

27/10/22

Kinetic Theory of Gases for

Kinetic theory was proposed by Maxwell & Boltzmann and others explained the behaviour of ideal gases.

Assumptions / Postulates

* A/c to this theory

1. All gases are made up of very large no. of tiny (small) particles ^{are} called molecules.
2. The molecules of a gas are considered to be rigid, perfectly elastic, solid sphere, identical in all aspects such as mass and size but they differ in these from gas to gas.
3. The molecules of a gas are in a state of continuous random motion, moving in all directions with all possible velocities. During their motion the molecules collide with one another and with the walls of container. At each collision, their velocities are altered in direction & magnitude.
4. All the collisions b/w the molecules and with the walls of the container are perfectly elastic. So that there is no loss of kinetic energy during collision.
5. The distance b/w the two successive collisions when a molecule moves in a straight line direction is called free path of the molecule. The avg. of

all free paths in a gas is called mean free path.

$$\text{Mean free path } \lambda = \frac{1}{\sqrt{\frac{1}{n} \pi d^2 n}}$$

d = diameter of the molecule

n = no. of molecules per unit volume

6. The molecules are small compared to the distance

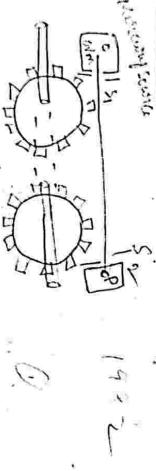
between them. Volume may be considered to be negligible compared with the total volume of gas.

7. The intermolecular distance in a gas is much larger than that of a solid or liquid. And molecules of a gas are free to move in the entire space available to them.

$$dN_{(c)} = N \left(\frac{m}{2\pi kT} \right)^{3/2} \cdot \frac{m^2}{c^2} \cdot \frac{e^{-mc^2/kT}}{c^2}$$

Experimental verification of Maxwell's speed distribution of molecular speed

Lamont's toothed wheel experiment



Working:

1. First the 2 wheels W_1 & W_2 are set into rapid rotation and the mercury vapour beam from slit S_1 is made to fall on wheel W_1 & pass through one of the slits of W_2 .
2. The molecules of particular speeds, after travelling the distance x , will pass through the slit of W_2

1. In "1912" Lamont used toothed experiment for sorting out the molecules having different velocities.
2. The experimental arrangement is as shown in fig.

Construction:

1. In this experiment we have two toothed wheels W_1 & W_2 . Each wheel has 50 teeths and 50 slits alternatively. The two wheels are mounted on the same axle with a separation ' x '.
2. They are kept rotating at very high speeds. The slit in W_2 are not parallel to those in W_1 , but are displaced an angle of 2° behind them.

that comes in the line of beam after 2° rotation of w_2 .

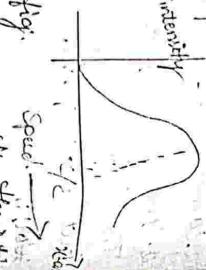
3. These molecules are collected on the plate 'P'. The intensity is measured with microphotometer.

4. This experiment is repeated by rotating the wheel with different speeds.

5. As the speed of rotation increases, it takes less time to rotate 2° . Then a particular high speed molecule will pass through the slit of w_2 that comes after w_1 .

Graph

* A graph is drawn by taking intensity of the molecules on Y-axis and speed of the molecules on X-axis.



This graph is also shown in fig.

* The graph shows that it resembles with the theoretical curve of maxwell's speed distribution law

of w_2

Thermo electric thermometer

Principle "Seebeck effect"

It works based on the principle of "Seebeck effect".

Seebeck effect: When two different metals are joined together, when 1 junction is heated and keeping the other junction is closed in a loop,

and keeping the other junction in cold in a loop, an EMF (Electromotive Force) is produced if current is passed through the circuit. This is known as Seebeck effect.

The magnitude of the emf depends upon the difference of the temperature b/w hot and cold junctions

Construction

1. It consists of two different types of wires joined at one end by welding. To provide insulation the two wires are enclosed in a

poroline tubes.

These wires are passed through a mica disc to keep them in position.

2. The whole arrangement is enclosed in a glass tube the free wires of the end are connected to two jumprads in b/w the galvanometer

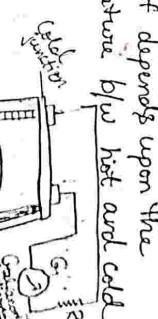
Working 1. The body whose temperature is to be

found is brought in contact with weldable

junction (hot junction) of the thermometer

2. After some time when the junction is attains

the temperature of the body, the deflection



on the galvanometer is noted. Three readings give constant.

the temperature of the body.

3. By choosing the suitable metallic wires, within help of this thermometer temperature upto 300°C can be measured.

Advantages:

1. The thermometer measures the temperature over range from 200°C to 300°C.
2. Rapidly varying temperatures can be measured with this thermometer.
3. It is cheap and easy construct.
4. It can be measure temperature at any point.

Disadvantages

1. It is not accurate over wide ranges.
2. Different thermo couples are required for different ranges of temperatures.
3. For each thermo couple, galvanometer supplied fresh calibration.

Maxwell's law of distribution of molecular speed
→ Maxwell consider the distribution of speeds among the molecular & made following assumptions

1. The gas consists of molecules with all possible speeds starting from 0 to ∞ .
2. When the gas is in steady state, its density remains

3. Through, the speed of individual molecules are changing, but definite number of molecules have speeds, b/w definite ranges.

4. Ac. to Maxwell law of distribution of molecular speeds, the no. of gas molecules [dN_c] having their

speeds b/w ' c ' & ' $c+dc'$ is given by

$$dN_c = 4\pi N \left[\frac{\mu}{2\pi kT} \right]^{3/2} e^{-\mu c^2/2kT} dc$$

where
 N = Total no. of molecules
 μ = Mass of each molecule
 k = Boltzmann constant 1.38×10^{-2} Joule/mole
 T = Temperature

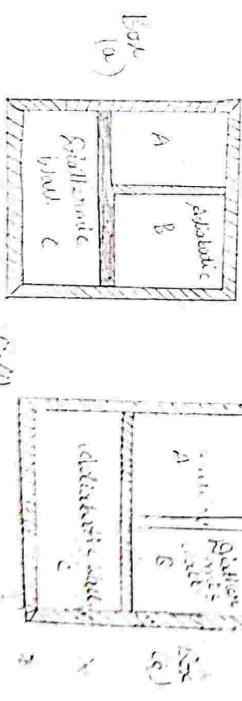
$$A = 6.023 \times 10^{23}$$

$$c = 3 \times 10^8 \text{ m/s}$$

Zeroth law of thermodynamics

⇒ This law states that if two systems A & B are separately in thermal equilibrium with another third system C, then A & B are in thermal equilibrium

with each other.



Expt: The zeroth law can be described by an experiment arrangement as shown in fig (1) As shown in fig (1) consider two systems A & B full of different gases which are separated by an adiabatic wall (which conducts heat). Now consider a third system C full of another gas & separated from both systems A & B by an diathermic wall (which permits heat to pass through it).

After sometime, a steady state is reached in the steady state A is in thermal equilibrium with C. As shown in (fig 1b). Let the two walls be replaced by each other. It is observed that there is no change in the slit of A and B. If we consider the states in term of temperature, the temperature of A and B is same. so by interchanging the walls A and B are also in thermal equilibrium.

So, we conclude that if A and B are in thermal equilibrium with C, then A and B are also in thermal equilibrium with each other.

Measurements of the temperature

* Liquid glass

* Constant pressure

* Constant volume

* Resistance

* Thermometer

* Pyrometer

Measurements of temperature

An instrument that measures the temperature of a body is called a thermometer.

There are various kinds of thermometer, each has some property of heat.

Types of thermometer:

Property of heat used

* Liquid of glass thermometer * Expansion of liquids with temperature.

* Constant pressure thermometer * Increase of volume of a gas with temperature

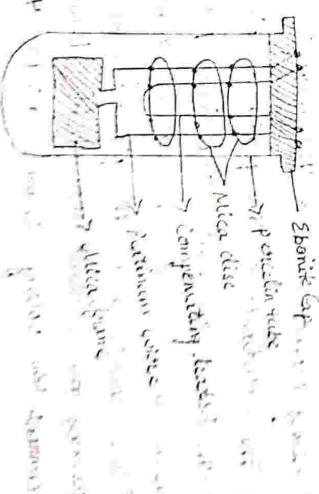
* Constant volume thermometer * Increase of pressure of a gas, temperature

* Resistance thermometer * Change of resistance with temperature.

