

CHAPTER 10

Date: _____

Day: M T W

THERMODYNAMICS

* Equivalence OF HEAT AND WORK:

When a given amount of work is done, the same amount of heat is always produced.

$$W \propto Q$$

$$W = JQ$$

J: Mechanical equivalent of heat

$$J = 4.18 \text{ Joule per calorie}$$

$$1 \text{ calorie} = 4.18 \text{ Joule}$$

$$\text{In SI Units: } J = 1$$

* CLOSED SYSTEM:

→ No transfer of mass

→ Only transfer of heat

* OPEN SYSTEM

Both transfer of mass and heat take place

* ISOLATED SYSTEM

→ No transfer of mass

→ No transfer of heat

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* STATE VARIABLES :

- Pressure
- Volume
- Temperature
- Internal Energy
- Entropy
- Enthalpy

* ENTHALPY (ΔH)

A thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume.

$$\Delta H = \Delta E + p\Delta V$$

* FIRST LAW OF THERMODYNAMICS

→ Based on law of conservation of energy

"Every thermodynamic system possess a state variable called the internal energy"

$$\Delta U = \Delta Q - \Delta W$$

ΔQ : +ve → when heat enters the system
-ve → when heat leaves the system

ΔU : +ve → when temp of system rises
-ve → when temp of system decreases

* IN A CYCLIC PROCESS:

In a cyclic process the system starts and returns to the same thermodynamic state.

$$\Delta U = U_B - U_A = \text{Zero} \quad (\text{As } U_A = U_B)$$

So

$$\Delta U = \Delta Q - \Delta W$$

$$0 = \Delta Q - \Delta W$$

$$\Delta Q = \Delta W$$

Thus in a cyclic process all the heat energy absorbed by the system is used in doing some useful work by the system.

* ISOCHORIC PROCESS:

→ Volume constant

→ $\Delta V = 0$ so $\Delta W = 0$

→ $\Delta Q = \Delta U$

The entire amount of heat supplied is converted to internal energy.

* ISOBARIC PROCESS:

→ Pressure constant

→ $\Delta Q = \Delta U + \Delta W$

→ $\Delta Q = \Delta U + P\Delta V$

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* ISOTHERMAL PROCESS:

→ Temperature remains constant

$$\rightarrow \Delta U = 0$$

$$\rightarrow \Delta Q = \Delta W$$

* ADIABATIC PROCESS

→ No heat enters or leaves the system

$$\rightarrow \Delta Q = 0$$

→ Truly adiabatic process is an ideal process

$$\Delta Q = \Delta U + \Delta W$$

$$0 = \Delta U + \Delta W$$

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

Increase in internal energy of the system in an adiabatic process is equal to work done on the system

If system does work, then in adiabatic process, the work is done at the cost of internal energy

* SPECIFIC HEAT OF A BODY

The quantity of heat required to raise the temperature of 1kg of a substance by 1K

* MOLAR SPECIFIC HEAT OF A GAS

The quantity of heat required to raise the temperature of $1 \text{ kg}^{\text{mol}}$ of a substance by 1 K

$$\Delta Q = C_m n \Delta T$$

C_m : constant of proportionality

Molar specific heat capacity ($\text{J mol}^{-1} \text{ K}^{-1}$)

* MOLAR SPECIFIC HEAT AT CONSTANT VOLUME

$$\Delta Q_v = n C_v \Delta T$$

* MOLAR SPECIFIC HEAT AT CONSTANT PRESSURE

$$\Delta Q_p = n C_p \Delta T$$

* RELATION BETWEEN C_p AND C_v

$$C_p > C_v$$

$$C_p = C_v + R$$

$$C_p - C_v = R$$

$$R = 8.315 \text{ J mol}^{-1} \text{ K}^{-1}$$

* HEAT RESERVOIR:

A heat reservoir is a constant temperature heat source or sink

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* EFFICIENCY OF A HEAT ENGINE

Efficiency = $\frac{\text{Work Done By The Engine}}{\text{Heat Absorbed By the Engine}}$

$$\eta = \frac{\Delta W}{Q_1}$$

$$\eta = \frac{Q_1 - Q_2}{Q_1} \quad \text{or} \quad \eta = \frac{T_1 - T_2}{T_1}$$

$$\eta = 1 - \frac{Q_2}{Q_1}$$

If $Q_2 = 0$

$$\eta = 100\%$$

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- It is impossible to construct 100% efficient heat engine
- Some heat Q_2 must be rejected from source to sink.

