



HEAT- 2

THEORY AND EXERCISE BOOKLET

CONTENTS

S.NO.	ΤΟΡΙϹ	PAGE NO.
1. Concept of a	n Ideal Gas	2
2. Kinetic theor	y of gases	2
3. Pressure of a	ı gas	
4. Gas Law		
5. Maxwell's Dis	tribution Law	12 – 13
6. Degree of Fre	edom	13 – 14
7. Internal Ener	'gy	
8. Thermodynai	nics	16 – 20
9. First Law of t	hermodynamics	21 – 24
10. Specific He	at	24 – 29
11. Exercise -I		30 – 61
12. Exercise - I	I	62 – 68
13. Exercise - I	II	69 – 79



1. CONCEPT OF AN IDEAL GAS

A gas has no shape and size and can be contained in a vessel of any size or shape. It expands indefinitely and uniformly to fill the available space. It exerts pressure on its surroundings.

The gases whose molecules are point massses (mass without volume) and do not attract each other are called **ideal** or **perfect** gases. It is a hypothetical concept which can't exist in reality. The gases such as hydrogen, oxygen or helium which cannot be liquified easily are called **permanent gases.** An actual gas behaves as ideal gas most closely at low pressure and high temperature.

1.1 Ideal gas Equation

According to this equation.

$$PV = nRT = \frac{m}{M}RT$$

In this equation n = number of moles of the gas = $\frac{m}{M}$

m = total mass of the gas.

M = molecular mass of the gas

R = Universal gas constant

= 8.31 J/mol-K

= 2.0 cal/mol- K

2. KINETIC THEORY OF GASES

Kinetic Theory of gases is based on the following basic assumptions.

- (a) A gas consists of very large number of molecules. These molecules are identical, perfectly elastic and hard spheres. They are so small that the volume of molecules is negligible as compared with the volume of the gas.
- (b) Molecules do not have any preferred direction of motion, motion is completely random.
- (c) These molecules travel in straight lines and in free motion most of the time. The time of the collision between any two molecules is very small.
- (d) The collision between molecules and the wall of the container is perfectly elastic. It means kinetic energy is conserved in each collision.
- (e) The path travelled by a molecule between two collisions is called free path and the mean of this distance travelled by a molecule is called mean free path.
- (f) The motion of molecules is governed by Newton's law of motion
- (g) The effect of gravity on the motion of molecules is negligible.

Note :

At higher temperature and low pressure or at higher temperature and low density, a real gas behaves as an ideal gas.

3. EXPRESSION FOR THE PRESSURE OF A GAS :

Let us suppose that a gas is enclosed in a cubical box having length ℓ . Let there are 'N' identical molecules, each having mass 'm'. Since the molecules are of same mass and perfectly elastic, so their mutual collisions result in the interchange of velocities only. Only collisions with the walls of the container contribute to the pressure by the gas molecules. Let us focus on a molecule having velocity v_1 and components of velocity v_{X_1} , v_{y_1} , v_{z_1} along x, y and z-axis as shown in figure.



```
Motion Comparison
```

$$v_1^{\ 2} = v_{x_1}^2 + v_{y_1}^2 + v_{z_1}^2$$

The change in momentum of the molecule after one collision with wall BCHE

$$= m v_{x_1} - (-m v_{x_1}) = 2 m v_{x_1}.$$

The time taken between the successive impacts on the face BCHE = $\frac{\text{distance}}{\text{velocity}} = \frac{2\ell}{v_{x_1}}$

Time rate of change of momentum due to collision = $\frac{\text{change in momentum}}{\text{time taken}} = \frac{2\text{mv}_{x_1}}{2\ell/\text{v}_{x_1}} = \frac{\text{mv}_{x_1}^2}{\ell}$

Hence the net force on the wall BCHE due to the impact of n N molecules of the gas is :

$$F_{x} = \frac{mv_{x_{1}}^{2}}{\ell} + \frac{mv_{x_{2}}^{2}}{\ell} + \frac{mv_{x_{3}}^{2}}{\ell} + \dots \dots \frac{mv_{x_{n}}^{2}}{\ell} = \frac{m}{\ell} \Big(v_{x_{1}}^{2} + v_{x_{2}}^{2} + v_{x_{3}}^{2} + \dots + v_{x_{n}}^{2} \Big) = \frac{mN}{\ell} < v_{x}^{2} > \dots + v_{x_{n}}^{2} \Big)$$

where $\langle v_x^2 \rangle =$ mean square velocity in x-direction. Since molecules do not favour any particular direction therefore $\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle$. But $\langle v^2 \rangle = \langle v_x^2 \rangle + \langle v_y^2 \rangle + \langle v_z^2 \rangle$

$$\Rightarrow \langle v_x^2 \rangle = \frac{\langle v^2 \rangle}{3}$$
. Pressure is equal to force divided by area.

$$P = \frac{F_x}{\ell^2} = \frac{M}{3\ell^3} \langle v^2 \rangle = \frac{M}{3V} \langle v^2 \rangle$$
. Pressure is independent of x, y, z directions where ℓ^3 = volume of the container = V

M = total mass of the gas, $\langle v^2 \rangle$ = mean square velocity of molecules

$$\Rightarrow \mathbf{P} = \frac{1}{3}\rho < \mathbf{v}^2 >$$

from PV = nRT

$$\begin{array}{l} \because n = \frac{Mass}{Molecular Weight} = \frac{M}{M_0} \mbox{ (in kg/mole)} \\ P = \frac{M}{M_0 V} RT = \frac{\rho RT}{M_0} \Rightarrow \frac{\rho RT}{M_0} = \frac{1}{3} \rho V_{rms}^2 \Rightarrow V_{rms} = \sqrt{\frac{3RT}{M_0}} \\ V_{rms} = \sqrt{\frac{3RT}{M_0}} = \sqrt{\frac{3RT}{mN_A}} = \sqrt{\frac{3Kt}{m}} \\ K = Boltzman's const. = \frac{R}{N_A} \end{array}$$

3.1 Co-ordinate of the gases

(P, V, T) is the coordinate of the gas

If initial condition of gas is given by $(P_1 V_1 T_1)$ and final condition of gas is given by $(P_2, V_2 T_2)$ such as

 $(\mathsf{P}_1 \mathsf{V}_1 \mathsf{T}_1) \Rightarrow (\mathsf{P}_2 \mathsf{V}_2 \mathsf{T}_2)$

Then (P, V, T) define situation of gas. When a gas changes from one coordinate system to another co-ordinate system, then we have to follow a process.

