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Unit 4-Energy Sources

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[A] Fuels

* Introduction:

- Definition of Fuel-

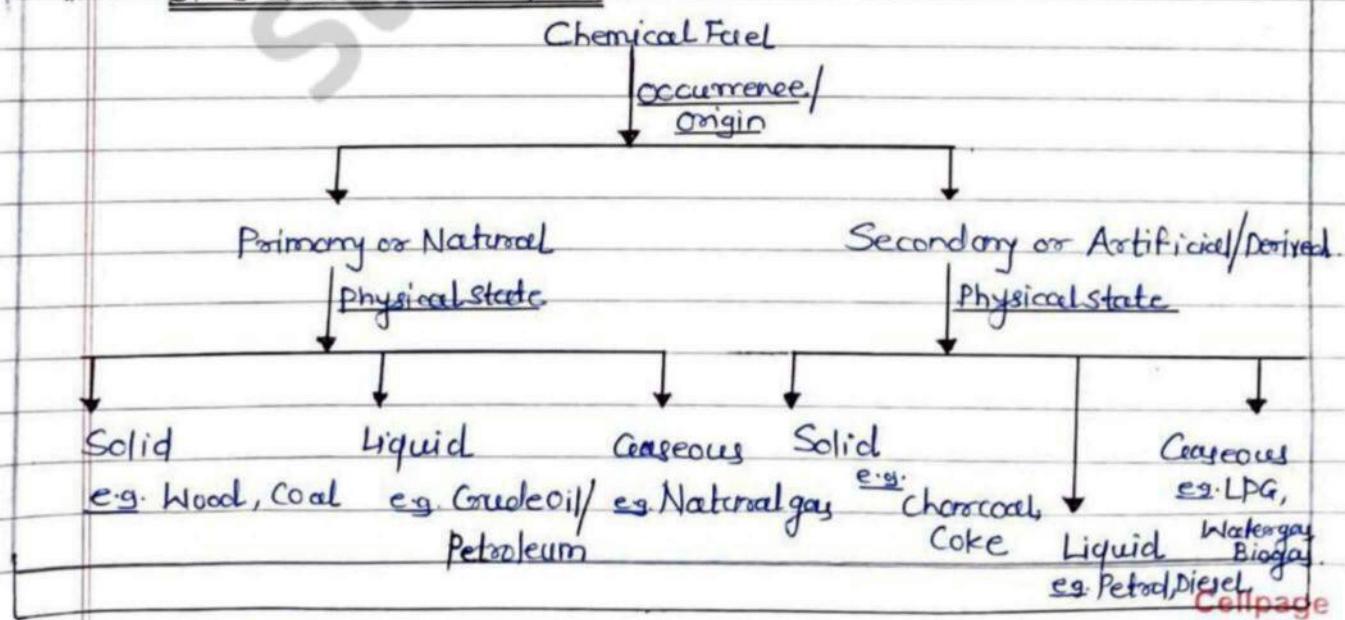
Fuel is defined as 'combustible substance' containing Carbon as main constituent which on proper burning in air produces large amount of heat which can be used economically for domestic and industrial purposes.

e.g. Wood, Coal, Charcoal, Kerosene, Diesel, Petrol, CNG gas, Water gas etc.

