

E-Content on Thermodynamics

B.Sc Second Semester

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Thermodynamics

Thermodynamics is the branch of physics which deals with the study of heat into other forms of energy and vice versa. It is the macroscopic science. The state of gas is described by macroscopic variables like pressure, volume, temperature, mass and composition etc.

System & Surrounding

Thermodynamics system is a body of matter or heat that is being subjected to thermodynamic study. Everything else is called its surrounding.

Types of Thermodynamic Systems

1. Open System
2. Closed System
3. Isolated System

Open System It is a thermodynamic system which can exchange energy and matter with its surroundings.

Eg: stem turbine, pool filled with water.

Closed System It is a thermodynamic system which can exchange only energy not the matter with the surroundings.

Eg: Cylinder with its valve closed.

Isolated System It is a thermodynamic system which exchange neither energy nor matter with the surroundings.

Thermodynamic State Variables & Equation of State

State variables of a system are the parameters which describe equilibrium state of the system like pressure P, volume V, temperature T, mass, composition etc.

Equation of state represents the relation between state variables of the system.

$$PV = \mu RT$$

Where μ is the number of moles of a gas and R is gas constant.

Further the thermodynamic variables are of two types.

Extensive and Intensive

Extensive and Intensive variables

Extensive variable change with the size of the system but intensive variable do not change with the size of the system.

Extensive Variable: Volume, charge, area, length, mass, internal energy etc.

Intensive Variable: Pressure, temperature, Density etc.

Thermodynamic Equilibrium

A system which is in thermal, mechanical and chemical equilibrium is said to be in thermodynamic equilibrium.

1. Mechanical Equilibrium- In this case there is no unbalanced forces between systems.
2. Thermal Equilibrium -If temperature in all parts of the system is uniform and same as that of surroundings, then the system is said to be in Thermal Equilibrium.
3. Chemical Equilibrium – If chemical composition of system is same, the system is said to be in chemical Equilibrium.

Thermodynamic Processes

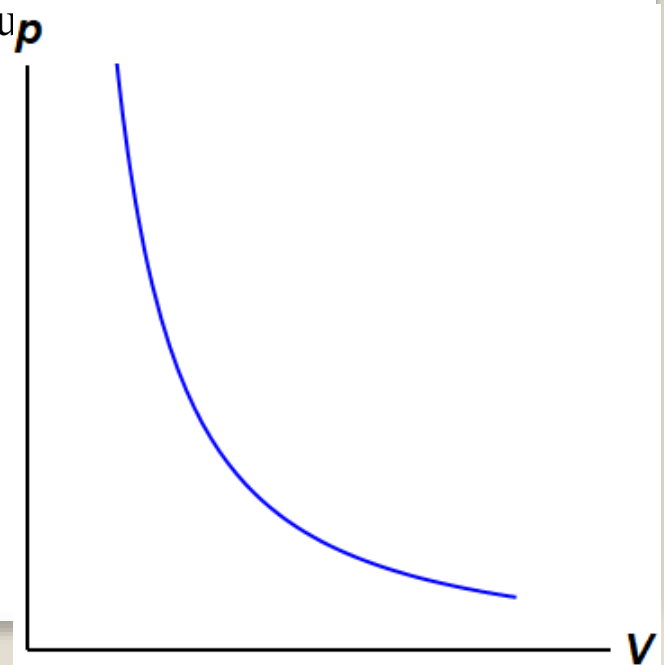
A thermodynamical process is said to take place when some changes occur in the state of a thermodynamic system i.e the thermodynamic parameters of the system changes with time. Some important thermodynamic processes are:

1. **Isothermal Process** : occurs at constant temperature
2. **Adiabatic Process** : in this process no heat leaves or enters the thermodynamic system during the change.
3. **Isobaric Process** : occurs at constant pressure.
4. **Isochoric or Isovolumic Process** : occurs at constant volume

Indicator Diagram OR P-V Diagram

This diagram or P-V diagram represents the variation of volume V of a system with the pressure P of the system.

Volume V is taken along x-axis and pressure is taken along y-axis



Isothermal Process

A change in pressure and volume of a gas without any change in its temperature is called an isothermal change. In this process there is a free exchange of heat between gas and its surroundings.