4. GAS LAWS

Assuming permanent gases to be ideal, through experiments, it was established that gases irrespective of their nature obey the following laws :





4.1 Boyle's Law

According to this law, for a given mass of a gas the volume of a gas at constant temperature (called **isothermal** process) is inversely proportional to its pressure, i.e.,

 $\begin{array}{ccc} V \propto \frac{1}{P} & (T = constant) \\ \text{or} & PV = constant \\ \text{or} & P_i V_i = P_f V_f \end{array}$ Thus, P - V graph in an isothermal process is a rectangular hyperbola. Or PV versus P or V graph is a straight line parallel to P or V axis.



4.2 Charle's law

According to this law, for a given mass of a gas the volume of a gas at constant pressure (called) **isobaric** process) is directly proportional to its absolute temperature, i.e.,



Thus, V – T graph in an isobaric process is a straight line passing through origin. Or V/T versus V or T graph is a straight line parallel to V or T axis.



4.3 Gay Lussac's Law or Pressure law

According to this law, for a given mass of a gas the pressure of a gas at constant volume (called **isochoric** process) is directly proportional to its absolute temperature i.e.,



Thus, P - T graph in an isochoric process is a straight line passing through origin or P/T versus P or T graph is a straight line parallel to P or T axis.



MOTION Surfuring potential through education Surfuring potential through education



4.4 Avogadro's Law

Two gases at same volume pressure and temperature contain equal amount of moles (mass of gas may be different) or we can say contain equal no. of particle. 1 mole = 6.023×10^{-23} Particles

4.5 Reading of P-V diagram



h Motion Constanting

Ť

Ť

А

≻Τ



Find out the values of co-ordinates at point A, B, C in terms of pressure , volume and temperature and draw curve.

	394,50 - Rajeev Gandhi Nagar Kota, Ph. No. : 93141-87482, 0744-2209671	
Nurturing potential through education	IVRS No: 0744-2439051, 52, 53, www. motioniitjee.com, info@motioniitjee.com	





Ex.3 Find out the values of co-ordinates at point A, B, C in terms of pressure , volume and temperature and draw curve.







 $C \rightarrow A$ Pressure Const (Isobaric) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$



Ex.4 Find out the values of co-ordinates at point A, B, C in terms of pressure , volume and temperature and draw curve.

Sol. $A \rightarrow B$ $P_1V_1 = P_2V_2$ $2P_0V_0 = 2V_0P_2$

$$\Rightarrow \qquad \mathsf{P}_2 = \frac{\mathsf{P}_0}{2}$$

 $B \rightarrow C$ volume constant (Isochoric) $\frac{P_B}{T_B} = \frac{P_C}{T_C}$

$$\Rightarrow \qquad \frac{P_0}{2T_0} = \frac{P_C}{2T_0} \qquad \Rightarrow \qquad P_C = P_0$$





Note : SOME COMMONLY USED TERM





finally pressure on both side is same then it doesn't move (massless)

Ex.5 If the temperature of the increases slowly from T_0 to $2T_0$ then how much piston will move ?







 $x\ \text{cm}$ of Hg pressure means if we placed a straight tube vertically in vaccum. fill the tube with Hg upto $x\ \text{in}$ of height.

Then the pressure exerted by Hg at the bottom of the tube is equals to pressure of the gas.

Ex.7 Find the new length of gas column in tube if tube is inverted (Assume temperature is constant)





Ex.9

Sol. Initially :

 $\begin{array}{l} \mathsf{P}_{\mathsf{gas}} + 10 = 75 \; \Rightarrow \; \mathsf{P}_{\mathsf{gas}} = 65 \\ \text{Finally} \\ 75 + 10 = \mathsf{P}_{\mathsf{gas}} \Rightarrow \; \mathsf{P}_{\mathsf{gas}} = 85 \; \text{cm} \\ \mathsf{P}_1 \mathsf{V}_1 = \mathsf{P}_2 \mathsf{V}_2 \end{array}$

 $85 \times A \times \ell = 65 \times 30 \times A \implies \ell = \frac{1950}{85}$

Ex.8 Find the new length of gas column in tube if tube is rotated at an angle 60° as shown. (Assume constant temperature)





Assume constant temperature if the tube is changed to vertical position and the pallet comes down by 5 cm then find out P_{o} .

Sol. For upper part $P_1V_1 = P_0V_0$ $P_1 35 A = P_0 30 A$ 30+5 Α $P_1 = \frac{30}{35}P_0$...(i) 5 For lower part $P_2V_2 = P_0V_0$ $P_0 30 A = P_2 25 A$ 40 30-5 = 25 $P_2 = \frac{30}{25}P_0$...(ii) В Again $P_1 + 40 = P_2$...(iii) From (i) and (ii) $\frac{30}{35}P_0 + 40 = \frac{30}{25}P_0$



PRESSURE VARIATION IN ATMOSPHERE.

Assuming temp. to be const.



5. MAXWELL'S DISTRIBUTION LAW

Distribution Curve – A plot of $\frac{dN(v)}{dv}$ (number of molecules per unit speed interval) against c is known as Maxwell's distribution curve. The total area under the curve is given by the

integral
$$\int_{0}^{\infty} \frac{dN(v)}{dv} dv = \int_{0}^{\infty} dN(v) = N$$

[Note : - The actual formula of $\frac{dN(v)}{dv}$ is not in JEE syllabus.]

Figure shows the distribution curves for two different temperatures. At any temperature the number of molecules in a given speed interval dv is given by the area under the curve in that interval (shown shaded). This number increases, as the speed increases, upto a maximum and then decreases asymptotically toward zero. Thus, maximum number of the molecules have speed lying within a small range centered about the speed corresponding the peak (A) of the curve. This speed is called the 'most probable speed' v_p or v_{mp} .





The distribution curve is asymmetrical about its peak (the most probable speed v_p) because the lowest possible speed is zero, whereas there is no limit to the upper speed a molecule can

attain. Therefore, the average speed \overline{v} is slightly larger than the most probable speed v_n .

The root-mean-square speed, v_{rms} , is still larger $/(v_{rms} > \overline{v} > v_p)$. Average (or Mean) Speed :

$$\overline{v} = \sqrt{\frac{8}{\pi} \frac{RT}{M_0}} = \sqrt{\frac{8RT}{\pi M_0}} = 1.59 \sqrt{kT/m}$$

(derivation is not in the course)

RMS Speed :

$$v_{rms} = \sqrt{(v^2)} = \sqrt{\frac{3RT}{M_0}} = \sqrt{\frac{3kT}{m}} = 1.73 \sqrt{\frac{kT}{m}}$$

Most Probable Speed :

The most probable speed v_p or v_{mp} is the speed possessed by the maximum number of molecules, and corresponds to the maximum (peak) of the distribution curve. Mathematically, it is obtained by the condition.