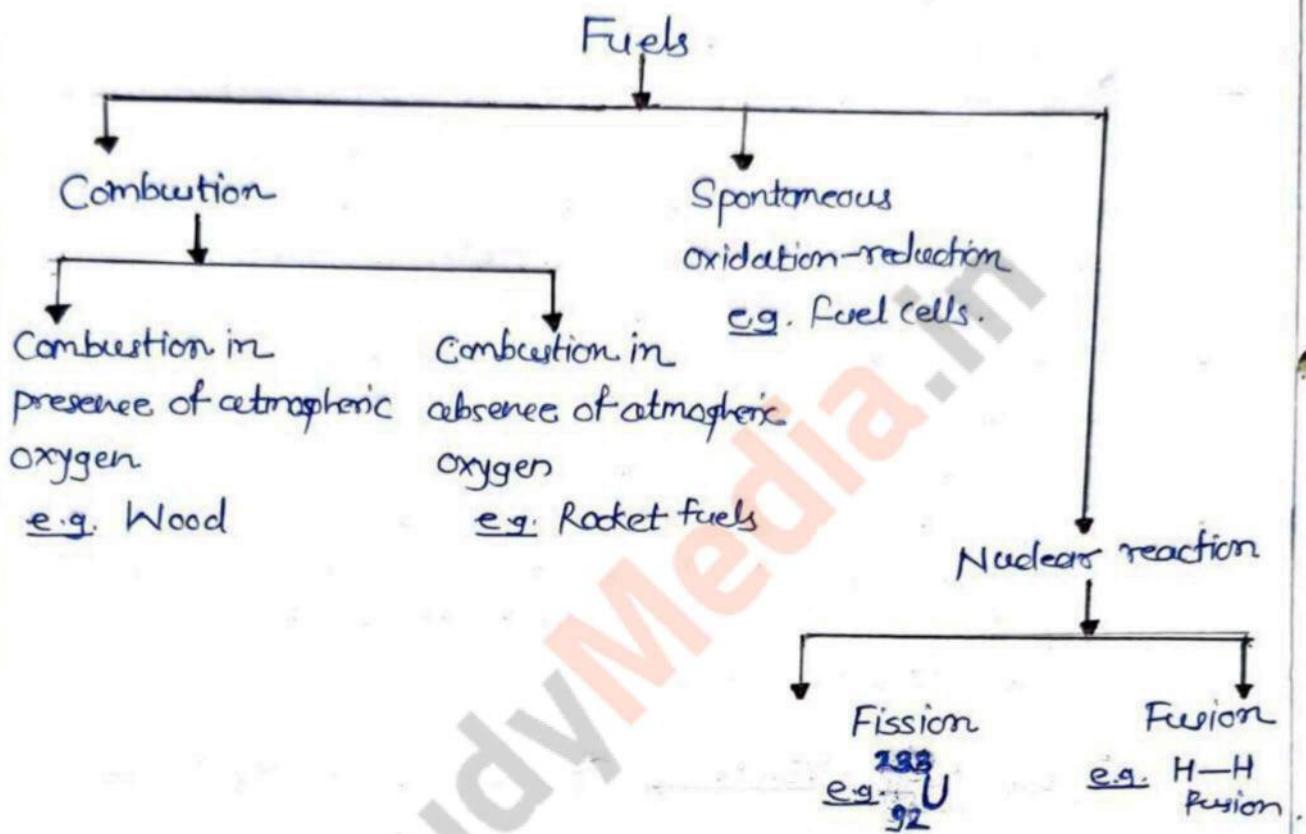
- The heat obtained by burning of fuels is utilized for industrial and domestic heating, power generation in thermal power plants, transportation etc.
- In the modern age of industrial revolution, there is a vast requirement of power and heat. Fuels on burning produces large amount of heat which can be converted into electricity.



* Classification of Fuel:



Based on Chemical Reactions :



* Calorific Value of fuel:

Calorific value is the most important property of fuels which gives idea about efficiency of a fuel to produce heat on combustion.

• Definition: It is defined as the total amount of heat liberated by complete combustion of unit mass of solid or liquid fuel or unit volume of gaseous fuel.

• Types of calorific value:

1. High / Gross Calorific Value (H.C.V. / G.C.V.)

2. Low / Net Calorific Value (L.C.V. / N.C.V.)

(1) High / Gross calorific value:

It is the total amount of heat liberated when unit mass of a solid or liquid fuel or unit volume of gaseous fuels are burnt completely in presence of sufficient oxygen or air and the combustion products are allowed to cool at room temperature.

(2) Low / Net Calorific Value:

It is the amount of heat liberated when unit mass of a solid or liquid fuel or unit volume of gaseous fuels are burnt completely in presence of sufficient oxygen or air and combustion products are allowed to escape as soon as they are formed.

• The N.C.V. & G.C.V. are related as;

$$G.C.V. = N.C.V. + L \quad \text{where; } L = \text{latent heat of condensation of water.}$$

$$\therefore G.C.V. = N.C.V. + 0.09 \times 1.1 \times 587 \frac{\text{cal/g}}{\text{kcal/kg}}$$

$$\therefore L = \frac{9 \times 1.1 \times 587}{100}$$

$$\text{or } L = 0.09 \times 1.1 \times 587 \frac{\text{cal/g}}{\text{kcal/kg}}$$

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* Units of Calorific Value:

| System | Calorific value | |
|--------|----------------------|-----------------------|
| | Solid or Liquid fuel | Gaseous fuel. |
| CGS | cal/g | cal/lit |
| MKS | kcal/kg | kcal/m ³ |
| SI. | joules/kg | Joules/m ³ |

- The interconversions of C.V. units for solid and liquid fuel is;

$$1 \text{ cal/g} = 1 \text{ kcal/kg} = 4.18 \text{ kJ/kg}$$

* Characteristics of Good Fuel:

Good fuel should have following characteristics.