Example: Melting process is an isothermal change, because temperature of a substance remains constant during melting, Boiling process is also an isothermal process.

Equation of isothermal change : **PV = constant**

In isothermal change $T = \text{constant}$, $\Delta T = 0$

$$\text{As } c = \frac{\Delta Q}{m\Delta T}$$

$$\text{therefore } c = \infty$$

During an isothermal change specific heat of the gas is infinite.

Adiabatic Process

A change in volume and pressure and volume of a gas in which temperature also changes is called an adiabatic process. In this process, no heat is allowed to enter into or leave from the system i.e there is no exchange of heat between the gas and its surroundings.

Example : sudden expansion or compression of gas.

Sudden bursting of the tube of bicycle tyre.

Propagation of sound wave in air and other gases.

Expansion of steam in cylinder of a steam engine.

Equation of Adiabatic change : $PV^\gamma = \text{Constant}$

$$\text{Where } \gamma = \frac{\text{specific heat at constant pressure}}{\text{specific heat at constant volume}}$$

In adiabatic change $\Delta Q = 0$

$$\text{As } c = \frac{\Delta Q}{m\Delta T}$$

$$c = 0$$

Hence in an adiabatic change, specific heat of the system is zero.

Slopes of Isothermal and Adiabatic curves

The slope of adiabatic and isothermal curve is given by $\frac{dP}{dV}$

For an isothermal change, $PV = K$

Differentiating both sides we get $P.dV + V.dP = 0$

$$V.dP = -P.dV$$

$$\frac{dP}{dV} = -\frac{P}{V}$$

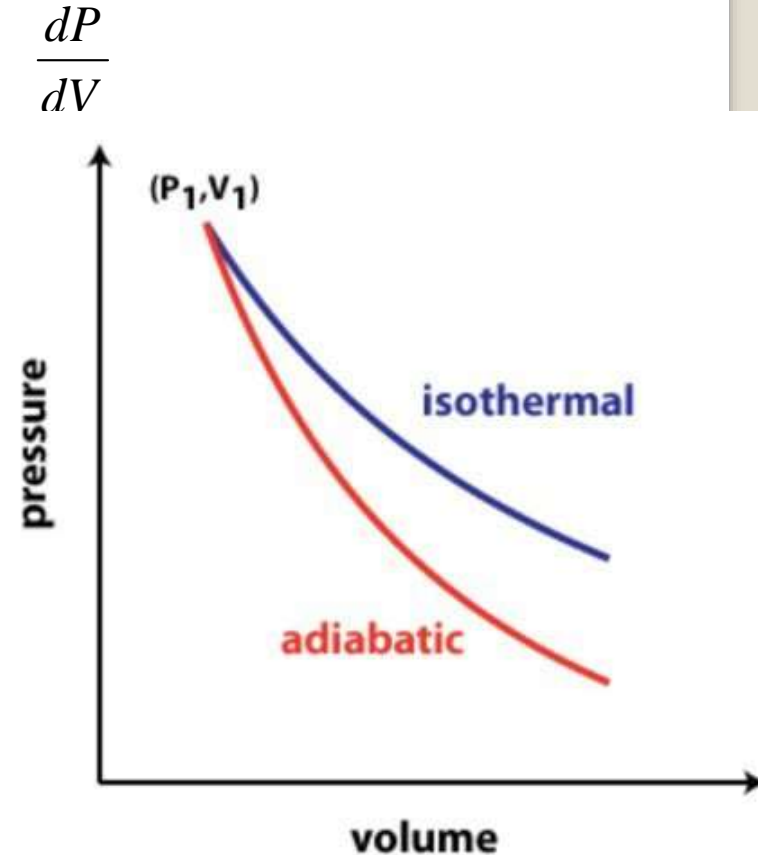
For an Adiabatic change $PV^\gamma = \text{Constant}$

Differentiating both sides we get $P^\gamma V^{\gamma-1} dV + V^\gamma dP = 0$

$$V^\gamma dP = -\gamma P V^{\gamma-1} dV$$

$$\frac{dP}{dV} = -\frac{\gamma P}{V}$$

Slope dP/dV of adiabatic curve is γ time the slope of isothermal curve.