 $\frac{dN(v)}{dv} = 0$ [by substitution of formula of dN(v) (which is not in the course)]

Hence the most probable speed is

$$v_p = \sqrt{\frac{2kT}{m}} = \sqrt{\frac{2RT}{M_0}}$$

From the above expression, we can see that

 $\mathbf{v}_{rms} > \overline{\mathbf{v}} < \mathbf{v}_{p}$. R = 8.314 J/mole k = Boltzmann counstant (k = 1.38 × 10⁻²³JK⁻¹)

6. DEGREE OF FREEDOM

Total number of independent co-ordinates which must be known to completely specify the position and configuration of dynamical system is known as "degree of freedom f". Maximum

possible translational degrees of freedom are three i.e. $\left(\frac{1}{2}mV_x^2 + \frac{1}{2}mV_y^2 + \frac{1}{2}mV_z^2\right)$

Maximum possible rotational degrees of freedom are three i.e. $\left(\frac{1}{2}I_x\omega_x^2 + \frac{1}{2}I_y\omega_y^2 + \frac{1}{2}I_z\omega_z^2\right)$

Vibrational degrees of freedom are two i.e. (Kinetic energy. of vibration and Potential energy of vibration)

 $\begin{array}{l} \mbox{Monoatonic} \\ \mbox{Eg}: (all inrent gases, He, Ar, etc.) \\ f = 3 \qquad (translational) \\ (V_{x'}, V_{y'}, V_Z) \end{array}$





Energy of one particle = $\frac{t}{2}$ KT, one mole = $\frac{t}{2}$ RT, n mole = $\frac{t}{2}$ nRT

Internal energy of a gas only dipends on the temperature of the gas desn't depend on the process taken by the gas to reach the tempreature.



7. INTERNAL ENERGY

The internal energy of a system is the sun of kinetic and potential energies of the molecules of the system. It is denoted by U. Internal energy (U) of the system is the function of its absolute temperature (T) and its volume (V). i.e. U = f(T, V)

In case of an ideal gas, intermolecular force is zero. Hence its potential energy is also zero. In this case, the internal energy is only due to kinetic energy. Which depends on the absolute

temperature of the gas. i.e. U = f(T). For an ideal gas internal energy U = $\frac{f}{2}$ nRT.

*Ex.*10 A light container having a diatomic gas enclosed with in is moving with velocity v. Mass of the gas is M and number of moles is n.



(i) What is the kinetic energy of gas w.r.t centre of mass of the system?(ii) What is K.E. of gas w.r.t ground?

Sol. (i) K.E. = $\frac{5}{2}$ nRT

(ii) Kinetic energy of gas w.r.t ground = Kinetic energy of centre of mass w.r.t ground + Kinetic energy of gas w.r.t center of mass.

K.E. =
$$\frac{1}{2}Mv^2 + \frac{5}{2}nRT$$

Ex.11 Two nonconducting containers having volume V_1 and V_2 contain monoatomic and dimatomic gases respectively. They are containers are P_1 , T_1 and P_2 , T_2 respectively. Initially stop cock is closed, if the stop cock is opened find the final pressure and temperature.



Sol. $n_1 = \frac{P_1V_1}{RT_1}$ $n_2 = \frac{P_2V_2}{RT_2}$

 $n = n_1 + n_2$ (number of moles are conserved) Finally pressure in both parts & temperature of the both the gases will be become equal.

$$\frac{P(V_1 + V_2)}{RT} = \frac{P_1V_1}{RT_1} + \frac{P_2V_2}{RT_2}$$

From energy conservation

$$\begin{split} &\frac{3}{2}n_1RT_1 + \frac{5}{2}n_2RT_2 = \frac{3}{2}n_1RT + \frac{5}{2}n_2RT \\ &\Rightarrow T = \frac{(3P_1V_1 + 5P_2V_2)T_1T_2}{3P_1V_1T_2 + 5P_2V_2T_1} \\ &P = \left(\frac{3P_1V_1 + 5P_2V_2}{3P_1V_1T_2 + 5P_2V_2T_1}\right) \left(\frac{P_1V_1T_2 + P_2V_2T_2}{V_1 + V_2}\right) \end{split}$$





8. THERMODYNAMICS

Thermodynamics is mainly the study of exchange of heat energy between bodies and conversion of the same into mechanical energy and vice versa.

Thermodynamic System

Collection of an extremely large number of atoms or molecules confined within certain boundaries such that it has a certain value of pressure (P),volume (V) and temperature (T) is called a thermodynamic system. Anything outside the thermodynamic system to which energy or matter is exchanged is called its surroundings. Taking into consideration the interaction between a system and its surroundings thermodynamic system is divided into three classes :

(a) **Open system :** A system is said to be an open system if it can exchange both energy and matter with its surroundings.

(b) Closed system : A system is said to be closed system if it can exchange only energy (not matter with its surrounding

(c) **Isolated system :** A system is said to be isolated if it can neither exchange energy nor matter with its surroundings.

Zeroth law of Thermodynamics :

If two systems (B and C) are separately in thermal equilirbrium with a third one (A), then they the mselves are in thermal equilibrium with each other.



Equation of State (for ideal gases) :

The relation between the thermodynamic variables (P, V, T) of the system is called equation of state. The equation of state for an ideal gas of n moles is given by

$$PV = nRT$$
,

Work done by a gas :

Let P and V be the pressure and volume of the gas. If A be the area of the piston. then force exerted by gas on the piston is, $F = P \times A$

Let the piston move through a small distance dx during the expansion of the gas. Work done for a small displacement dx is dW = F dx = PA dx

Since A dx = dV, increase in volume of the gas is dV \Rightarrow dW = P dV



Area enclosed under P-V curve gives work done during process





DIFFERENT TYPES OF PROCESSES

(a) Isothermal Process :

T = constant [Boyle's law applicable] **PV = constant**



There is exchange of heat between system and surroundings. System should be compressed or expanded very slowly so that there is sufficient time for exchange of heat to keep the temperature constant.