1. High Calorific Value-

- A good fuel has high calorific value, so that larger amount of heat will be obtained on burning smaller quantity of fuel.
- Solid fuels contain some quantity of non-combustible material & it is left as Ash.
- Therefore solid fuels have lower calorific value than liquid & gaseous fuels.

2. Moderate Ignition Temperature-

- Ignition point is the minimum temperature at which continuous combustion of the fuel starts.
- Gaseous fuels have very low ignition temp. (C below 350°C) and it is risky to store and transport.
- Solid fuels have very high ignition point means it

is difficult to start combustion especially in rainy & winter seasons.

- Liquid fuels have moderate ignition temp. and are preferable in this regard.

3. Velocity of Combustion Controllable -

- A fuel is good if its combustion rate is controllable. By the proper rate of combustion, the required high temp. is attained easily and such fuel can be used economically.
- Rate of combustion of liquid and gaseous fuels can be easily controlled by use of nozzle, carburetor, jet, injection, burner etc. designs.

4. Harmless products of Combustion -

- A good fuel does not liberate any polluting or poisonous product gases.
- Solid fuels may contain upto 2% of sulphur and release SO_x pollutant. Combustion of a fuel with supply of excess of air, does not release CO pollutant.

5. No ash (Non-combustible residue) matter -

- A good fuel does not contain any non-combustible matter. If a fuel contains minerals, it leaves the matter in the form of ash.
- All solid fuels contain more or less non-combustible matter.
- Each percent of ash in a fuel decreases calorific value by 1.5%.

6. Low cost / Cheap in cost -

A good fuel is cheap and the cost of production & storage in bulk is low.

7. Easy to store & transport -

- Fuel must be easy to handle, store and transport at low cost.
- Solid fuels are risk free in transportation but laborious.
- Gaseous fuel can be easily piped but there is danger of explosion in transportation.
- Liquid fuels are good in this regard.

8. No moisture -

- If fuel contains moisture, it decreases C.V. in the form of latent heat loss.
- Liquid & gaseous fuels do not contain moisture and are good fuels in this regard.

9. Volatile matter -

- The portion of the fuel, which leaves in product gases without burning, is known as volatile matter.
- V.M. elongates flame, decreases flame temperature and decreases cal. Value of fuel.
- A good fuel does not contain any V.M. The volatile matter causes air pollution.
- Solid fuels usually contain V.M.. If the combustion of a fuel is carried out in the presence of insufficient air, then the smoke is rich with volatile matter.

* Solid Fuel - Coal

- Coal is a highly carbonaceous matter that has been formed as a result of alteration of vegetable matter such as plant under certain favourable conditions. It is chiefly composed of C, H, O and N besides non-combustible inorganic matter.

or

Coal is a complex organic compound derived from the dead plants under certain favourable conditions.

- The origin of the coal is due to gradual decomposition of vast deposits of wood buried under the earth long ago, under excessive pressure, by the action of aerobic & anaerobic bacteria for a long time.
- The process of conversion of wood into coal is known as Coalification.
- Uses of Coal -
 - i) As an industrial fuel for heating furnaces and boilers.
 - ii) In many metallurgical operations
 - iii) In the manufacture of fuel gases like coal gas, water gas and producer gas.
 - iv) In the manufacture of Synthetic petrol.

* Various Types Of Coal:

- The important types of coal are - peat, Lignite, Bituminous, Anthracite.
- The conversion of wood (plant matter) into coal takes place progressively. Depending upon the extent of transformation, Coals are divided into 4 types or grades or ranks.

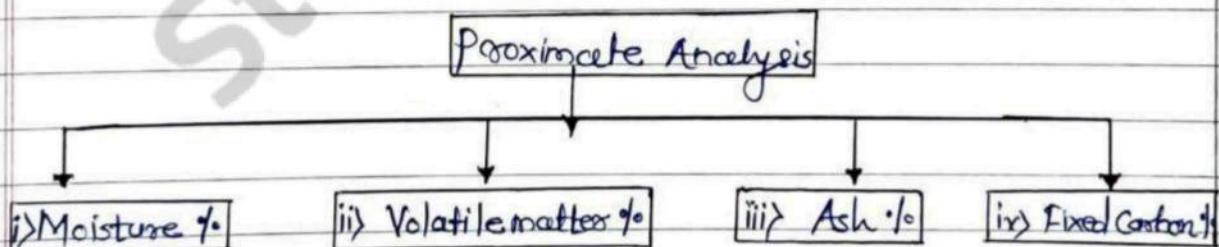
* Analysis of Coal.

