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UNIT – 1 ENTROPY AND SECOND LAW OF THERMODYNAMICS

B.SC. SEM - V

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CYCLIC PROCESS

- WHEN A SYSTEM COMPLETES A SERIES OF CHANGES AND ULTIMATELY RETURNS TO ITS ORIGINAL STATE, IT IS KNOWN TO HAVE COMPLETED ONE CYCLE. THE ENTIRE PROCESS OF CHANGES IS KNOWN AS A CYCLIC PROCESS.
- SINCE THE INTERNAL ENERGY OF A SYSTEM DEPENDS ONLY UPON ITS STATE, IT FOLLOWS THAT IN A CYCLIC PROCESS, THE NET CHANGE OF INTERNAL ENERGY IS ZERO, I.E.,

  ACCORDING TO FIRST LAW OF THERMODYNAMICS; $\Delta E = 0 = Q - W$

  $Q = W$

- IF A SERIES OF CHANGES ARE CONDUCTED AT A CONSTANT TEMPERATURE, THE CYCLE IS KNOWN AS AN **ISOTHERMAL CYCLE.**
- IF THE CHANGES ARE CARRIED OUT REVERSIBLY, THEN THE CYCLE IS KNOWN AS A **REVERSIBLE CYCLE.**
- THE MOST WELL KNOWN CYCLIC PROCESS IS **CARNOT'S CYCLE.**

CARNOT CYCLE

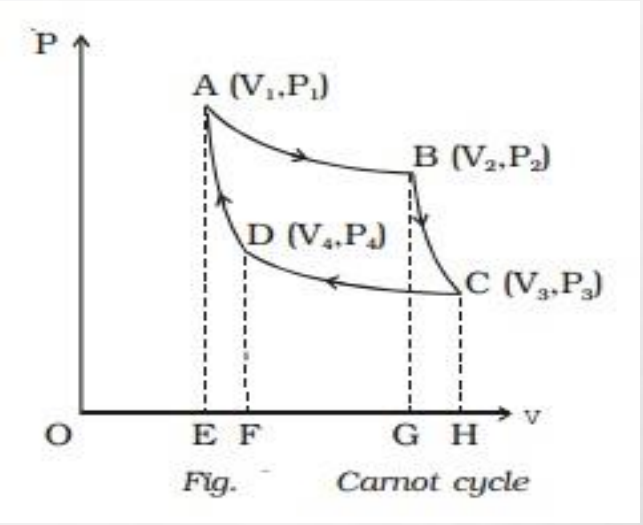

Fig. Carnot cycle

- THE SYSTEM CONSISTS OF ONE MOLE OF AN IDEAL GAS WHICH IS SUBJECTED TO A SERIES OF FOUR SUCCESSIVE OPERATIONS KNOWN AS FOUR STROKES.

(I) STROKE 1 :- ISOTHERMAL EXPANSION

- THE GAS IS ALLOWED TO EXPAND REVERSIBLY AND ISOTHERMALLY AT THE TEMPERATURE T_2 SO THAT THE VOLUME INCREASES FROM V_1 TO V_2 (POINT A TO B).
- EXPANSION IS ISOTHERMAL, SO $\Delta U = 0$.
- ACCORDING TO FIRST LAW OF THERMODYNAMICS; $\Delta U = Q - W$ $\therefore$ Q = W, I.E. THE HEAT ABSORBED BY THE SYSTEM IS EQUAL TO THE WORK DONE BY THE SYSTEM ON THE SURROUNDINGS. SUPPOSE HEAT ABSORBED IS q_z AND WORK DONE IS W_1 THEN

$$q_z = W_1 = RT_2 \, l_n \, (V_2/V_1) \_\_\_\_\_ (1)$$

(II) STROKE 2 :- ADIABATIC EXPANSION

- THE GAS IS ALLOWED TO EXPAND REVERSIBLY AND ADIABATICALLY FROM THE VOLUME V_2 TO V_3 I.E. FROM POINT B TO C. HERE HEAT IS NOT ABSORBED, SO THE TEMPERATURE FALLS FROM T_2 TO T_1. Q = 0, SO ΔU = -W.
- SINCE THE WORK IS DONE BY THE SYSTEM ON THE SURROUNDINGS BY CONVENTION, W IS NEGATIVE.