Slope of P-V curve in isothermal process :

PV = constant = C

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

Work done in isothermal process :



Internal energy in isothermal process : $U = f(T) \Rightarrow \Delta U = 0$

(b) Iso-Choric Process (Isometric Process) :

 $V = constant \Rightarrow Change in volume is zero$

$$\frac{P}{T}$$
 is constant

$$\frac{P}{T}$$
 = const. (Galussac-law)

Work done in isochoric process :

Since change in volume is zero therefore

dW = p dV = 0

 \Rightarrow

Indicator diagram of isochoric process :



$$\Delta U = n \frac{f}{2} R \ \Delta T$$



Heat given in isochoric process :

$$\Delta Q = \Delta U = n \frac{f}{2} R \Delta T$$

(c) Isobaric Process : Pressure remains constant in isobaric process

$$\therefore$$
 P = constant \Rightarrow $\frac{V}{T}$ = constant

Indicator diagram of isobaric process :



 $\Delta W = P \ \Delta V = P \ (V_{final} - V_{initial}) = nR(T_{final} - T_{initial})$ Change in internal energy in isobaric process :

$$\Delta U = n \frac{f}{2} R \Delta T$$

Heat given in isobaric process : $\Delta Q = \Delta U + \Delta W$

$$\Delta Q = n \frac{f}{2} R \Delta T + P[V_f - V_i] = n \frac{f}{2} R \Delta T + n R \Delta T$$

Above expression gives an idea that to increase temperature by ΔT in isobaric process heat required is more than in isochoric process.

(d) Cyclic Process :

In the cyclic process initial and final states are same therefore initial state = final state Work done = Area enclosed under P-V diagram.

Change in internal Energy $\Delta U = 0$

 $\Delta \mathsf{Q} = \Delta \mathsf{U} + \Delta \mathsf{W}$

 $\therefore \qquad \Delta \mathsf{Q} = \Delta \mathsf{W}$

If the process on P-V curve is clockwise, then net work done is (+ve) and vice-versa. The graphs shown below explains when work is positive and when it is negative



Ex.13 The cylinder shown in the figure has conducting walls and temperature of the surrounding is T, the pistion is initially in equilibrium, the cylinder contains n moles of a gas. Now the piston is displaced slowly by an external agent to make the volume double of the initial. Find work done by external agent in terms of n, R, T.



Sol. 1st Method :

Work done by external agent is positive, because F_{ext} and displacement are in the same direction. Since walls are conducting therefore temperature remains constant. Applying equilibrium condition when pressure of the gas is P

$$\begin{array}{|c|c|} \hline PA & \longleftarrow P_{atm}A \\ \hline \hline F_{ext} \end{array}$$

$$PA + F_{ext} = P_{atm}A$$

$$F_{ext} = P_{atm} A - PA$$

$$W_{ext} = \int_{0}^{d} F_{ext} dx = \int_{0}^{d} P_{atm} A dx - \int_{0}^{d} PA dx = P_{atm}A \int_{0}^{d} dx - \int_{V}^{2V} \frac{nRT}{V} dV = P_{atm} A d - nRT \ln 2$$

2nd Method

Applying work energy theorem on the piston

$$\begin{split} \Delta k &= 0 \\ W_{all} &= \Delta k \\ W_{gas} &+ W_{atm} + W_{ext} = 0 \\ nRT & ln \frac{V_{f}}{V_{i}} - nRT + W_{ext} = \\ W_{ext} &= nRT (1 - ln2) \end{split}$$

Ex.14 A nonconducting piston of mass m and area of cross section A is placed on a nonconducting cylinder as shown in figure. Temperature, spring constant, height of the piston are given by T, K, h respectively. Initially spring is relaxed and piston is at rest. Find (i) Number of moles

0



- (ii) Work done by gas to displace the piston by distance d when the gas is heated slowly.
- (iii) Find the final temperature

Sol. (i)
$$PV = nRT \Rightarrow \left(P_{atm} + \frac{mg}{A}\right)Ah = nRT \Rightarrow n = \frac{\left(P_{atm} + \frac{mg}{A}\right)Ah}{RT}$$

 $mg + P_{atm} A + Kx = P_{aas} A$ $W_{gas} = \int_{0}^{d} P_{g} A dx = \int_{0}^{d} (mg + P_{atm}A + Kx) dx$

$$dx \uparrow \square P_{gas}A$$

$$\Rightarrow \qquad W_{gas} = mgd + P_{atm}dA + \frac{1}{2}Kd^{2}$$

Applying newton's law on the piston

2nd method

(ii) 1st method

Applying work energy theorem on the pistion $W_{all} = \Delta KE$

Since piston moves slowly therefore $\Delta KE = 0$ $W_{gravity} + W_{gas} + W_{atm} + W_{spring} = 0$

$$- mgd + W_{gas} + (-P_{atm}Ad) + [-(\frac{1}{2}Kd^2 - 0)] = 0$$

$$\Rightarrow W_{gas} = mgd + P_{atm}dA + \frac{1}{2}Kd^{2}$$



*Ex.*15 Find out the work done in the given graph. Also draw the corresponding T-V curve and P-T curve.

Sol. Since in P-V curves area under the cycle is equal to work done therefore work done by the gas is equal to P_0V_0 .

Line AB and CD are isochoric line, line BC and DA are isobaric line. the T-V curve and P-T curve are drawn as shown.



Ex.16 *T-V curve of cyclic process is shown below, number of moles of the gas n find the total work done during the cycle.*

Sol. Since path AB and CD are isochoric therefore work done is zero during path AB and CD. Process BC and DA are isothermal, therefore

$$W_{BC} = nR2T_{0} \ln \frac{V_{C}}{V_{B}} = 2nRT_{0} \ln 2$$
$$W_{DA} = nRT_{0} \ln \frac{V_{A}}{V_{D}} = -nRT_{0} \ln 2$$

Total work done = $W_{BC} + W_{DA}$ = $2nRT_0 \ln 2 - nRT_0 \ln 2$ = $nRT_0 \ln 2$





Ex.17 *P-T curve of a cyclic process is shown. Find out the work done by the gas in the given process if number of moles of the gas are n.*

- **Sol.** Since path AB and CD are isochoric therefore work done during AB and CD is zero. Path BC and DA ar isobaric. Hence $W_{BC} = nR\Delta T = nR(T_3 - T_2)$ $W_{DA} = nR(T_1 - T_4)$ Total work done = $W_{BC} + W_{DA} = nR(T_1 + T_3 - T_4 - T_2)$
- *Ex.18* Consider the cyclic process ABCA on a sample of 2.0 mol of an ideal gas as shown in figure. The temperatures of the gas at A and B are 300 K and 500 K respectively. A total of 1200 J heat is withdrawn from the sample in the process. Find the work done by the gas in part BC. Take R = 8.3 J/mol-K.