The purposes of coal analysis are:

- i) To decide price of coal.
- ii) To determine quality.
- iii) To specify use of coal for a particular purpose.
- iv) To calculate theoretical calorific value of coal.
- v) To calculate air requirement for complete combustion of coal & design the furnace fire box scientifically.
 - A sample of coal taken out from coal mine is analyzed in two ways;
 - ① Proximate analysis
 - ② Ultimate analysis

① Proximate analysis of coal :

- Definition: Proximate analysis is the study or analysis of coal sample in which % of moisture, % of volatile matter, % of Ash & the % of fixed carbon is determined experimentally.



- The proximate analysis is easy and quicker. It gives a fair idea about the quality of coal.
- Procedure for proximate analysis of coal:-

i) Moisture %

- A known weight of powdered air dried coal

sample is taken in a crucible, and it is placed in an oven for 1 hour at 110°C.

- Then the coal is cooled in a desiccator and weighed out.
 - If the initial weight of the coal is ' m ' gms and final weight is ' m_1 ' gms, then the loss in weight ($m - m_1$) corresponds to moisture in coal.
- Formula: Moisture % = $\frac{\text{Loss in weight}}{\text{Weight of Coal Sample}} \times 100$
 $= \frac{m - m_1}{m} \times 100$.

ii) Volatile Matter %

- Moisture free coal left in the crucible in first step expt. (m_1) is covered with a lid loosely.
- Then it is heated at $925^\circ \pm 20^\circ C$ in a muffle furnace for 9 minutes.
- The hot crucible is taken out and cooled first in air, then inside a desiccator and weighed again (m_2 gms).
- The loss in weight ($m_1 - m_2$) is due to loss of volatile matter in the ' m ' gms of the coal sample.

• Formula: Volatile matter % = $\frac{\text{Weight of volatile matter}}{\text{Weight of air dried sample}} \times 100$
 $= \frac{(m_1 - m_2)}{m} \times 100$

- The volatile matter % can also be determined by taking the fresh weight of the air dried coal but the loss in weight at $925^\circ C$, will be due to loss of

moisture and volatile matter both.

- If w is the weight of air dried coal & w_1 is the mass of coal left at 925°C heating, then

$$\begin{aligned}\text{Volatile matter \%} &= \frac{\text{Loss in wt. due to moisture} \times 100}{\text{Weight of Coal Sample}} - \text{moisture \%} \\ &= \frac{(w-w_1) \times 100}{w} - \text{moisture \%}\end{aligned}$$

iii) Ash %

- The residual coal in the crucible in step(e) is then heated with open lid (in presence of oxygen) in a muffle furnace at above 750°C for half an hour.
- The coal gets burnt. The ash left in crucible is cooled in a desicator and weighed (in gms).

• Formula: $\text{Ash \%} = \frac{\text{Weight of Ash} \times 100}{\text{Weight of Coal}} = \frac{m_2}{m} \times 100$

iv) Fixed Carbon %

The percentage of fixed carbon in a coal is determined by deducting the sum of total percentage of moisture, volatile matter and ash from 100.

• Formula: Percentage of fixed carbon = $100 - \% \text{ of } [\text{Moisture} + \text{Volatile matter} + \text{Ash}]$

or

$$\text{Fixed carbon \%} = 100 - (\text{moisture \%} + \text{V.M. \%} + \text{Ash \%})$$

* Significance of proximate Analysis: (Importance of proximate Analysis)
Proximate analysis provides valuable information in assessing the quality of coal as given below;

i) Moisture:

- Quality of coal gets reduced due to presence of excess moisture in it.
- Moisture in coal evaporates during the burning of coal and removed as steam, it takes same amount of heat.
- Therefore, presence of moisture in coal reduces its calorific value and it increases the transportation charges. Also it increases ignition point of coal.
- Hence lesser the moisture content, better the quality of coal as fuel.

ii) Volatile Matter:

- A high volatile matter content means high proportion of fuel distills over as gas and large proportion of which escapes unburnt, so higher amount of vol. matter in coal is not desirable.
- A high vol. matter containing coal burns with a long flame, high smoke and has low calorific value.
- Hence, lesser the volatile matter, better will be the rank of coal.

iii) Ash:

- It is useless, non-combustible matter and it reduces calorific value of fuel.
- Moreover, ash causes the hindrance to the flow of air and heat, thereby lowering the temperature.
- Due to formation of clinkers (Fused ash lumps), it causes trouble during firing and which blocks the interpaces of the grate, on which coal is being burnt. Also, it causes

obstruction to air supply, thereby the burning of coal becomes irregular.

