expands in volume from 1.6 L to 5.4 L at constant temperature. What is the work done in joules if the gas expands (a) against a vacuum and (b) against a constant pressure of 3.7 atm?

$$w = -P\,\Delta V$$

(a) $\Delta V = 5.4\text{ L} - 1.6\text{ L} = 3.8\text{ L}$ $\qquad P = 0\text{ atm}$

$$W = -0\text{ atm} \times 3.8\text{ L} = 0\text{ L•atm} = 0\text{ joules}$$

(b) $\Delta V = 5.4\text{ L} - 1.6\text{ L} = 3.8\text{ L}$ $\qquad P = 3.7\text{ atm}$

$$w = -3.7\text{ atm} \times 3.8\text{ L} = -14.1\text{ L•atm}$$

$$w = -14.1\text{ L•atm} \times \frac{101.3\text{ J}}{1\text{L•atm}} = -1430\text{ J}$$

References:

1- Thermodynamics, Kinetic theory and Statistical thermodynamics (Sears, Salinger, 3 rd. edition 1976)

2- Thermodynamic demystified (Merle- C. Potter, 2010)

3-Thermodynamics: Fundamentals and its Application in Science, (Ricardo Morales – Rodriguez, 2012).

4- Concept in thermal Physics, (Stephen J. Blundell and Katherime M. Blundell, 2006)

5-Engineering thermodynamics, (Wayne Hacker, 2009)

6- Lecture Notes on thermodynamics , (Joseph M. Power, 2018

Do You Have Any Questions?