Sol. The change in internal energy during the cyclic process is zero. Hence, the heat supplied to the gas is equal to the work done by it. Hence, $W_{AB} + W_{BC} + W_{CA} = -1200 \text{ J.} \dots (i)$ The work done during the process AB is $W_{AB} = P_A(V_B - V_A)$ $= nR(T_B - T_A)$ = (2.0 mol) (8.3 J/mol-K) (200 K) = 3320 J



The work done by the gas during the process CA is zero as the volume remains constant. From (i)

or
$$\begin{array}{c} 3320 \text{ J} + \text{W}_{\text{BC}} = -1200 \text{ J} \\ \text{W}_{\text{BC}} = -4520 \text{ J} \\ = -4520 \text{ J} \end{array}$$

Signature
Motion
Introduction394,50 - Rajeev Gandhi Nagar Kota, Ph. No. : 93141-87482, 0744-2209671
IVRS No : 0744-2439051, 52, 53, www. motioniitjee.com, info@motioniitjee.com



HEAT-2



9. FIRST LAW OF THERMODYNAMICS

The first law of thermodynamics is the law of conservation of energy. It states that if a system absorbs heat dQ and as a result the internal energy of the system changes by dU and the system does a work dW, then dQ = dU + dW

But,
$$dW = P dV$$
 $dQ = dU + P dV$

which is the mathematical statement of first law of thermodynamics.

Heat gained by a system, work done by a system and increase in internal energy are taken as positive.

Heat lost by a system, work done on a system and decrease in internal energy are taken as negative.

Ex.19 1 gm water at 100°C is heated to convert into steam at 100°C at 1 atm. Find out change in internal energy of water. It is given that volume of 1 gm water at 100°C = 1 cc. volume of 1 gm steam at 100°C = 1671 cc. Latent heat of vaporization = 540 cal/g. (Mechanical equivalent of heat J = 4.2 J/cal.)

Sol. From first law of thermodynamic $\Delta Q = \Delta u + \Delta w$ $\Delta Q = mL = 1 \times 540$ cal. = 540 cal.

$$\Delta W = P \Delta V = \frac{10^5 (1671 - 1) \times 10^{-6}}{4.2}$$

$$= \frac{10^{5}(1670) \times 10^{-6}}{4.2} = 40 \text{ cal.}$$

$$\Delta U = 540 - 40 = 500 \text{ cal.}$$

Ex.20 Two moles of a diatomic gas at 300 K are kept in a nonconducting container enclosed by a piston. Gas is now compressed to increase the temperature from 300 K to 400 K. Find work done by the gas



Sol. $\Delta Q = \Delta u + \Delta W$ Since container is conconducting therefore $\Delta Q = 0 = \Delta u + \Delta w$

 $\Rightarrow \Delta W = -\Delta u = -n\frac{f}{2}R\Delta T = -2 \times \frac{5}{2}R(400 - 300)$ $= -5 \times 8.314 \times 100 \text{ J} = -5 \times 831.4 \text{ J} = -4157 \text{ J}$

Ex.21 A sample of an ideal gas is taken through the cyclic process abca (figure. It ab-sorbs 50 J of heat during the part ab, no heat during bc and reflects 70 J of heat during ca. 40 J of work is done on the gas during the part bc.(a) Find the internal energy of the gas at b and c if it is 1500 J at a. (b) Calculate the work done by the gas during the part ca.





Sol. (a) In the part ab the volume remains constant. Thus, the work done by the gas s zero. The heat absorbed by the gas is 50 J. The increase in internal energy from a to b is $\Delta U = \Delta Q = 50$ J.

As the internal energy is 1550 J at a, it will be 1550 J at b. In the part bc, the work done by the gas is $\Delta W = -40J$ and no heat is given to the system. The increase in internal energy from b to c is

 $\begin{array}{l} \Delta \mathsf{U} = - \Delta \mathsf{W} = 40 \; \mathsf{J}.\\ \text{As the internal energy is 1550 J at b, it will be 1590 J at C.}\\ (b) The change in internal energy, from c to a is \\ \Delta \mathsf{U} = 1500 \; \mathsf{J} - 1590 \; \mathsf{J} = -90 \; \mathsf{J}\\ \text{The heat given to the system is } \Delta \mathsf{Q} = -70 \; \mathsf{J}\\ \text{Using } \Delta \mathsf{Q} = \Delta \mathsf{U} + \Delta \mathsf{W},\\ \Delta \mathsf{W}_{\mathsf{ca}} = \Delta \mathsf{Q} - \Delta \mathsf{U} = -70 \; \mathsf{J} + 90 \; \mathsf{J} = 20 \; \mathsf{J}. \end{array}$

- Ex.22 The internal energy of a monatomic ideal gas is 1.5 nRT. One mole of helium is kept in a cylinder of cross-section 8.5 cm². The cylinder is closed by a light frictionless piston. The gas is heated slowly in a process during which a total of 42 J heat is given to the gas. If the temperature rises through 2°C, find the distance moved by the piston. Atmospheric pressure = 100 kPa.
- **Sol.** The change in internal energy of the gas is $\Delta U = 1.5 \text{ nR} (\Delta T)$ = 1.5 (1 mol) (8.3 J/mol-K) (2K) = 24.9 JThe heat given to the gas = 42 J The work done by the gas is $\Delta W = \Delta Q - \Delta U = 42 \text{ J} - 24.9 \text{ J} = 17.1 \text{ J}$ If the distance moved by the piston is x, the work done is $\Delta W = (100 \text{ kPa}) (8.5 \text{ cm}^2) \text{ x}.$ Thus, $(10^5 \text{ N/m}^2) (8.5 \times 10^{-4} \text{ m}^2) \text{ x} = 17.1 \text{ J}$ or, x = 0.2 m = 20 cm.
- Ex.23 A sample of an ideal gas has pressure $p_{o'}$ volume v_o and temperature T_o . It is isothermally expanded to twice its original volume. It is then compressed at constant pressure to have the original volume V_o . Finally, the gas is heated at constant volume to get the original temperature. (a) Show the process in a V T diagram (b) Calculate the heat absorbed in the process.
- **Sol.** (a) The V-T diagram for the process is shown in figure. The initial state is represented by the point a. In the first step, it is isothermally expanded to a volume $2V_0$. This shown by ab. Then the pressure is kept constant and the gas is compressed to the volume V_0 . From the ideal gas equation, V/T is constant at constant pressure. Hence, the process is shown by a line bc which passes through the origin. At point c, the volume is V_0 . In the final step, the gas is heated at constant volume to a temperature T_0 . This is shown by ca. The final state is the same as the initial state.