Measurement of temperature

Platinum resistance thermometer [PRT]

Principle: PRT works on the principle of the change of the platinum changes with the change of temperature



(For exchanged surroundings)

In this platinum resistance thermometer it consists of a platinum wire double on itself to avoid the wound on a thin plate of a mica. Enclosed in a porcelain tube. Here, the mica is used as an insulator and it is placed at the end of the tube. The elastite cap is placed at the other end of the tube / open end of the tube.

→ The free ends P_1 & P_2 of the leads are connected to the terminals at the top of instrument.

→ For reducing the effect of platinum wire resistance on the thermometer, the two similar copper wires S_1 & S_2 their lower edges joined together are placed close to the platinum thermometer leads as shown above figure. These wires are called compensating leads.

Working:

- * We know that platinum is a unreactive element and it can easily drawn into fine wires. Because of these properties of the platinum, it is used as a sensing element in a thermometer.
- * The resistance of the platinum increases linearly with the temperature and this property of the metal is used for measuring temperature.
- * The resistance of the platinum is measured by passing the current through it. Because of the current the voltage induces across the metal which

measures through the voltmeter.

* The reading of the voltage is converted into the temperature with the help of calibration equation, which is given by

$$t_p = \left[\frac{R_t - R_0}{R_{100} - R_0} \right] \times 100^\circ$$

∴ By knowing the values of R_0 , R_{100} and R_t at 0° , 100° and unknown temperature, t_p can be calculated.

Advantages :

- * The thermometer measures the temperature over range from 200° to 1200° .
- * Thus thermometer is quite sensitive.
- * The platinum has some resistance at the same temperature
- 1. There is no change of 0° . The temperature measured through platinum resistance thermometer is easier than compare to the gas thermometer.
- 2. Advantages :
- 3. Disadvantages :
- 4. * The thermometer gives slow response.
- * It's not suitable for measuring unstable and rapidly varying temperatures.
- * The melting point of the thermometer is 1700° but when platinum measures the temperature higher than 1200° .
- * It has large thermal capacity and very slow thermal conditions.

Unit Thermodynamics

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System

Surroundings

P. V. T.

Thermodynamic aspects

i) Isothermal process : Temp. constant.
 ii) Adiabatic " : Heat " .
 iii) Isochoric " : Volume "
 iv) Isobaric " : pressure "

Isothermal process Adiabatic Process

1. Defn: If a system undergoes a physical change at constant temperature then that change is called isothermal process.

1. If a system undergoes a physical change by keeping the amount of heat constant then that change is called adiabatic process.

Q. In this process temp-
erature is constant

2. In this process the quantity
of heat is constant.

$\frac{dQ}{dt} = \text{constant}$ (ex) $\frac{dQ}{dt} = 0$; $dQ = 0$; $i.e. Q = \text{constant}$

3. In this process heat is 3. This process has not heat exchanged from the exchange from surrounding

Surroundings.

TESTIMONY

Process

The amount of heat consumed or released during a process is called **heat transfer**.

In this process the quantity of heat is constant.

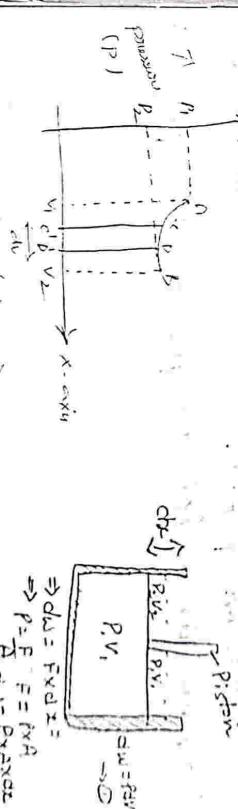
$\delta Q = 0$

\Rightarrow If there
the incor.
 \therefore Then

- gas expansion
- decreasing volume
the workers

the volume

one more
pressure P.



Work done in a isothermal process

4. The container is a good conductor.
5. This process is a slow process.

But from Boyle's law $PV = RT$

$$P = \frac{RT}{V}$$

$$\boxed{\frac{dW = \frac{RT}{V} dV}{V}} \rightarrow \textcircled{2}$$

The total workdone $W = \int_{V_1}^{V_2} dW$, $W = RT (\log V_2 - \log V_1)$

$$= \int_{V_1}^{V_2} \frac{RT}{V} dV = RT \left[\log V_2 - \log V_1 \right]$$
$$W = \alpha \int_{V_1}^{V_2} \left(\frac{1}{V} \right) dV = \alpha R T \log \left(\frac{V_2}{V_1} \right)$$

This is the final equation for workdone in a isothermal process.

Workdone in a ~~isothermal~~ adiabatic process:

But from Poisson's law $PV^\gamma = k \rightarrow \textcircled{1}$

$$P = kV^{-\gamma}$$
$$dW = kV^{-\gamma} dV$$
$$W = k \int_{V_1}^{V_2} V^{-\gamma} dV = k \left[\frac{V^{1-\gamma}}{1-\gamma} \right]_{V_1}^{V_2}$$

$$W = \frac{k}{1-\gamma} \left[V_2^{1-\gamma} - V_1^{1-\gamma} \right]$$
$$W = \frac{1}{1-\gamma} \left[P_2 V_2^{\gamma} - P_1 V_1^{\gamma} \right]$$

Let 1 gm of mole of the gas is expanding isothermally as shown above fig. let the initial pressure and volume of the gas are P_1, V_1 and the final pressure and volume of the gas are P_2, V_2 . The heat Q remains constant.

$$W = \left(\frac{1}{1-\gamma} \right) \left[P_2 V_2^{\gamma} - P_1 V_1^{\gamma} \right]$$

But ideal gas equation $PV = RT$ so $P_2 V_2 = P_1 V_1 \Rightarrow P_2 V_2^{\gamma} = P_1 V_1^{\gamma}$

$$\omega = \left(\frac{1}{1-\gamma} \right) [RT_2 - RT_1]$$

$$W = \left[\frac{R}{1-\gamma} \right] [T_2 - T_1]$$

The above eqn shows workdone in adiabatic process.

First law of thermodynamics

Law of conservation of energy

⇒ This law is essentially the principle of conservation of energy i.e.

"The heat energy is supplied to a system is equal to the sum of increase the internal energy & external work

$$\therefore dQ = dw + du$$

Explanation:

If dQ is amount of heat energy given to a system,

1. A part of energy is used raising the temperature of the system which is equal to the internal kinetic energy (dw) of the system.
2. A part of energy is doing internal work against to molecular attraction, which is equal to increase of the potential energy of a system (du).

3. The rest part of energy is used in doing external work (dw),

$$dQ = dw + du + dw$$

$$dQ = dw + PdV$$

∴ The above equation is known as mathematical form of first law.

Significance:

1. Heat is a form of energy.
2. Energy is conserved in thermodynamic system.
3. Every thermodynamic system in equilibrium state possess internal energy, which is a function of the system.

Reversible process:

Definition: If all the changes are occurring in direct

1. If all the changes are occurring in the opposite direction then that process is called reversible process.

Conditions: i) Dissipative forces like friction, viscosity, electrical resistance etc.

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must be completely absent.

- ii) The temperature difference b/w system and surroundings must be very small.
- iii) The direct & reversible must takes place uniformly & slow reaction.

Ex:

1. Conversion of solid into liquid are vice versa at the same temperature.

2. Slowly performed isothermal & adiabatic processes are examples of reversible processes.

③ Peltier effect:

Inversible process:

1. Def: If all the changes that occurs in the direct process are not exactly repeated, then that process is called irreversible process.

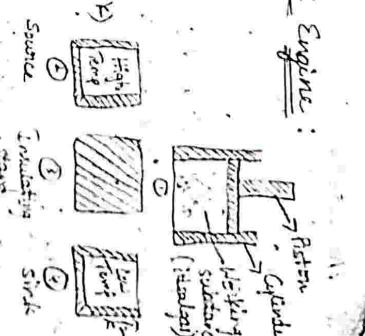
2. All natural processes are irreversible processes.