* SECOND LAW OF THERMODYNAMICS

Tells how heat energy can be converted into useful work

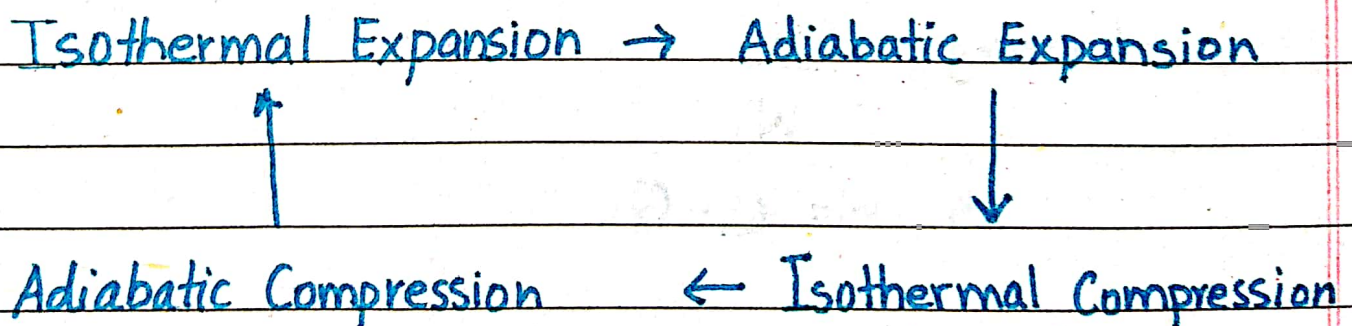
1. LORD KELVIN STATEMENT

"There is no heat engine in the world which takes the heat from HTR and converts whole of it into mechanical work"

* RUDOLF CLAUSIUS STATEMENT

"It is impossible to cause heat to flow from a cold body to hot body without the expenditure of work"

* CARNOT CYCLE



$$\eta = 1 - \frac{T_2}{T_1} \quad \text{or} \quad \eta = \frac{T_1 - T_2}{T_1}$$

* ENTROPY

$$\Delta S = \frac{\Delta Q}{T}$$

ΔS : +ve \rightarrow when heat is added

-ve \rightarrow when heat is removed

* In all natural processes where heat flows from one system to another; there is always net increase in entropy

* Only those processes are probable for which entropy of the system increase or remain constant

* For all adiabatic processes ($\Delta Q=0$) the entropy of the system does not change.

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* FOR ISOTHERMAL :

$$PV = \text{constant}$$

* FOR ADIABATIC :

$$PV^\gamma = \text{constant}$$

* The process which is performed quickly:

Adiabatic process

* $C_p > C_v$ because:

In case of C_p heat is needed to do external work against external pressure

* A real gas can be approximated to an ideal gas at:

Low Density

* PYROMETER:

An instrument for measuring very high temperature

Range: $(-40^\circ\text{C} \text{ to } 3500^\circ\text{C})$

* CALORIMETER RANGE:

0.06K to 3K

-273°C to -270°C

* A cycle tire burst suddenly. This represents an Adiabatic process.

* CARNOT CYCLE

1. ISOTHERMAL EXPANSION $\rightarrow (\Delta T = 0)$
 $P_1, V_1, T_1 \rightarrow P_2, V_2, T_1$

2. ADIABATIC EXPANSION
 $P_2, V_2, T_1 \rightarrow P_3, V_3, T_2$

3. ISOTHERMAL COMPRESSION
 $P_3, V_3, T_2 \rightarrow P_4, V_4, T_2$

4. ADIABATIC COMPRESSION
 $P_4, V_4, T_2 \rightarrow P_1, V_1, T_1$

5. ADIABATIC EXPANSION
Temperature Falls

6. ADIABATIC COMPRESSION
Temperature Rises

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* The minimum number of thermodynamic parameters required to specify the state of a gas system: Two

* Triple point temperature of water:
0.01°C

* FOR ADIABATIC PROCESS

$$PV^\gamma = \text{constant}$$

$$\gamma = \frac{C_p}{C_v}$$

* A Carnot engine working between 100K and 200K has a work output of 60J per cycle. How much heat energy is supplied to the engine from the source of each cycle

Sol:

$$Q = \frac{\Delta W}{\text{Efficiency}}$$

$$\eta = \frac{T_1 - T_2}{T_1}$$

$$= \frac{200 - 100}{200}$$

$$= \frac{100}{200} = \frac{1}{2}$$

$$Q = \frac{60}{0.5} = 120 \text{ J}$$

* A perfect gas goes from state A to another state B by absorbing $8 \times 10^5 \text{ J}$ of heat and doing $6.5 \times 10^5 \text{ J}$ of external work. It is now transferred between the same two states in another process in which it absorbs 10^5 J of heat. Then in second process, work done on the gas is :

Sol:

For First Process :

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta U = \Delta Q - \Delta W$$

$$= 8 \times 10^5 - 6.5 \times 10^5$$

$$\Delta U = 1.5 \times 10^5 \text{ J}$$

Since the final and initial states are same in both processes ΔU will be same in both processes.

For Second Process:

$$\Delta Q = \Delta U + \Delta W$$

$$\Delta W = \Delta Q - \Delta U$$

$$= 10^5 - 1.5 \times 10^5 \text{ J}$$

$$\Delta W = -0.5 \times 10^5 \text{ J}$$

As ΔW is -ve so work is done on the system.

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