(b) The process is cylic so that the change in internal energy is zero. The heat supplied is, therefore, equal to the work done by the gas. The work done during ab is

$$W_{_{1}} = nRT_{_{0}} ln \frac{2V_{_{0}}}{V_{_{0}}} = nRT_{_{0}} ln 2 = p_{_{0}}V_{_{0}} ln 2.$$

Also from the ideal gas equation

$$p_a V_a = p_b V_b$$



394,50 - Rajeev Gandhi Nagar Kota, Ph. No. : 93141-87482, 0744-2209671 Urturing potential through education IVRS No : 0744-2439051, 52, 53, www. motioniitjee.com, info@motioniitjee.com



or,
$$p_{b} = \frac{p_{a}V_{a}}{V_{b}} = \frac{p_{0}V_{0}}{2V_{0}} = \frac{p_{0}}{2}.$$

In the step bc, the pressure remains constant. Hence the work done is,

$$W_2 = \frac{p_0}{2}(V_0 - 2V_0) = -\frac{p_0V_0}{2}$$

In the step ca, the volume remains constant and so the work done is zero. The net work done by the gas in the cyclic process is

 $W = W_1 + W_2 = p_0V_0 [ln 2 - 0.5] = 0.193 p_0V_0.$ Hence, the heat supplied to the gas is 0.193 p_0V_0 .

Ex.24 A sample of ideal gas (f = 5) is heated at constant pressure. If an amount 140 J of heat is supplied to the gas, find (a) the change in internal energy of the gas (b) the work done by the gas.

Sol. Suppose the sample contains n moles. Also suppose the volume changes from V_1 to V_2 and the temperature changes from T_1 to T_2 .

The heat supplied is

$$\Delta Q = \Delta U + P \Delta V = \Delta U + nR \Delta T = \Delta U + \frac{2\Delta U}{f}$$

(a) The change is internal energy is

$$\Delta U = n \frac{f}{2} R(T_2 - T_1) = \frac{f}{2} R n(T_2 - T_1) = \frac{f}{2 + f} \Delta Q = \frac{140J}{1.4} = 100 J$$

(b) The work done by the gas is

 $\Delta W = \Delta Q - \Delta U = 140 \text{ J} - 100 \text{ J} = 40 \text{ J}$

- **Ex.25** There are two vessels. Each of them contains one mole of a monoatomic ideal gas. I nitial volume of the gas in each vessel is 8.3×10^{-3} m³ at 27°C. Equal amount of heat is supplied to each vessel. In one of the vessels, the volume of the gas is doubled without change in its internal energy, whereas the volume of the gas is held constant in the second vessel. The vessels are now connected to allow free mixing of the gas. Find the final temperature and pressure of the combined gas system.
- **Sol.** 369.3K, 2.462 × 10⁵ N/m²

Efficiency of cycle (η) :

total Mechanical work done by the



Ex.26 n moles of a diatomic gas has undergone a cyclic process ABC as shown in figure. Temperature at A is T_o.
Find

(i) Volume at C ?
(ii) Maximum temperature ?

(iii) Total heat given to gas ?

(iv) is heat rejected by the gas, if yes how much heat is rejected ?

(v) Find out the efficiency

394,50 - Rajeev Gandhi Nagar Kota, Ph. No. : 93141-87482, 0744-2209671 VRS No : 0744-2439051, 52, 53, www. motioniitjee.com, info@motioniitjee.com



2P.

P

Sol. (i) Since triangle O A V_0 and OC V are similar therefore

$$\frac{2P_0}{V} = \frac{P_0}{V_0} \implies V = 2V_0$$

(ii) Since process AB is isochoric hence

$$\frac{P_{A}}{T_{A}} = \frac{P_{B}}{T_{B}} \Rightarrow T_{B} = 2T$$

Since process BC is isobaric therefore $\frac{T_B}{V_B} = \frac{T_C}{V_C}$

$$\Rightarrow$$
 I_c = 2I_B = 4I₀
(iii) since process is cyclic therefore

$$\Delta Q = \Delta W = area under the cycle = \frac{1}{2} P_0 V_0$$

(iv) Since Δu and ΔW both are negative in process CA $\therefore \Delta Q$ is negative in process CA and heat is rejected in process CA $\Delta Q_{CA} = \Delta w_{CA} + \Delta u_{CA}$ $= -\frac{1}{2} [P_0 + 2P_0] V_0 - \frac{5}{2} nR (T_c - T_a)$ $= -\frac{1}{2} [P_0 + 2P_0] V_0 - \frac{5}{2} nR \left(\frac{4P_0V_0}{nR} - \frac{P_0V_0}{nR}\right)$

$$= -\frac{1}{2} \left[P_0 + 2P_0 \right] V_0 - \frac{1}{2} nR \left(\frac{1}{nR} - \frac{1}{nR} \right)$$

= -9P_0V_0 = Heat injected.
(v) η = efficiency of the cycle

$$= \frac{\text{work done by the gas}}{\text{heat injected}} = \eta = \frac{\frac{P_0 V_0 / 2}{Q_{\text{injected}}} \times 100$$
$$\Delta Q_{\text{inj}} = \Delta Q_{AB} + \Delta Q_{BC}$$
$$= \left[\frac{5}{2} nR(2T_0 - T_0)\right] + \left[\frac{5}{2} nR(2T_0) + 2P_0(2V_0 - V_0)\right]$$
$$= \frac{19}{2} P_0 V_0 \qquad \eta = \frac{100}{19} \%$$

10. SPECIFIC HEAT

The specific heat capacity of a substance is defined as the heat supplied per unit mass of the substance per unit rise in the temperature. If an amount ΔQ of heat is given to a mass m of the substance and its temperature rises by ΔT , the specific heat capacity s is given by equation

$$s = \frac{\Delta Q}{m\Delta T}$$

The molar heat capacities of a gas are defined as the heat given per mole of the gas per unit rise in the temperature. The molar heat capacity at constant volume, denoted by C_v , is :

$$C_{v} = \left(\frac{\Delta Q}{n\Delta T}\right)_{\text{constant volume}} = \frac{f}{2}R$$

and the molar heat capacity at constant pressure, denoted by $C_{_{\!\!\! D}}$ is,

$$C_{P} = \left(\frac{\Delta Q}{n\Delta T}\right)_{\text{constant Pressure}} = \left(\frac{f}{2} + 1\right)R$$

where n is the amount of the gas in number of moles and f is degree of freedom. Quite often, the term specific heat capacity or specific heat is used for molar heat capacity. It is advised that the unit be carefully noted to determine the actual meaning. The unit of specific heat capacity is J/kg-K whereas that of molar heat capacity is J/mol-K.