$$\therefore \Delta U = -W$$

- NOW, $C_v = (\sigma U/\sigma T)_v$ _____(2)

$\therefore \Delta U = C_v \Delta T = C_v(T_1 - T_2) = - W$ _____(3)

$W = C_v\,(T_2 - T_1)$ _____(4)

- IF WORK W IS DENOTED BY W_2 , THEN

$W_2 = C_v\,(T_2 - T_1)$ _____(5)

(III) STROKE 3 :- ISOTHERMAL COMPRESSION

- THE GAS IS SUBJECTED TO A REVERSIBLE AND ISOTHERMAL COMPRESSION AT TEMPERATURE T_1.
- THE VOLUME DECREASES FROM V_3 TO V_4 . I.E. FROM POINT C TO D.
- IN THIS CASE WORK IS DONE ON THE SYSTEM SO HEAT IS PRODUCED AND GIVEN UP TO THE SURROUNDINGS.
- PROCESS IS ISOTHERMAL AND REVERSIBLE SO, $\Delta U = 0$.
- IF HEAT IS DENOTED BY q_1 AND WORK BY w_3

$$-q_1 = -w_3 = RT_1 \ln(V_4/V_3) \qquad \text{_____(6)}$$

(IV) STROKE 4 :- ADIABATIC COMPRESSION

- THE GAS IS SUBJECTED TO A REVERSIBLE AND ADIABATIC COMPRESSION.
- THE VOLUME DECREASES FROM V_4 TO V_1. I.E. FROM POINT D TO A.
- WORK IS DONE ON THE SYSTEM, HENCE W IS POSITIVE.
- Q = 0, SO $\Delta U = Q - W = W = -C_v (T_2 - T_1)$
- IF W IS DENOTED BY W_4 THEN,

$$W_4 = -C_v (T_2 - T_1) \qquad \text{\_\_\_\_\_(7)}$$

- THE NET HEAT ABSORBED BY THE SYSTEM IS

$$Q = Q_2 + (-Q_1) = RT_2 \ln(V_2/V_1) + RT_1 \ln(V_4/V_3)$$
$$= RT_2 \ln(V_2/V_1) - RT_1 \ln(V_3/V_4) \quad \text{_____(8)}$$

- NOW, $V_3/V_2 = V_4/V_1$ OR $V_2/V_1 = V_3/V_4$ _____(9)

$$\therefore Q = Q_2 - Q_1 = R\,(T_2 - T_1) \ln(V_2/V_1) \quad \text{_____(10)}$$

- SIMILARLY, THE NET WORK DONE BY THE GAS IS

$$W = W_1 + W_2 + W_3 + W_4$$
$$= RT_2 \ln(V_2/V_1) - C_v\,(T_2 - T_1) + RT_1 \ln(V_4/V_3) + C_v\,(T_2 - T_1)$$
$$= RT_2 \ln(V_2/V_1) - RT_1 \ln(V_3/V_4) \quad \text{_____(11)}$$

- SINCE; $V_2/V_1 = V_3/V_4$

$$W = R\,(T_2 - T_1) \ln(V_2/V_1) \quad \text{_____(12)}$$

- FROM EQUATION (10) AND (12), Q = W
- THUS, THE ESSENTIAL CONDITION FOR A CYCLIC PROCESS THAT THE NET WORK DONE IS EQUAL TO THE NET HEAT ABSORBED WHICH IS FULLY SATISFIED.
- THE RELATION BETWEEN W, THE NET WORK DONE BY THE SYSTEM AND Q_2 THE QUANTITY OF HEAT ABSORBED AT A HIGHER TEMPERATURE T_2 IS OBTAINED BY DIVIDING EQUATION (12) BY (1)

  $W = Q_2 (T_2 - T_1)/T_2$ _____(13)
- SINCE $(T_2 - T_1)/T_2 < 1$, $W < Q_2$.

- THUS, WORK DONE IS LESS THAN THE HEAT ABSORBED.
- THIS MEANS THAT ONLY A PART OF THE HEAT IS ABSORBED BY THE SYSTEM AT THE HIGHER TEMPERATURE T_2 IS TRANSFORMED INTO WORK.
- THE REST OF THE HEAT Q_1 IS GIVEN TO THE SURROUNDING AT THE TEMPERATURE T_1.


THANK
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