Example:

- 1. Free expansion of gases
- 2. Joule-Thomson effect
- 3. Joule-Heating effect
- 4. All types of chemical reactions

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Carnot's Reversible Heat Engine:



1. The working substance.

2. The source.

3. The insulating stand.

4. The sink.

A heat engine is a device to convert heat energy into mechanical one.

In the year 1824 a french engineer Carnot developed a theoretical engine, which is free from all the defects of practical engine is called Carnot's reversible heat engine.

This engine shows the above fig.

The engine consist of 4 parts, they are

1. The working substance & the source
2. The insulating stand
3. The sink

1. The Working Substance:

* The working substance is an ideal gas

- 1. Free expansion of gases
- 2. Joule-Thomson effect
- 3. Joule-Heating effect
- 4. All types of chemical reactions

2. The source :

A hot body of high temperature T_1 K serves as a source.

3. Insulating stand in a perfectly non-conducting platform which serves as a stand for cylinder.

4. Sink :

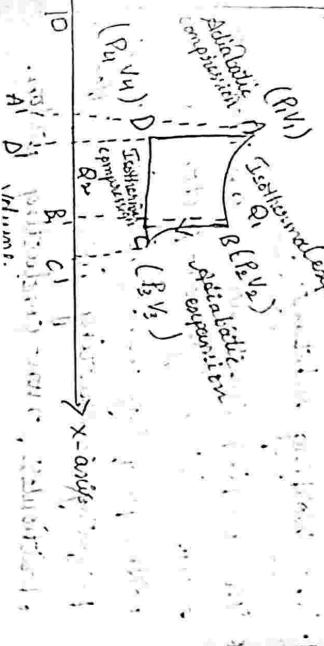
A cold body maintained at a low temperature T_2 K which serves as a sink. Usually this is surrounding temperature.

Carnot's Cycle:

* The working substance undergoes all cyclic operations in the following 4 parts.

- ① Isothermal expansion
- ② Adiabatic expansion
- ③ Isothermal compression
- ④ Adiabatic compression

All these operations are shown in below fig.



Isothermal expansion: When the cylinder is kept on the source, the gas expands isothermally from A ($P_1 V_1$) to B ($P_2 V_2$). Here the working substance absorbs Q_1 amount of heat from the source. The work done $w_1 = Q_1 = 2.303 R T_1 \log_{10} \left(\frac{V_2}{V_1} \right) \rightarrow ①$

$$\therefore \text{The workdone } w_1 = Q_1 = 2.303 R T_1 \log_{10} \left(\frac{P_1}{P_2} \right) (T_2 - T_1)$$

Adiabatic Expansion: When the cylinder is separated from the source and placed on the insulating stand. The gas expands adiabatically from B ($P_2 V_2$) to C ($P_3 V_3$) till the temperature falls down from T_2 K to T_3 K. The amount of workdone (w_2) by the gas is given by $w_2 = \left(\frac{R}{\gamma - 1} \right) (T_2 - T_3) \rightarrow ②$

Isothermal Compression: When the cylinder is placed on the sink (T_2 K) the gas is compressed isothermally from C ($P_3 V_3$) to D ($P_4 V_4$). Substance rejects Q_2 amount of heat to sink. The work done w_3 on the gas is equal to the workdone w_3 by the gas given by $w_3 = Q_2 = 2.303 R T_2 \log_{10} \left(\frac{V_3}{V_4} \right)$

Adiabatic compression: When the cylinder is separated from the sink and placed on the insulating stand the

gas is compressed adiabatically from V_4 to A (P, V_1)

The work done by w_4 by the working substance during this process is given by

$$w_4 = \left(\frac{R}{1-\gamma} \right) (T_1 - T_2) \rightarrow (4)$$

$$w_4 = - \left(\frac{R}{1-\gamma} \right) (T_2 - T_1) \rightarrow (4)$$

\therefore Total work done by the gas per cycle w is given by

$$\begin{aligned} w &= w_1 + w_2 + w_3 + w_4 \\ &= 2.303 RT_1 \log_{10} \left(\frac{V_2}{V_1} \right) + \left(\frac{R}{1-\gamma} \right) (T_2 - T_1) - 2.303 RT_2 \log_{10} \left(\frac{V_3}{V_2} \right) \\ &\quad - \left(\frac{R}{1-\gamma} \right) (T_2 - T_1). \end{aligned}$$

$$w = 2.303 RT_1 \log_{10} \left(\frac{V_2}{V_1} \right) - 2.303 RT_2 \log_{10} \left(\frac{V_3}{V_2} \right) =$$

$$Q_1 - Q_2 \rightarrow (5)$$

For curve 'BC', in adiabatic expansion, $T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1}$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_3} \right)^{\gamma-1} \rightarrow (6)$$

For curve 'DA', Adiabatic compression $T_2 V_4^{\gamma-1} = T_1 V_1^{\gamma-1}$

$$T_2 V_4^{\gamma-1} = T_1 V_1^{\gamma-1} \rightarrow (7)$$

$$\frac{T_1}{T_2} = \left(\frac{V_4}{V_1} \right)^{\gamma-1} \rightarrow (8)$$

Carnot's theorem:
Statement: No engine is more efficient than reversible engine working b/w the same two

From (6) & (7) we get

$$\frac{V_3}{V_2} = \frac{V_4}{V_1} \quad (9)$$

From eq (5) & (8)

$$w = Q_1 - Q_2 = 2.303 RT_1 \log_{10} \left(\frac{V_2}{V_1} \right) - 2.303 RT_2 \log_{10} \left(\frac{V_3}{V_2} \right)$$

$$w = Q_1 - Q_2 = 2.303 R \log_{10} \left(\frac{V_2}{V_1} \right) (T_1 - T_2) \rightarrow (10)$$

Efficiency of Carnot engine

$$\eta = \frac{w}{Q_1} = \frac{\text{Workdone by the engine}}{\text{Heat takes from the source}} = \frac{w}{Q_1}$$

Substitute eq (10) & (10) in eq (10) we have

$$\eta = \frac{Q_1 - Q_2}{Q_1} = \frac{2.303 R \log_{10} \left(\frac{V_2}{V_1} \right) (T_1 - T_2)}{2.303 R \log_{10} \left(\frac{V_2}{V_1} \right) (T_1)}$$

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

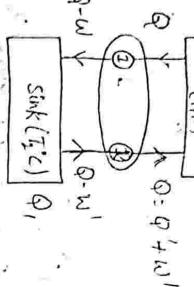
$$\therefore \eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$\text{temperatures. } w_1 = q_1 = -2303 RT_1 \log_{10} \left(\frac{T_2}{T_1} \right)$$

Explanation:

$$\Rightarrow \frac{w_1}{Q} > \frac{w_1}{Q}$$

$$\Rightarrow w_1 > Q \rightarrow \textcircled{1}$$



* Consider a reversible engine "R" and an irreversible engine "T" working on the same source S_0 sink.

* Irreversible engine "T" works in forward direction and the reversible engine "R" works in backward direction.

* Let "T" absorb heat Q from source at $T_1^{\circ}\text{K}$.

* The engine converts some energy into work w and thus remaining energy $(Q-w)$ is transferred to the sink at $T_2^{\circ}\text{K}$.

* Similarly the engine "R" absorbs heat energy Q' from the sink at $T_2^{\circ}\text{K}$, w' is the work done on the substance.

* The energy transferred to the source $(Q+w')$

* Let the source gives S_0 takes the same amount of energy $in Q + w'$ $\Rightarrow (or) [w' = Q - Q']$

* We can assume the efficiency of irreversible engine "T" greater than reversible engine "R"

$$i.e. \eta_T > \eta_R$$

$$\Rightarrow \frac{w_1}{Q} > \frac{w_1}{Q}$$

* Now we can couple the two engines in compound engine the sink takes the heat $(Q-w)$ and gives the heat $(Q-w')$

So that the amount of heat energy given by the sink $\Rightarrow (Q-w) - (Q-w')$

$$\Rightarrow Q - w' - Q + w$$

$$\Rightarrow w - w' \rightarrow \textcircled{2}$$

As per eqn ①, eqn ② is positive than $(Q-w')$ is greater than $(Q-w)$.

