PHYSICS

CLASS NOTES FOR CBSE

Chapter 13. Thermodynamics

01. Thermal Equilibrium and Temperatur

Two systems are said to be in thermal equilibrium with each other, if they are at the same temperature.

02. Zeroth Law of Thermodynamics

It states that if two systems A and Bare in thermal equilibrium with a third system C, then A and B must be in thermal equilibrium with each other.

03. A Few Definitions

(i) **Thermodynamic System**
An assembly of extremely large number of particles having a certain value of pressure, volume and temperature is called a thermodynamic system. For example, a large collection of gas molecules is a thermodynamic system.

(ii) **Thermodynamic Variables**
The variables which determine the thermodynamic behaviour of a system are called thermodynamic variables. The quantities like pressure (P), volume (V) and temperature (T) are thermodynamic variables. There are some other thermodynamic variables, such as internal energy (U), entropy (S), etc. All other thermodynamic variables can be expressed in terms of P, V and T.

(iii) **Equation of State**
A relation between pressure, volume and temperature for a system is called its equation of state. The state of a system is completely known in terms of its pressure, volume and temperature.
For example, for 1 mole of an ideal gas, the equation of state is

$$PV = RT$$

In a simple system, such as a gas contained in a cylinder, any two variables out of the three variables P, V and T determine the state of the system. The third v ariable can be known by using the equation of state.

(iv) **Thermodynamic process**
A thermodynamic process is said to be taking place, if the thermodynamic variables of the system change with time.
IN practice, the following types of thermodynamic processes can take place :

(a) ***Isothermal Process :*** *A thermodynamic process that takes place at constant temperature is called isothermal process.*
(b) ***Isobaric Process :*** *A thermodynamic process that takes place at constant pressure is called isobaric process.*
(c) ***Isochoric Process :*** *A thermodynamic process that takes place at constant volume is called isochoric process.*
(d) ***Adiabatic Process :*** *A thermodynamic process in which no heat enters or leaves the system is called adiabatic process.*
(e) ***Cyclic Process :*** *A thermodynamic process in which the system returns to its original state is called a cyclic process.*

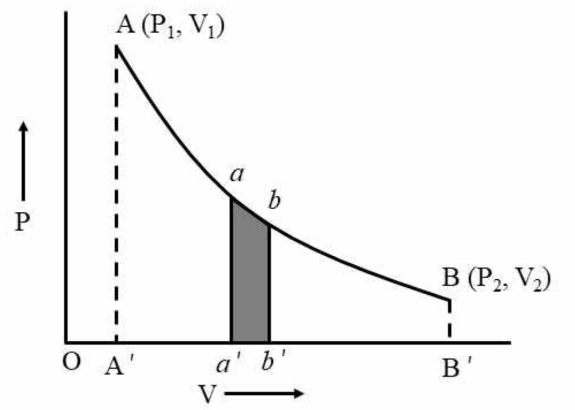
04. Work done during Expansion

Total work done is given by

$$W = \int_{V_1}^{V_2} P\, dV \qquad \text{...(i)}$$

By Indicator Diagram

Suppose that the initial state (P_1, V_1) and the final state (P_2, V_2) of the system are represented by the points A and B on the P-V diagram as shown in fig.



Let a be any point on the indicator diagram and P and V be the values of pressure and volume corresponding to it. Suppose that volume increases to V + dV corresponding to point b on the indicator diagram, such that the pressure remains constant.

Then, $aa' = bb' = P$, the constant pressure on the system

and $a'b' = dV$, increase in volume

Now, small work done during the change of the system form the state a to state b

$$dW = P\,dV = aa' \times a'b'$$

$$= \text{area of the shaded strip } abb'a'$$

The total work done by the gas during expansion from the intial state A (P_1, V_1) to the final state B (P_2, V_2) can be obtained by adding the areas of all strips such as a b b ' a ' formed between AA ' and BB ' under the P-V diagram. Obviously, the total work done will be

$$W = \text{area } ABB'A' \qquad \text{...(ii)}$$

Thus, *work done by a system is numerically equal to the area under the P-V diagram.*

05. First Law of Thermodynamics

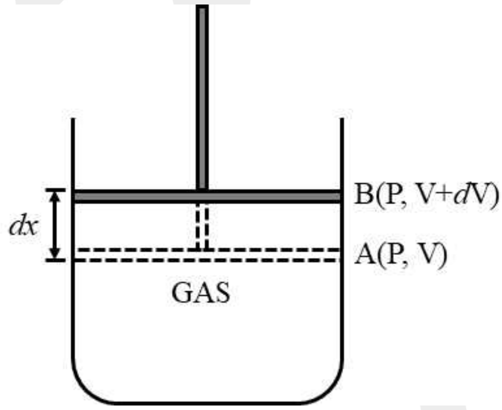
First law of thermodynamics is, in fact, the law of conservation of energy. According to the law of conservation of energy, *the energy can neither be created nor it can be destroyed but can change itself from one form to another.*

The first law of thermodynamics extends this law, so as to include heat energy and internal energy of system.
According to first law of thermodynamics, *if an amount of heat dQ is added to a system, a part of it may increase its internal energy by an amount dU, while the remaining part may be used up as the external work dW done by the system.*
Thus, if dQ, dU and dW all are in same units, then

$$dQ = dU + dW \qquad \text{...(i)}$$

Consider as gas enclosed in a cylinder provided with a frictionless and weightless piston. suppose that corresponding to the initial state A, pressure and volume of the gas are P and V respectively. Further, suppose that the piston moves through an infinitesimally small distance dx at constant pressure P [fig.], so that its volume in the final state B becomes $V + dV$. Then, the small work done,

$$dW = \text{force on piston} \times dx$$



If a is are of cross-section of the piston, then force on the piston will be equal to P a. Therefore,

$$dW = P\,a \times dx = P \times (a\,dx)$$

Now, $a \times dx = dV$, the small increase in volume. Therefore,

$$dW = P\,dV$$

Hence, the equation (i) may be rewritten as

$$dQ = dU + P\,dV \qquad \text{...(ii)}$$

06. Two Specific Heats of a Gas

(i) **Specific Heat of a Gas at Constant Volume**
It is defined as the amount of heat required to raise the temperature of 1 g of a gas through 1°C at constant volume. It is denoted by c_v.