MOLAR HEAT CAPACITY OF IDEAL GAS IN TERMS OF R :

(i) For a monoatomic gas f = 3

$$C_v = \frac{3}{2}R$$
, $C_p = \frac{5}{2}R \Rightarrow \frac{C_p}{C_v} = \gamma = \frac{5}{3} = 1.67$

(ii) For a diatomic gas f = 5

$$C_v = \frac{5}{2}R$$
, $C_p = \frac{7}{2}R$, $\gamma = \frac{C_p}{C_v} = 1.4$

(iii) For a Triatomic gas f = 6 $C_v = 3R, C_p = 4R$ $\gamma = \frac{C_p}{C_v} = \frac{4}{3} = 1.33$

[Note for CO_2 ; f = 5, it is linear]

In general if f is the degree of freedom of a molecule, then

$$C_{V} = \frac{f}{2}R$$
, $C_{P} = \left(\frac{f}{2} + 1\right)R$, $\gamma = \frac{C_{P}}{C_{V}} = \left[1 + \frac{2}{f}\right]$

for any general process C = $\frac{fR}{2} + \frac{work \text{ done by gas}}{n\Delta T}$

- Ex.27 Two moles of a diatomic gas at 300 K are enclosed in a cylinder as shown in figure. Piston is light. Find out the heat given if the gas is slowly heated to 400 K in the following three cases.
 (i) Piston is free to move
 (ii) If piston does not move
 (iii) If piston is heavy and movable.
- *Sol. (i) Since pressure is constant*

$$\therefore \Delta Q = nC_{P}\Delta T = 2 \times \frac{7}{2} \times R \times (400 - 300) = 700 R$$
(ii) Since volume is constant

$$\therefore \Delta W = 0$$
 and $\Delta Q = \Delta u$ (from first law)

$$\Delta Q = \Delta u = nC_v \Delta T = 2 \times \frac{5}{2} \times R \times (400 - 300) = 500 R$$
(iii) Since pressure is constant

$$\therefore \Delta Q = nC_{p} \Delta T = 2 \times \frac{7}{2} \times R \times (400 - 300) = 700R$$

Ex.28 P-V curve of a diatomic gas is shown in the figure. Find the total heat given to the gas in the process AB and BC

Sol. From first law of thermodynamics $\Delta Q_{ABC} = \Delta u_{ABC} + \Delta W_{ABC}$

$$\Delta W_{ABC} = \Delta W_{AB} + \Delta W_{BC} = 0 + nRT_B ln \frac{V_C}{V_B} = nRT_B ln \frac{2V_0}{V_0}$$

= $nRT_B ln 2 = 2P_0 V_0 ln 2$
$$\Delta u = nC_v \Delta T = \frac{5}{2} (2P_0 V_0 - P_0 V_0) \Rightarrow \Delta Q_{ABC} = \frac{5}{2} P_0 V_0 + 2P_0 V_0 ln 2.$$







Ex.29 Calculate the value of mechanical equivalent of heat from the following data. Specific heat capacity of air at constant volume = 170 cal/kg-K, $\gamma = C_p/C_v = 1.4$. and the density of air at STP is 1.29 kg/m³. Gas constant R = 8.3 J/mol-K Sol. Using pV = nRT, the volume of 1 mole of air at STP is $V = \frac{nRT}{p} = \frac{(1 \text{ mol}) \times (8.3 \text{ J} / \text{ mol} - \text{K}) \times (273 \text{K})}{1.0 \times 10^5 \text{ N} / \text{m}^2} = 0.0224 \text{ m}^3.$ The mass of 1 mole is, therefore, $(1.29 \text{ kg/m}^3) \times (0.0224 \text{ m}^3) = 0.029 \text{ kg}.$ The number of moles in 1 kg is $\frac{1}{0.029}$. The molar heat capacity at constant volume is $C_v = \frac{170 \text{ cal}}{(1/0.029) \text{ mol} - \text{K}} = 4.93 \text{ cal/mol-K}$ Hence, $Cp = \gamma C_{\gamma} = 1.4 \times 4.93$ cal/mol-K $C_p - C_v = 0.4 \times 4.93$ cal/mol-K =1.97 cal/mol-K or, Thus, 8.3 J = 1.97 cal. The mechanical equivalent of heat is $\frac{8.3 \text{ J}}{1.97 \text{ cal}} = 4.2 \text{ J/cal}.$ **Average Molar Specific Heat of Metals :** 6 [Dulong and Petit law] At room temperature average molar specific heat

of all metals are same and is nearly equal to 3R

(6 cal. mol⁻¹K⁻¹)

[Note : Temp. above which the metals have constant C_v is called Debye temp.]

Mayer's equation : $C_p - C_v = R$ (for ideal gases only)

ADIABATIC PROCESS

When no heat is supplied or extracted from the system the process is called adiabatic. Process is sudden so that there is no time for exchange of heat. If walls of a container are thermally insulated no heat can cross the boundary of the system and process is adiabatic.

Equation of adiabatic process is given by

 $PV^{\gamma} = constant$ [Poission law]

 $T^{\gamma}P^{1-\gamma} = constant$

 $T V^{\gamma-1} = constant$

Slope of P-V curve in adiabatic process : Since PV^{γ} is constant

$$\therefore \qquad \frac{dp}{dV} = -\gamma \left(\frac{P}{V}\right)$$

Slope of P – T – curve in adiabatic process : Since $T^{\gamma} P^{1-\gamma}$ is a constant

$$\therefore \qquad \frac{dV}{dT} = -\frac{\gamma}{(1-\gamma)}\frac{P}{T} = \frac{(\gamma)}{(\gamma-1)}\frac{P}{T}$$











$$\Delta W = -\Delta U = nC_v (T_i - T_f) = \frac{P_i V_i - P_f V_i}{(\gamma - 1)}$$

$$=\frac{nR(T_{i}-T_{f})}{\gamma-1}$$

work done by system is (+ve), if $T_i > T_f$ (hence expansion) work done on the system is (-ve) if $T_i < T_f$ (hence compression)

- Ex.30 A quantity of air is kept in a container having walls which are slightly conducting. The initial temperature and volume are 27°C (equal to the temperature of the surrounding) and 800 cm³ respectively. Find the rise in the temperature if the gas is compressed to 200 cm³ (a) in a short time (b) in a long time. Take $\gamma = 1.4$.
- **Sol.** (a) When the gas is compressed in a short time, the process is abiabatic. Thus, $T_{\alpha} V_{\alpha}^{\gamma-1} = T_{\alpha} V_{\alpha}^{\gamma-1}$

$$= \left(V_{1} \right)^{\gamma-1} \quad (2200)^{\gamma-1} \quad (800)^{\gamma-4}$$

or
$$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{T_1} = (300 \text{ K}) \times \left[\frac{800}{200}\right]^{0.4} = 522 \text{ K}.$$

Rise in temperature = $T_2 - T_1 = 222K$

(b) When the gas is compressed in a long time, the process is isothermal. Thus, the temperature remains equal to the temperature of the surrounding that is 27° C. The rise in temperature = 0.