This means that the sink takes less heat $(Q-w)$ and gives more heat $(Q-w')$ without changing the temperature of the sink.

This is impossible after second law of thermodynamics. So eqn ① & ② are wrong.

Hence, the efficiency of irreversible engine is greater than the efficiency of reversible engine that is $\boxed{\eta_R > \eta_T}$

Second law of Thermodynamics:

- 1) Kelvin statement
- 2) Clausius statement

1) Kelvin statement of 2nd law:

It is impossible to derive a continuous supply of work by cooling a body to temperature lower than that of the coldest of its surroundings ^{temperature}.

Exile: We know that a heat engine takes heat from the source, converts a part into work & the remaining is rejected into sink.

As the engine absorbs more energy and ~~more heat~~ continuously from the source the temperature of source falls down & after some time it becomes as that of surroundings.

Hence, no heat ~~is~~ flow. In this case engine stops work i.e. no work can obtain from the engine. This contribution ~~leads~~ to the Kelvin statement of thermodynamics. (2nd law)

2) Clausius statement:

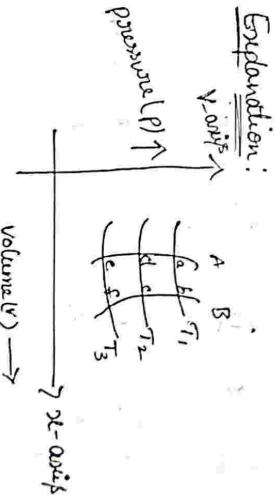
It is impossible for a self acting machine to transfer heat from any external agency to a cold body to a hot body

Exile:

This statement is based on the working of refrigeration. In refrigerator the transfer of heat takes place from cold body to hot body with the aid of external agency. This consideration leads to Clausius statement of second law of Thermodynamics.

Entropy: The thermal property of a body which remains constant in adiabatic process is called entropy. It is denoted by "S".

Explanation:



* consider different isothermal processes at T_1, T_2 & T_3 etc and two adiabatic process A-E, B.

* The adiabatic processes intersects the isotherms at a, b, c, d, e, f, ... etc. as shown in above figure.

* Take a reversible Carnot cycle along a vertical blue temperatures T_1 & T_2 .
 * Let Q_1 be the heat taken at T_1 & the heat rejected Q_2 at T_2 .

$$\therefore \frac{Q_1}{Q_2} = \frac{T_1}{T_2} \quad (07) \quad \frac{Q_1}{Q_2} = \frac{\theta_2}{\theta_1} \rightarrow ①$$

* If the reversible Carnot cycle acted below temperatures T_2^* K and T_3^* K.

* Let Q_1 heat absorbed at T_2 K and Q_2 heat which will be rejected at T_3 K

$$\text{In general } \frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_3}{T_3} = \dots = \frac{Q}{T} = \text{constant}$$

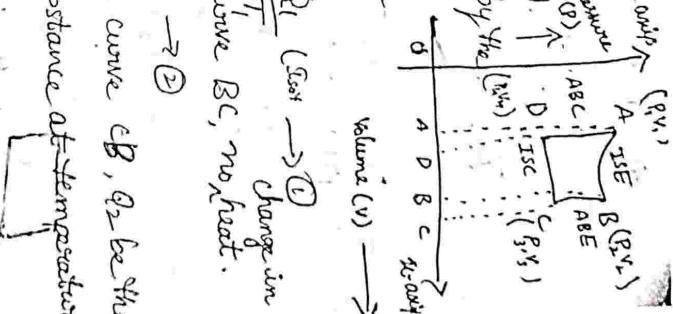
* Measurement of absolute entropy is not possible.
So the change of entropy is measured.

$$\frac{1}{DP} = SP$$

Change in entropy in reversible process:

$\Delta S_{\text{cycle}} = 0 \rightarrow$ Q
 \therefore The net change in entropy for the complete cycle ABCDA is.

Substance taking in reversible γ -work \uparrow
 Carnot cycle ABCD. pressure (P_1, V_1)
 Let the initial state is A. \uparrow



Substance taking in reversible γ -work cannot cycle ABCD.

* Let the initial state is A.

Now Q₁ be the heat taken by substance for its isothermal expansion AB at temperature

$\therefore \text{change of entropy } dS_1 = \frac{Q_1}{T_1} \quad (\text{Isot} \rightarrow \text{C})$
 $\Rightarrow \text{In adiabatic expansion curve BC, no heat exchange}$

\therefore change in entropy $dS_2 = 0 \rightarrow ②$

\Rightarrow In isothermal compression curve cB , Q_2 be the

heat rejected by the substance at temperature $T_2^{\circ}\text{K}$.

change in entropy
Isothermal compression

-
2

\Rightarrow In adiabatic compression curve A₁, no change in heat.

\therefore change in entropy
Adiabatic compression

$\text{③} \leftarrow a = \text{hsp}$

The net change in entropy for the complete combustion of propane is

$$ds = ds_1 + ds_2 + ds_3 + ds_4$$

$$= \frac{Q_1}{T_1} + 0 - \frac{Q_2}{T_2} + 0$$

$$ds = \frac{Q_1}{T_1} - \frac{Q_2}{T_2}$$

\Rightarrow But from the Kelvin statement for temperatures,

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

$$So \ ds = \frac{Q_2}{T_2} - \frac{Q_2}{T_2}$$

$$ds = 0$$

Hence the changing entropy in reversible process is "0".

Change in entropy in irreversible process

Let us consider a simple irreversible process.

Let Q_1 be the heat absorbed $T_1 K$ and Q_2 be the

heat rejected at $T_2 K$.

\therefore Efficiency of irreversible cycle

$$(or) \eta_I = \frac{Q_1 - Q_2}{Q_1}$$

Efficiency of reversible cycle

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

As per cannot theorem

$$\eta_I < \eta_R$$

$$1 - \frac{Q_2}{Q_1} < 1 - \frac{T_2}{T_1}$$

$$\frac{Q_2}{Q_1} > \frac{T_2}{T_1}$$

$$\frac{Q_2}{T_2} - \frac{Q_1}{T_1} > 0 \quad (\because s = \frac{Q}{T})$$

$$ds > 0 \text{ or } ds = \text{positive}$$

\therefore Change in entropy is ^{increase in} irreversible process

Change in entropy in universe:

In irreversible process the entropy increases. In reversible process the entropy remains constant.

\therefore So the natural process in the universe are irreversible.

* Hence the entropy of the universe increases

(or) the available energy decreases.

* In cannot rejects Q_1 be the heat taken

from the hot body at $T_1^{\circ}\text{K}$ and Q_2 be the heat rejected to the cold body at temperature $T_2^{\circ}\text{K}$.

Here $Q - Q_2$ is the heat energy converted into work and is called available energy.

$$\text{Available energy} = Q_1 - Q_2$$

$$= Q_1 \left(1 - \frac{Q_2}{T_1}\right)$$

$$= Q_1 \left(1 - \frac{T_2}{T_1}\right) \quad (\because \frac{Q_2}{Q_1} = \frac{T_2}{T_1})$$

If T_2 is decreases the available energy is decreases. [available]

If T_0 is the lowest temperature then 1. Available energy before transfer = $1 - \frac{T_2}{T_0}$

2. Available energy after transfer = $Q_1 \left(1 - \frac{T_2}{T_0}\right)$

\therefore Loss of available energy = $T_0 \left(\frac{Q_1}{T_1} - \frac{Q_1}{T_0}\right)$

$$= T_0 \left(\frac{Q_1}{T_2} - \frac{Q_1}{T_0}\right)$$

$$\text{or } \Delta S = T_0 (S_2 - S_1) = T_0 dS$$

where dS is change in entropy

From the above eqn says that change in entropy increases in reversible process for irreversible

Joule-Thomson effect

Unit - III. Measurement of low temperature

1. Freezing mixture
2. Evaporation of liquid under reduced pressure

3. Joule-Thomson expansion

4. Adiabatic demagnetization
5. Regenerative cooling

Introduction: We know that the properties of substances changes abnormally, low temperatures. Some of the substances shows very interesting properties.

Hence the branch of low temperature physics is much significant. The branch of physics which deal with production and application of low temperature is known as cryogenics.

* The process of reaching low temperature below the melting point of ice is known as refrigeration.

