First Law of Thermodynamics

$PV = nRT$

$n = \frac{m}{M}$ | $n = \frac{N}{N_A}$

$PV = mrT$

or, $P = \rho rT$

$(dQ)_V = mc_V dT$

$(dQ)_V = nC_V dT$

$(dQ)_P = mc_P dT$

$(dQ)_P = nC_P dT$

$dQ = dU + dW$

$dU = nC_V dT$

$dU = mc_V dT$

$c_P - c_V = r$

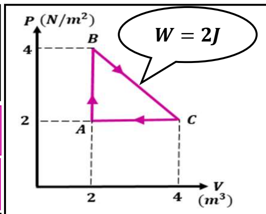
$C_P - C_V = R$

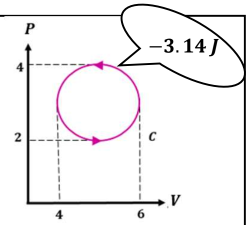
$\gamma = \frac{c_P}{c_V}$

Specific heat ratio

$\gamma = \frac{C_P}{C_V}$

Molar heat ratio





In a cyclic process,

$W = \text{area enclosed by the the graph}$

For clockwise cycle, work done is $+ve$ and vice- versa.

In a cyclic process, the change in internal energy is zero.

Isobaric Process ($dP = 0$)

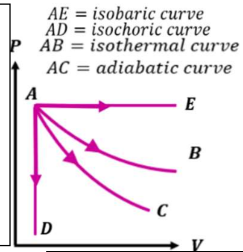
$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Work done:

$$W = PdV = P(V_2 - V_1)$$

OR

$$W = nRdT = nR(T_2 - T_1)$$



Isochoric Process ($dV = 0$)

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

Work done:

$$W = 0$$

For work to be done, volume should be changed.

Isothermal Process ($dT = 0$)

$$P_1V_1 = P_2V_2$$

Work done:

$$W = nRT \ln\left(\frac{P_1}{P_2}\right)$$

A Slow Process

OR

$$W = nRT \ln\left(\frac{V_2}{V_1}\right)$$

✓ In an isothermal process,

$dU = 0$

(change in internal energy is zero)

$\therefore$ $dQ = dW$

Hence, during an isothermal expansion all the heat given to the system is converted to work done by the system.

Adiabatic Process ($dQ = 0$)

A quick Process

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$P_1^{1-\gamma} T_1^{\gamma} = P_2^{1-\gamma} T_2^{\gamma}$$

Work done:

$$W = \frac{1}{\gamma - 1}(P_1V_1 - P_2V_2)$$

OR

$$W = \frac{nR}{\gamma - 1}(T_1 - T_2)$$

✓ In an adiabatic process, $dQ = 0$,

Then, the first law of thermodynamics becomes,

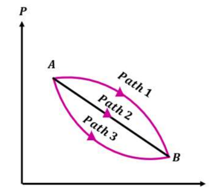
$$dW = -dU$$

This shows that, in an adiabatic expansion, work is done by the gas in the expense of its internal energy.

- **Different** amount of heat is required to change the equal temperature when gas is heated at constant pressure and at constant volume. Hence, gas has two heat capacities.
- **Lager** heat is required at constant pressure than at constant volume. Hence, $C_p > C_V$.
- The slope of adiabatic curve is greater than that of an isothermal process.
- ✓ If the gas is compressed adiabatically, the gas heats up (the internal energy increases.)

1. a. What is internal energy of an ideal gas? Internal energy of an ideal has is the state function. Comment. 2

   b. In the given PV diagram, a system undergoes thermodynamic change from point A to point B via three different paths. Through which path the work done is maximum? Explain. 2



   c. Why gas has two heat capacities? 2

   d. C_p is greater than C_V, why? 2

   e. Establish relation between molar heat capacities. 3

   f. The density of a gas is 1.775kgm^{-3} at 27^{0}C and 10^5 Nm^{-2} pressure and its specific heat capacity at constant pressure is 346 J/Kg K. Find the ratio of specific heat capacity at constant pressure to that at constant volume. [Ans:1.29] 3

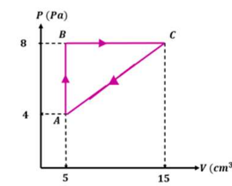
   g. If the ratio of specific heat capacities of gas is 1.4 and its density at S.T.P is 0.09 kg, calculate the values of specific heat capacities at constant pressure and at constant volume. [Ans: 1.44 x 10^4 J /KgK, 1.03 x 10^4 J/KgK 3

   h. The given PV diagram shows a cyclic process ABCA. Find,

   i. the work done. ii. Change in internal energy.

   iii. Work done in the step BC only.

   iv. Work done in the step CA only.



2. a. What is isobaric process? Write the formula for the work done in an isobaric process.

   b. A gas is compressed at a constant pressure of 0.8 atm from 9 liter to 2 liter. In the process, 400 J of thermal energy leaves the gas.

   i. What is the work done by the gas?

   ii. What is the change in its internal energy? (Ans: **- 565.6 J, 165.6 J**)

   c. What happens to the energy added to an ideal gas when it is heated at (i) constant volume, (ii) at constant pressure 2

3. a. What is isothermal process. Write the equation of state for an isothermal process. 2

   b. Obtain an expression for the work done in an isothermal process. 3

   c. Five moles of an ideal gas are kept at constant temperature of 53^{o}C while the pressure of the gas is increased from 1 atm to 3 atm. Calculate the work done by the gas. **(-14881J)** 2

   d. During an isothermal expansion all the heat given to the system is converted to work done by the system. Comment this on the basis of first law of thermodynamics. 2

4. a. State and explain first law of thermodynamics. 2

   b. Apply first law of thermodynamics for adiabatic process. 2

   c. Define adiabatic process. 1

   d. In an adiabatic expansion, the system does work on its surroundings. But if there is no heat input to the gas where does the energy come from? 2

   e. Obtain the equation of state for adiabatic process. 3

   f. Why does the temperature of a gas undergoing adiabatic expansion decrease? 2

   g. Derive an expression for work done in an adiabatic system. 3

   h. Air at NTP is compressed adiabatically to half of its volume. Calculate the change in its temperature. Also find the final pressure. Assuming 1 mole of air, calculate the work done. 3

   i. An ideal gas initially at 4 atmosphere and 300 K is permitted to expand adiabatically twice its initial volume. Find the final Pressure and temperature if the gas is (a) monoatomic with $C_V = 3R/2$ and (b) diatomic with $C_V = 5R/2$. (**Ans: 1.25 atm, 188.5 K; 1.52 atm, 277.36 K**) 3

   j. Air is compressed adiabatically to half of its volume. Calculate the percentage change in its temperature. **(32%)** **2**

   k. Is it possible to increase temperature of a body without giving heat to it? Explain. 2

   l. What happens to internal energy of gas during (i) adiabatic expansion (ii)isothermal expansion? 2