- Ex.31 A monoatomic gas is enclosed in a nonconducting cylinder having a piston which can move freely. Suddenly gas is compressed to 1/8 of its initial volume. Find the final pressure and temperature if initial pressure and temperature are P₀ and T₀ respectively.
 Solution pressure is adjusted to therefore.
- **Sol.** Since process is adiabatic therefore

$$P_0 V^{\frac{5}{3}} = P_{\text{final}} \left(\frac{V}{8}\right)^{5/3}$$

 $\gamma = \frac{C_p}{C_v} = \frac{5R}{2} / \frac{3R}{2} = \frac{5}{3}$

Since process is adiabatic therefore.

$$\mathsf{T}_{1}\mathsf{V}_{1}^{\gamma-1} = \mathsf{T}_{2} \mathsf{V}_{2}^{\gamma-1} \qquad \Rightarrow \mathsf{T}_{0}\mathsf{V}_{0}^{2/3} = \mathsf{T}_{\mathsf{final}} \left(\frac{\mathsf{V}_{0}}{8}\right)^{2/3} \Rightarrow \mathsf{T} = 4\mathsf{T}_{0}$$





Ex.32 A cylindrical container having nonconducting walls is partitioned in two equal parts such that the volume of the each parts is equal to V₀. A movable nonconducting piston is kept between the two parts. Gas on left is slowly heated so that the gas on right is

compressed upto volume $\frac{V_0}{8}$. Find pressure and temperature on both sides if initial pressure and temperature, were P_0 and T_0 respectively. Also find heat given by the heater to the gas. (number of moles in each part is n)



Sol. Since the process on right is adiabatic therefore

$$\begin{array}{l} \mathsf{PV}^{\gamma} = \text{constant.} \\ \Rightarrow \qquad \mathsf{P}_{0}\mathsf{V}_{0}^{\gamma} = \mathsf{P}_{\text{final}} \; (\mathsf{V}_{0}/8)^{\gamma} \\ \Rightarrow \qquad \mathsf{P}_{\text{final}} = 32 \; \mathsf{P}_{0} \\ \mathsf{T}_{0}\mathsf{V}_{0}^{\gamma-1} = \mathsf{T}_{\text{final}} \; (\mathsf{V}_{0}/8)^{\gamma-1} \end{array}$$

Let volume of the left part is V₁

$$\Rightarrow \qquad 2V_0 = V_1 + \frac{V_0}{8} \qquad \Rightarrow V_1 = \frac{15V_0}{8}$$

Since number of moles on the left parts remains constant therefore for the left part PV/T = constant.

Final pressure on both sides will be same

$$\Rightarrow \frac{P_0 V_0}{T_0} = \frac{P_{\text{final}} V_1}{T_{\text{final}}} \Rightarrow T_{\text{final}} = 60 T_0$$

$$\Delta Q = \Delta u + \Delta w$$

$$\Delta Q = n \frac{5R}{2} (60T_0 - T_0) + n \frac{3R}{2} (4T_0 - T_0)$$

$$\Delta Q = \frac{5nR}{2} \times 59T_0 + \frac{3nR}{2} \times 3T_0$$

Free Expansion

TION CISE ISATINTSE

Jurturing potential through education

If a system, say a gas expands in such a way that no heat enters or leaves the system and also no work is done by or on the system, then the expansion is called the "free expansion". $\Delta Q = 0$, $\Delta U = 0$ and $\Delta W = 0$. Temperature in the free expansion remains constant.

Ex.33 A nonconducting cylinder having volume 2V₀ is partitioned by a fixed nonconducting wall in two equal part. Partition is attached with a valve. Right side of the partition is a vaccum and left part is filled with a gas having pressure and temperature P₀ and T₀ respectively. If valve is opened find the final pressure and temperature of the two parts.



HEAT-2



Sol. From the first law thermodynamics $\Delta Q = \Delta u + \Delta W$

Since gas expands freely therefore $\Delta W = 0$, since no heat is given to gas $\Delta Q = 0$

 $\Rightarrow \qquad \Delta u = 0$ and temperature remains constant.

$$T_{final} = T_0$$

Since the process is isothermal therefore

 $\begin{array}{l} \mathsf{P}_{_{0}} \times \mathsf{V}_{_{0}} = \mathsf{P}_{_{\text{final}}} \times 2\mathsf{V}_{_{0}} \\ \Rightarrow \qquad \mathsf{P}_{_{\text{final}}} = \mathsf{P}_{_{0}}/2 \end{array}$

Reversible and Irreversible Process

A process is said to be reversible when the various stages of an operation in which it is subjected can be traversed the back in the opposite direction in such a way that substance passes through exactly the same conditions at every step in the reverse process as in the direct process.

Comparison of slopes of Iso-thermal and Adiabatic Curve





In compression up to same final volume :

$$|W_{adia}| > |W_{isothermal}|$$

In Expansion up to same final volume :

$$W_{isothermal} > W_{adia}$$

Limitations of Ist Law of Thermodynamics :

The first law of thermodynamics tells us that heat and mechanical work are interconvertible. However, this law fails to explain the following points :

- (i) It does not tell us about the direction of transfer of heat.
- (ii) It does not tell us about the conditions under which heat energy is converted into work.
- (iii) It does not tell us whether some process is possible or not.

Mixture of non-reacting gases :

(a) Molecular weight =
$$\frac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$$

M₁ & M₂ are molar masses.

(b) Specific heat
$$C_v = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$$
, $C_P = \frac{n_1 C_{P_1} + n_2 C_{P_2}}{n_1 + n_2}$

(c) for mixture,
$$\gamma = \frac{C_{P_{mix}}}{C_{V_{mix}}} = \frac{n_1 C_{P_1} + n_2 C_{P_2} + \dots}{n_1 C_{V_1} + n_2 C_{V_2} + \dots}$$

(d) Degree of freedom for mixture
$$f = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2}$$