* They process of reaching different methods of producing low temperatures. The important method among them are

1. Freezing mixture
2. Evaporation of liquid under reduced pressure

3. Joule-Thomson Expansion

4. Adiabatic de magnetization
5. Regenerative cooling

1. Freezing mixture:

The temperature lower than 0°C can be produced by using mixture of certain salts with ice is known as freezing mixture.

Ex: 1. Using the mixture of common salt and the temperature of about -22°C produced.

2. Using caustic soda (Kott) with ice, the temperature of about -65°C can be produced.

2. Evaporation of liquid under reduced pressure

When a liquid is evaporated vis with takes latent heat vapourisation, comes. Surroundings: So if temperature. Hence low temperature can be produced.

Ex: 1: By boiling liquid helium reduced pressure

A temperature of about $-273^{\circ}\text{C}(15)$ can be obtained.

3. Joule - Thomson Expansion:

When a gas at ~~isothermally~~ low temperature is allow to pass to porous plug. From the mass of constant high pressure to mass of low constant. Then the temperature of the gas is phenomenon as Joule Thomson

Expansion

4. Adiabatic demagnetisation:

When paramagnetic substance is already magnetized is suddenly demagnetized adiabatic, its temperature falls slightly. They is called adiabatic demagnetisation.

1. By using this process, the temperature 0.001°K can be produced.

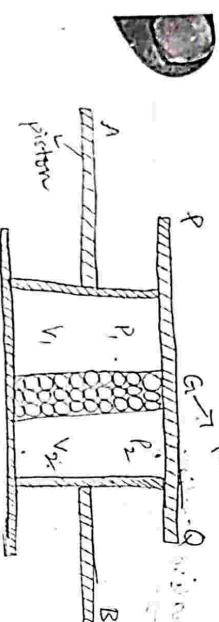
5. Regenerative cooling:

In this process, take portion of the gas which is cooled by Joule Thomson expansion, is used to cool the other. Portion of incoming gas before it undergoes Joule Thomson expansion is called regenerative cooling.

Toulle kelvin effect:

Statement: When a gas is passed through a porous plug from high constant pressure region to a low constant pressure region, then the gas suffers change in temperature. This effect is called Toulle Kelvin or Joule Thomson effect.

Porous plug Experiment:



As shown fig. PQ is the thermally isolated halo cylinder. The porous plug G (wood and cotton) having porous plug G. The porous plug G divides the cylinder into two parts. A Σ B two non-conducting pistons on both sides of the cylinder.

The gas in left compartment at higher constant pressure P_1 and in right compartment has low constant pressure P_2 .

When the gas in left compartment at higher pressure P_1 is compressed, then the gas pass through the porous plug & goes to right compartment

of lower constant pressure P_2 , then the distance between the molecules of a gas increases in a gas & it suffers change in temperature.

Results

* All the gases suffers a change in temperature after passing through the porous plug.

* At room temperature hydrogen and helium shows

heating effect and all other gases shows cooling effect.

* The changing temperature is directly proportional to change in pressure on the two sides of the porous plug.

$$\text{i.e. } dT \propto (P_1 - P_2)$$

$$dT \propto dP$$

Joule expansion

Adiabatic expansion

- ① Force expansion into vacuum.
- ② The compressed gas is suddenly expands into air.
- ③ Vacuum.
- ④ It is a slow process.
- ⑤ It is a quick process.
- ⑥ Surrounding medium is air.
- ⑦ External work is done against atmosphere.
- ⑧ Internal work is done against intermolecular attraction.
- ⑨ Heating or cooling effect takes place depending upon the initial external work.

Talor-Thomson/Kelvin expansion

① Here the gas flows from high pressure to low pressure

② It is a slow process.

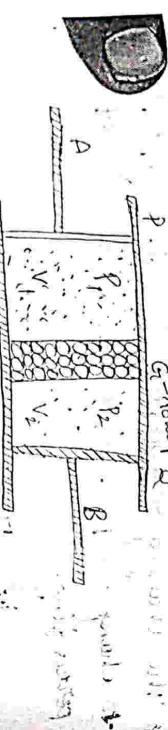
③ It has a surrounding medium.

④ External work is done on the gas by the gas.

⑤ Intermolecular work is done again intermolecular attraction.

⑥ Heating or cooling takes place depending upon the incoming temperature of gas.

Touke-Thomson cooling experiment



⇒ Consider PQ is a thermally insulated cylinder, which is divided into 2 parts by porous plug G.

Let $V_1 \leq V_2$ be the volume of a 1gm mole of gas on the high pressure P_1 & low pressure P_2 both

side of the porous plug respectively.

⇒ During the expansion of the gas, it has to do external work as well as internal work.

⇒ The external work on the gas by piston A ($= P_1 V_1$)

" " " " " Piston B by the gas ($= P_2 V_2$)

∴ Net external work done by the gas is

$$= P_2 V_2 - P_1 V_1$$

A/c to Van der Waals eqn, it is assumed that the molecules of a gas attract one another and the attraction is equal to internal pressure $P = \frac{a}{V^2}$

where 'a' is constant. Hence, when the gas expands from V_1 to V_2 the workdone (W) against the intermolecular attraction is given by

$$W = \int_{V_1}^{V_2} P dV = \int_{V_1}^{V_2} \left(\frac{a}{V^2} \right) dV$$

$$= a \left(\frac{1}{V_2} - \frac{1}{V_1} \right) \quad (\because \int \frac{1}{V^2} dV = \frac{1}{V})$$

$$W = a \left(\frac{1}{V_1} - \frac{1}{V_2} \right)$$

$$W = \left(\frac{a}{V_1} - \frac{a}{V_2} \right)$$

From the Van der Waals gas equation =

$$\left(P + \frac{a}{V^2} \right) (V - b) = RT$$

Total work done = $(P_2 V_2 - P_1 V_1) + \left(\frac{a}{V_1} - \frac{a}{V_2} \right) \rightarrow \textcircled{O}$

From eqn \textcircled{O}

$$PV - Pb + \frac{a}{V} - \frac{ab}{V^2} = RT$$

For small values of a and b , $\frac{ab}{V^2}$ term will be neglected.

$$\boxed{PV - Pb + \frac{a}{V} = RT}$$

$$PV = RT + pb - \frac{a}{V} \rightarrow ③$$

$$\text{Hence } P_1 V_1 = RT_1 + P_1 b - \frac{a}{V_1} \rightarrow ④$$

$$\text{and } P_2 V_2 = RT_2 + P_2 b - \frac{a}{V_2} \rightarrow ⑤$$

Substitute eqn ④ & ⑤ in eqn ③ we get

$$(RT + P_2 b - \frac{a}{V_2}) - (RT + P_1 b - \frac{a}{V_1}) + \left(\frac{a}{V_1} - \frac{a}{V_2} \right)$$

$$= R\bar{T} + P_2 b - \frac{a}{V_2} - RT - P_1 b + \frac{a}{V_1} + \frac{a}{V_1} - \frac{a}{V_2}$$

$$= (P_2 - P_1) b + \left(\frac{a}{V_1} - \frac{a}{V_2} \right) + \left(\frac{a}{V_1} - \frac{a}{V_2} \right)$$

$$= (P_2 - P_1) b + 2 \left(\frac{a}{V_1} - \frac{a}{V_2} \right)$$

$$= (P_2 - P_1) b + 2a \left(\frac{1}{V_1} - \frac{1}{V_2} \right)$$

$$= 2a \left(\frac{1}{V_1} - \frac{1}{V_2} \right) - b(P_1 - P_2) \rightarrow ⑥$$

But ideal gas eqn:

$$PV = RT$$

$$V = \frac{RT}{P}$$

$$\therefore \frac{1}{V} = \frac{P}{RT}$$

$$\text{Hence, } \frac{1}{V_1} = \frac{P_1}{RT}, \frac{1}{V_2} = \frac{P_2}{RT} \rightarrow ⑦$$