Isochoric And Isobaric Process

In Isochoric process volume V is constant. No work is done on or by the gas. Heat absorbed by the gas goes completely to change its internal energy and its temperature. The change in temperature for a given amount of heat is determined by specific heat of the gas at constant volume.

In an isobaric process, pressure p is fixed, work done by the gas is

$$W = P (V_2 - V_1) = \mu (T_2 - T_1)$$

As the temperature changes, internal energy of the gas also changes.

Internal energy of a system is the total energy possessed by the system due to molecular motion and molecular configuration.

Internal energy of a system is a macroscopic state variable of the system.

Internal energy of a gas can be changed by changing any of the macroscopic state variable of the gas.

Heat and work are two different modes of changing state of a thermodynamic system and hence changing internal energy of the system.

Zeroth Law of Thermodynamics

This law says that, when the thermodynamic systems A and B are separately in thermal equilibrium with a third thermodynamic system C, then the systems A and B are in thermal equilibrium with each other also.

The physical quantity that determines whether or not a given system A is in thermal equilibrium with another system B is called Temperature.

The Zeroth Law of Thermodynamics may be stated as:

There exists a scalar quantity, called temperature, which is the property of all thermodynamic systems, such that equality of temperature is the only condition for the thermodynamic system to be in thermal equilibrium.

Temperature of a body measures the degree of hotness of the body. It determines the direction of flow of heat when two bodies are placed in thermal contact with each other. Heat always flows from a body at higher temperature to a lower temperature. The flow of heat stops as soon as the temperature of the two bodies becomes equal. The two bodies are then said to be in thermal equilibrium.

First Law of Thermodynamics

This law is simply based on the law of conservation of energy. The internal energy U of a system can change through two modes of energy transfer : heat and work

dQ = small amount of heat supplied to the system by the surroundings.

dW = small amount of work done by the system on the surroundings.

dU = small change in internal energy of the system.

So according to the principal of conservation of energy

$$\mathbf{dQ = dU + dW}$$

i.e the energy supplied dQ to the system is spent partially in increasing the internal energy of the system dU and rest in doing work on the surroundings.

When heat is supplied to the system dQ is +ive, when heat is drawn away dQ is -ive

When a gas expands, work is done by the gas, dW is +ive

When a gas is compressed, work is done on the gas, dW is -ive

When temp. of gas increases, internal energy of the gs increases, dU is +ive

When temp. of gas decreases, internal energy of the gas decreases, dU is -ive.

Applications of First Law of Thermodynamics

(a) Isothermal Process

In an isothermal change temperature is constant i.e. $dU = 0$. So, the first law of thermodynamics implies $dQ = dU + dW = 0 + dW$

$$dW = dQ$$

Heat supplied in this process is used entirely to do work against the external surroundings.

(b) Adiabatic Process

In an adiabatic process no heat energy enters or leaves the system i.e. $dQ = 0$

$$dU = -dW$$

When a gas expands adiabatically, dW is +ive. Therefore dU must be -ive i.e. internal energy of the system would decrease and the gas will be cooled. The reverse is also true.

(c) Isovolumic Process

When volume of the system is kept constant $dW = PdV = 0$.

First law implies $dQ = dU$. If heat is absorbed by system at constant volume, its internal energy increases by the same amount and vice-versa.

(d) Cyclic Process

In such process, the system is returned to its initial state after any number of changes.

$$dU = 0$$

The first law implies $dQ = dU + dW$

$$\mathbf{dQ = dW}$$

Net work done during a cyclic process must exactly equal the amount of heat energy transferred.

(e) Melting Process

When a solid melts into liquid, its internal energy increases, which can be calculated from first law of thermodynamics.

Let m = mass of solid, L = latent heat of solid

Amount of heat absorbed during the melting process $dQ = mL$

When a substance melts, the change in its volume dV is very small and so it can be neglected

$$dW = dU + dW$$

$$mL = dU + 0$$

$$\mathbf{dU = mL}$$

**Thank
You**