Substitute eqn ⑦ into eqn ⑥

$$w = 2a \left(\frac{P_1}{RT} - \frac{P_2}{RT} \right) - b(P_1 - P_2)$$

$$= \frac{2a}{RT} \cdot (P_1 - P_2) = b(P_1 - P_2)$$

$$w = \left(\frac{2a}{RT} - b \right) (P_1 - P_2) \rightarrow ⑧$$

$$d\bar{T}, c_p$$

$$\text{But } w = c_p d\bar{T} \rightarrow ⑨$$

where c_p = specific heat at constant pressure

$d\bar{T}$ = change in temperature of gas

From eqn ⑧ & ⑨

$$c_p d\bar{T} = \left(\frac{2a}{RT} - b \right) (P_1 - P_2)$$

$$\boxed{d\bar{T} = \frac{1}{c_p} \left(\frac{2a}{RT} - b \right) (P_1 - P_2)} \rightarrow ⑩$$

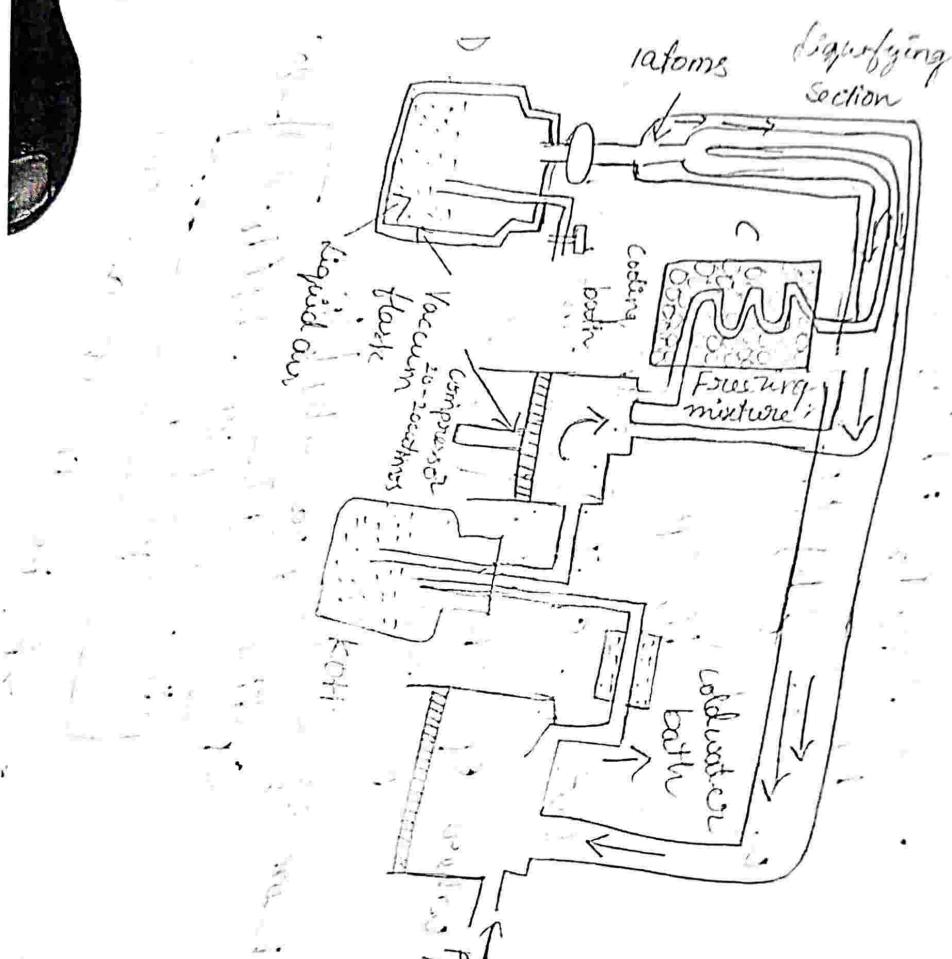
Case(i): $\frac{2a}{RT} > b$, i.e. $d\bar{T} = +ve$ and called a cooling effect

Case(ii): $\frac{2a}{RT} < b$, i.e. $d\bar{T} = -ve$ = heating effect

$$\frac{2a}{RT} = b, \text{ i.e. } d\bar{T} = 0 = \text{No effect or zero effect.}$$

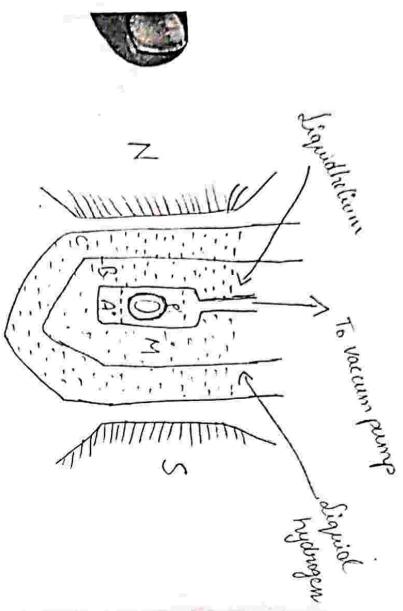
i.e. the temperature is unchanged, it is

$$\therefore T = \frac{2a}{R_b}$$



Adiabatic demagnetisation

Construction & Working:



When a paramagnetic substance is magnetised, external work is done on it. This result in a rise of temperature. Similarly under adiabatic condition, when it is demagnetised

the temperature falls. This principle was utilised by Debay, Gräfe and others in producing low temperature.

Principle:

When a paramagnetic substance already magnetised is suddenly demagnetized adiabatically, its temperature falls slightly. This phenomenon is called adiabatic demagnetisation.

Working:

First the vessel A is filled with helium gas at

low temperature. At low temperature helium is highly conductive.

- * The paramagnetic material comes into thermal contact with liquid helium at 1K.
- * Now the magnet field is switched on & the paramagnetic substance magnetised and heated.
- * This heat is flown out through helium gas into liquid helium. The temperature of substance falls to 1K. After this the helium gas is

* A paramagnetic substance gadolinium is suspended in vessel A.

- * The vessel A is connected a vacuum pump.
- * A coil 'M' is wound on the vessel A to measure the temperature by susceptibility measurement method.

* The vessel 'A' is placed in a bath B containing liquid helium at 1K temperature.

* The place B is placed in a other bath

place B containing liquid hydrogen for two pole

of magnetic field.

pumped out. Then the paramagnetic substance is.

* Now the magnetic field is switched off, the temperature of the paramagnetic falls due to adiabatic

* The fall in temperature of the substance is measured by susceptibility measurement method by using the coil wound on vessel A.

* The lowest temperature so far attained in this method is 0.0014 K

Principle of Refrigerator:

The process of cooling a body below that of its surroundings is called refrigeration.

The device used for this purpose is called refrigerator.

Principle: A machine used for producing low temperatures below surroundings by removing the excess heat at the temperature is called refrigerator.

Explanation:-

* An refrigerator is a heat engine working in reverse direction

is an ideal refrigerator

In this principle of refrigerator the working substance takes an amount of $\omega \rightarrow$ $Q_1 + Q_2$ heat from the cold body at T_1 and an

amount of Q_2 heat is released in the hot body $\omega = Q_1 - Q_2$

* Work done by an electric motor is used

in working substance

By the definition of coefficient of performance

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

* According to first law of thermodynamics heat is released in the hot body $Q_1 = Q_2 + \omega$

$$\therefore \boxed{\omega = Q_1 - Q_2} \rightarrow \text{Eq}$$

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

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

$$= \frac{\left(\frac{T_1}{T_2} - 1\right)}{\left(\frac{T_1}{T_2} - 1\right) - 1} \quad \left[\because \frac{Q_1}{Q_2} = \frac{T_1}{T_2}\right]$$

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

The coefficient of performance greater when smaller the difference of temperature b/w cold and hot bodies.

$$\boxed{\text{hot body } T_1 \text{ }^\circ\text{K}}$$

$$\boxed{\text{cold body } T_2 \text{ }^\circ\text{K}}$$

$$\boxed{Q_1 + Q_2}$$

Applications and Properties of substances at low temperature:

1. At low temperature below 90K most of the chemical reactions stoped, at this temperature animals & vegetables matter can be preserved with
2. At temperature below 83K lead loses elastic property & exhibit plastic nature.
3. The substances like rubber & glass extremely brittle get these temperature. Rubber cooled to such a low temperature breaks into pieces when hammered.
4. Oxygen is not paramagnetic substance in the gaseous state but when they are converted into liquid at low temperature it becomes paramagnetic substance.
5. The electrical resistance of most metals decrease as the temperature is reduced. At a particular temperature the resistance becomes zero & the conductivity becomes infinity. This property is called superconductivity.
6. The entropy of a substance becomes 0 when

it is exposed to very low temperature.

7. For all the substances the atomic heat becomes 0 at absolute temperature.
8. Liquid ^{oxygen} hydrogen is used in hospital for

For ammonia, sulphur dioxide and fluorine in liquid state are used in refrigeration and air conditioners.

4. Measurement lamp & theories of Radiation

- | | | |
|------------------|--------------------------------------|-----------------------|
| <u>Radiation</u> | <u>Heat \Rightarrow</u> | 1) conduction (solid) |
| | | 2) convection (fluid) |
| | | 3) Radiation |

Radiation: The radiation emitted by a body ^{without} without its temperature without the involvement of medium is known as radiation.

Properties: ① The radiation travels in vacuum, it travels in straight line path ② It undergoes reflection, refraction and total internal reflection

④ It follows inverse square law.

⑤ It exhibits the phenomenon of interference, diffraction & polarization.

⑥ When the radiation falls on the surface it exerts some pressure on the surface it is called thermal pressure.

Blackbody:

A body that absorbs all the radiation incident on it is called black body.

1. Its absorptive power is $(\alpha) = 1$ ~~Lambdaback = 0.2~~

2. As per Kirchoff's law good absorbers are good emitters. So Blackbody is a good absorber as well as emitter.

3. When this is heated at a particular temperature it emits the radiation of all the wavelengths \Rightarrow gives continuous spectrum.

4. The wavelength of emitted radiation depends on the temperature of the blackbody but not on the nature of material of the body.

5. There is no perfectly black body in the universe but platinum black & Lampblack considered as black body because their absorptive power is nearly 0.98.

Foucault Black Body:

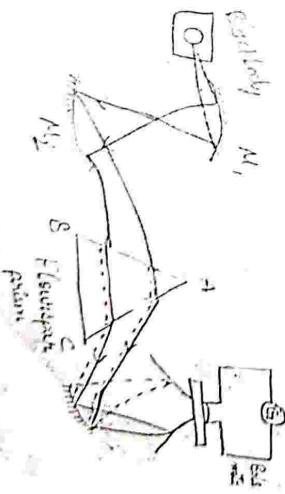
1. Foucault black body is a double walled spherical. The space between the two walls is evacuated to avoid loss of heat by conduction & convection.

2. The outer surface of outer sphere is polished with Nickel and the inner surface of the inner sphere is coated black.

3. It has some opening 'O' for the entrance of radiation into black body. A conical projection 'P' is arranged quite opposite to the opening 'O' to avoid normal incidence of radiation.

4. The radiation entered through the opening 'O' will get multiple-reflections on the black body surface. At each reflection some energy is absorbed like this total energy is absorbed.

5. The opening 'O' act as a black body.



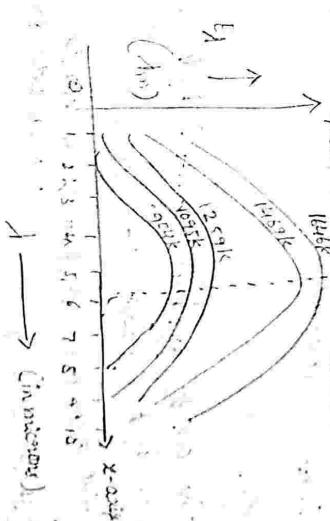
Energy distribution of black body radiation:

- The divergent beam of radiation from the black body is made convergent beam by the concave mirror m_1 , if this beam is made parallel by the concave mirror m_2 .
 - This parallel beam of radiation incident on closed path prism. This beam is dispersed into different wavelengths.
 - Different wavelengths come out in different directions. Rays of same wavelength are parallel to one another.
 - The concave mirror m_3 focused on different wavelengths in different directions. The bolometer is placed in the path of radiation. By rotating m_3 , different wavelengths can be focused on bolometer.
 - E_λ (incident radiation) is measured by using bolometer for different values of λ .
 - The experiment is repeated by keeping the black body at different temperatures.
- Properties: The graph is drawn by taking E_λ on y -axis & λ on x -axis is called characteristic curve.

- The black body emits all wavelengths so it gives continuous spectrum. The energy distributed non-uniformly i.e. the energy emitted is small at very short wave lengths. Because the curve is asymmetric about peak.
- The area below the curve is numerically equal to total radiation emitted by a blackbody. The E_λ values increases corresponding temperature of the body increases.

4. The peak or most probable wavelength λ decreases as temperature 'T' increases, i.e. Wien's displacement law = $\lambda \propto T^{-1}$ constant.

$$\text{Wien's Displacement law} = \lambda \propto T^{-1} \text{ constant}$$



Loss of thermal radiation

$$G^1 \text{ Stefan's law} = \epsilon \sigma T^4$$

At a given temperature and wavelength the ratio of emissive power to absorptive power is same for all bodies and it equal to emissive power of the black body at that temperature.

1) Stefan Boltzmann law:

The amount of radiant energy emitted by a black body per unit time and unit area is directly proportional to the fourth power of the absolute temperature.

$$S = C \sigma T^4$$

where $C = \text{Stefan's constant} = 5.67 \times 10^{-8} \text{Watt/m}^2\text{K}^4$

Wein's displacement law:

The product of wavelength corresponding to maximum energy emitted by the black body and its absolute temperature is constant

$$\therefore \lambda \cdot T = \text{constant}$$

Wein's law

The energy distribution emitted by the black body is given by the

$$\frac{E_{\lambda} d\lambda}{E_{\text{total}} d\lambda} = A_1 e^{-\frac{\lambda}{A_2 T}}$$

where A_1, A_2 are constant $\lambda = \text{wavelength}$

Rayleigh-Jeans law

The energy distribution emitted by the black body

$$E_{\text{total}} = \frac{8 \pi k T}{\lambda^4} \text{d}\lambda$$

where $T = \text{absolute temperature}$

Bolzmann's law

The energy distribution emitted by the black body is given by

$$E_{\text{total}} = \frac{S \text{ Time}}{2^{5/4} \pi^5 h c^3 \lambda^5}$$

where $T = \text{absolute temperature of the body}$

Pyrometers:

Pyrometers are the instruments to measure the very high temperatures by using the laws of thermal radiation.

Types: There are 2 types of pyrometers

1. Total radiation pyrometers
2. Optical/Spectral pyrometers.

1. Total radiation pyrometers:

* These instrument measure the total radiation emitted by a body. In this pyrometer, the temperature is calculated by using Stefan's law.

2. Optical/Spectral pyrometers:

* These instrument compare the radiation of particular wavelength emitted by a body to that of the radiator of same wavelength emitted by a standard body.

* In this pyrometer the temperature calculated by using Wein's displacement law

Advantages: 1. These are used to measure the very high temperatures.

2. The body may not be in contact,
3. The body may be at infinite distance.

3. Any temperature can be measured by extrapolating the graphs of radiation laws.

Disadvantages: 1. The minimum temperature to be measured with pyrometer is 600°C .

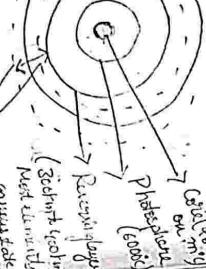
2. The measured temperature with pyrometer is always less than the actual value.

Temperature of Sun:

The different layers of the sun as shown in fig. The sun consist of a central

hot core having a temperature of $20 \text{ million}^{\circ}\text{C}$.

thus first cell photosphere has boundary



of 600°C . The boundary of this first cell photosphere has boundary \rightarrow 600°C . The next 300km to 600km thick layer is called reverberating layer which contain most of the elements in gaseous state. The extension of reverberating layer is called chromosphere. Finally we get a gaseous layer which extends to more than half million km is called corona.

Consider the sun as the perfectly black body &

the solar constant value "S" is 1340 W/sec . Let 'R' be the radius of the photosphere of the sun. Hence the surface area of the photosphere of the sun is $4\pi R^2$.

now with

from Stefan's law,

$$\text{The energy emitted from the surface of the sun per minute} = 4\pi R^2 \times 574 \times 60 \rightarrow (1)$$

The same energy spread in all directions from the sun let us consider distance b/w the sun & earth is smaller. Then surface area of the sphere of the earth = $4\pi r^2$.

If 'S' is the solar constant & the energy received on the surface area of the sphere = $4\pi r^2 \times S \rightarrow (2)$

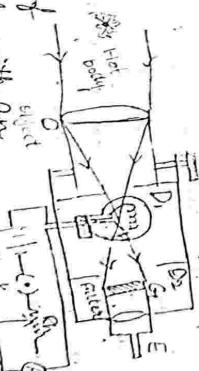
$$\therefore (1) \& (2) \text{ are equal}$$

$$4\pi r^2 \times S = 4\pi R^2 \times 574 \times 60$$

$$T^4 = \left(\frac{r}{R} \right)^2 \times \left(\frac{S}{574 \times 60} \right)^{1/4}$$

Disappearing filament Optical pyrometer:

Construction:



The disappearing filament optical pyrometer consist of a telescope fitted with an objective 'O' at one end & eyepiece 'E' at the other end. The distance b/w objective &

expiece can be adjusted by a screw & pilion screw arrangement.

- * From the fig the cross wires are the telescope are replaced by a electric lamp.

The filament of the bulb is connected to a battery, plugkey, Rheostat & Ammeter (A) in series.

(C) (E)

(Rn)

- * A red filter G₁ is arranged in front of the eyepiece S two D₁ & D₂ diaphragms are arranged before S after the bulb cone of radiation entering the telescope.

Working: 1. The objective of the pyrometer is facing the hot body whose temperature is to be measured.

2. By adjusting rock-pilon screw the image of the hot body is found on the filament of the bulb. The image of the filament & the image of the hot body are mixed by expiece E through the red filter.

3. Now the current is send to the filament by switching on the plug key 'K' and the current is varied by adjusting Rheostat until the filament disappears. The manual. The current is measured with the ammeter 'A'.

- 4. As both filament & image are equally bright, they must be emitting equal amount of energy for unit area per second. Hence they must be at same temperature.

Calculation: The temperature 'T' of the body is calculated by using a formula is given by

$$T = a + b\bar{T} + cT^2$$

where, \bar{T} = strength of the current flows through the circuit, a, b, c are constants.

These constants can be determined by calculating the against known temperatures. By using this pyrometer the temperature 600°C to 1500°C can be measured.

Solar Constant: (It is defined as, the amount of solar energy is received by a black surface per unit area per unit time when the surface is placed to the sun in

at the main distance of the earth from the sun in the absence of earth's atmosphere.

∴ The solar constant 'S' = 1340 watt/m² (or)

$$= 1.937 \text{ cal/cm}^2/\text{min}$$

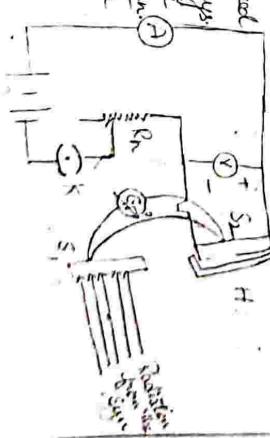
$$= 8100 \text{ J/m}^2/\text{min}$$

Determination of Solar Constant - Pyrometer

Construction: The Angstrom Pyrometer consist of two similar identically equal blackened platinum strips S₁, S₂.

These two strips are placed to normal to the surfaces. Here S₁ is open to receive the radiation from the sun. (2)

The strip S₂ is covered with double called shield H.



The backside of the two strips are connected to the junctions of thermocouple through a galvanometer.

* The strip S_2 is connected to an electrical circuit. In the circuit battery (B), plug key K , Ammeter A & Rheostat R are connected in series and voltmeter V is connected in parallel.)

Working:

1. (If the two strips S_1, S_2 are uncovered, they both exposed to sun radiation). Then the two strips or two junctions of thermocouple are at the same temperature & no affection is observed in the galvanometer.
2. (If the strip S_2 is covered with the shield H . Then the strip H_1 is at high temperature and the strip H_2 is at a low temperature.)
3. Now the current is sent through the circuit $\&$ is adjusted by using Rheostat until the galvanometer shows zero deflection. Then note the voltage V and I values.
4. At this stage the two strips are at the same temperature. That strip both strips receive same amount of heat.
- ∴ Heat received by S_1 from the sun = Heat received by S_2 from the circuit.

$$S \propto A \propto V \times I$$

$$\therefore S = \frac{VIT}{A}$$

where S = solar constant
 A = Area of the front surface
 V = voltmeter reading
 I = current

The experiment is repeated throughout the year for different zenith angles. The average solar constant throughout the year for different zenith angles is calculated by using formula $[S = S_0 T_{\text{sec}}]$

Here T = Transmission coefficient of atmosphere

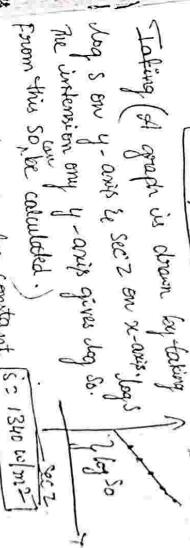
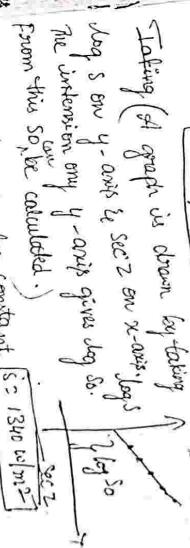
S_0 = Actual solar constant $\&$

Taking the logarithms on both side of the equation

$$\log S = \log S_0 T_{\text{sec}}$$

$$= \log S_0 + \log T_{\text{sec}}$$

$$\Rightarrow \log S = \log S_0 + \log T_{\text{sec}}$$



$$S_0 = 1340 \text{ W/m}^2$$

Unit-S. Thermoelectricity

Sebek effect: Thermoelectricity is phenomenon in which heat energy is converted into electrical energy

Introduction: Thermoelectricity is phenomenon in which heat energy \Rightarrow electrical energy

Heat energy \Rightarrow electrical energy. May occur in numbers, having a certain

* In this phenomena one junction has a higher at junctions of dissimilar conductors 2. Peltier at junctions of similar conductors 1. Seebeck effect

Effect 3. Thomson effect.

1. Siebeck effect: In 1826, Siebeck discovered that "when two wires of dissimilar metals (copper & iron) are joined in a series formed a closed circuit & their junctions are maintained at different temperatures, an EMF is developed & electric thermo EMF is the phenomena is known as siebeck effect : The current generated is called thermo electric current."

* The thermo EMF depend upon 1. Nature of the two materials used.

2. The temperature difference of the metals

Explanation:

The above figure shows arrangement to demonstration of siebeck effect. From the fig. a copper wire & an Fe wire are joined to form two junctions A(Cold) & B(Hot). A galvanometer 'G' is connected in the circuit to know the direction of current.

In one of the junction is kept at 0°C & the others gradually heated, an electric current flows through the circuit.

The direction of current is from Cu to Fe through the hot junction. The thermo EMF developed in this thermo couple which is 38 mV for the temperature difference of 100°C is measured using potentiometer.

Thus, heat energy is converted into electrical energy.

In 1856, Thomson observed that when two parts of a single conductor are maintained at different temperatures & a current is passed through it, heat is absorbed or evolved in different sections of the conductor. Thus heat is measure of joules heat $Q = i^2 R t$. This effect is known as Thomson effect.

A/C to Thomson effect heat is absorbed or evolved in excess of jades heat when current is passed through an unequal heated conductor.

Explanation:

In case of Cu rod if the current is passed as indicated fig (a), heat will be absorbed in the AB part & heat evolved in the part BC. Thus heat is absorbed i.e. the cold - Heat is evolved when the current flows from the hot to cold end. In this case Thomson effect said to be positive.

Increase of iron rod, if the current is passed as indicated in fig B. Heat will be evolved in part AB & heat is absorbed in part C. Thus heat evolved when the current flows from cold to hot end & the

heat is absorbed from hot end to cold end

In this case

Thomson coefficient:

It is defined as the amount of heat absorbed or evolved are 1 Coulomb positive charge is passed through a part of conductor whose ends are maintained at a unit temperature difference.

This is denoted by ' σ ' Therefore Thomson coefficient

$$\sigma = \frac{\Delta H}{(\Delta Q)(\Delta T)}$$