- The presence of ash increases cost of transportation, handling & storage. Also, there is a big problem of ash disposal.
- Hence, better is the quality of coal if ash content is low.

iv) Fixed Carbon:

- A high percentage of fixed carbon is desirable, it increases the rank of the coal.
- Therefore, higher the percentage of fixed carbon, greater is its calorific value and better the quality of coal.
- Hence, a good fuel should have higher percentage of carbon.

② Ultimate Analysis Of Coal:

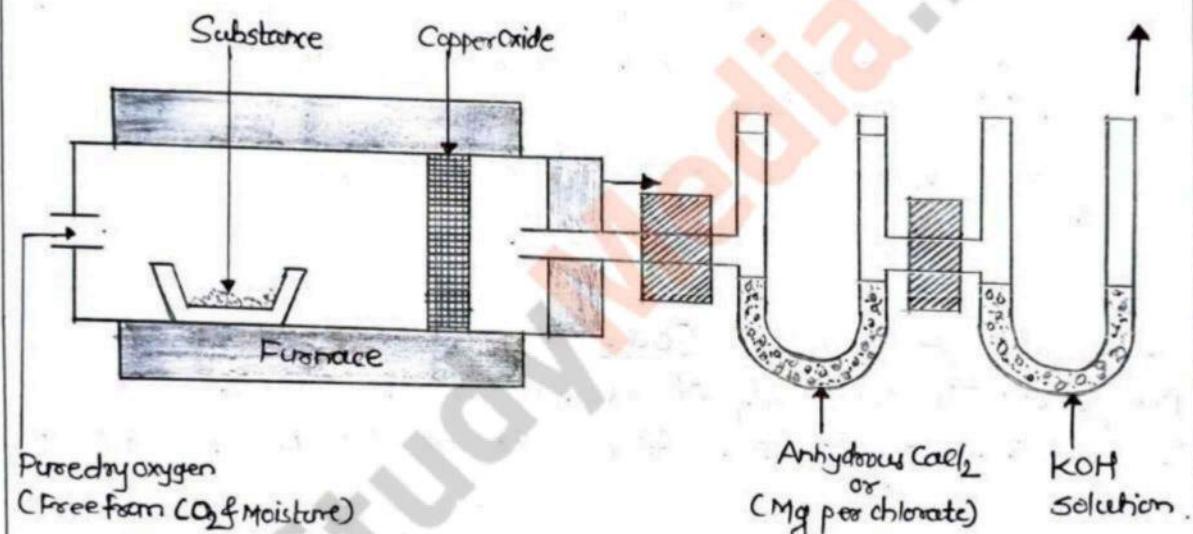
- Definition: The analysis of coal in which percentage of C, H, N, S & O elements are found out, is known as ultimate analysis.

i) Determination of percentage of Carbon & Hydrogen.

- * principle: The carbon in the coal gets converted to CO_2 and hydrogen to H_2O vapours, on burning in the presence of pure O_2 .

* Method:

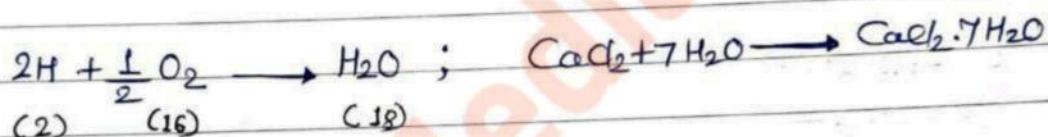
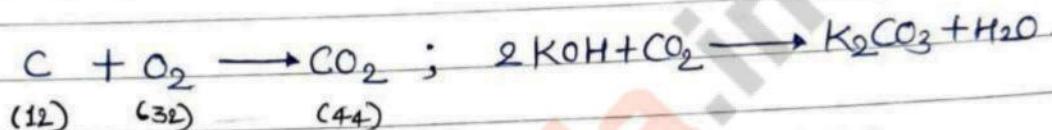
- i) A known weight of powdered and air dried coal sample is burnt in the presence of pure oxygen, in a combustion apparatus. C & H are converted to CO_2 and H_2O respectively.



* Combustion Apparatus *

- ii) The gaseous products of combustion are absorbed in U-tubes containing KOH and CaH₂, CO₂ is absorbed in KOH tube and H₂O is absorbed in CaH₂ tube.
- iii) The increase in weights of these tubes are then determined.
- iv) Then the amount of carbon & hydrogen can be calculated.

* Reactions:



* Formulae for Calculation:

$$C \% = \frac{\text{Weight of } CO_2 \text{ formed}}{\text{Weight of coal sample}} \times \frac{12}{44} \times 100$$

$$H \% = \frac{\text{Weight of } H_2O \text{ formed}}{\text{Weight of coal sample}} \times \frac{2}{18} \times 100$$

ii) Determination of percentage of Nitrogen.

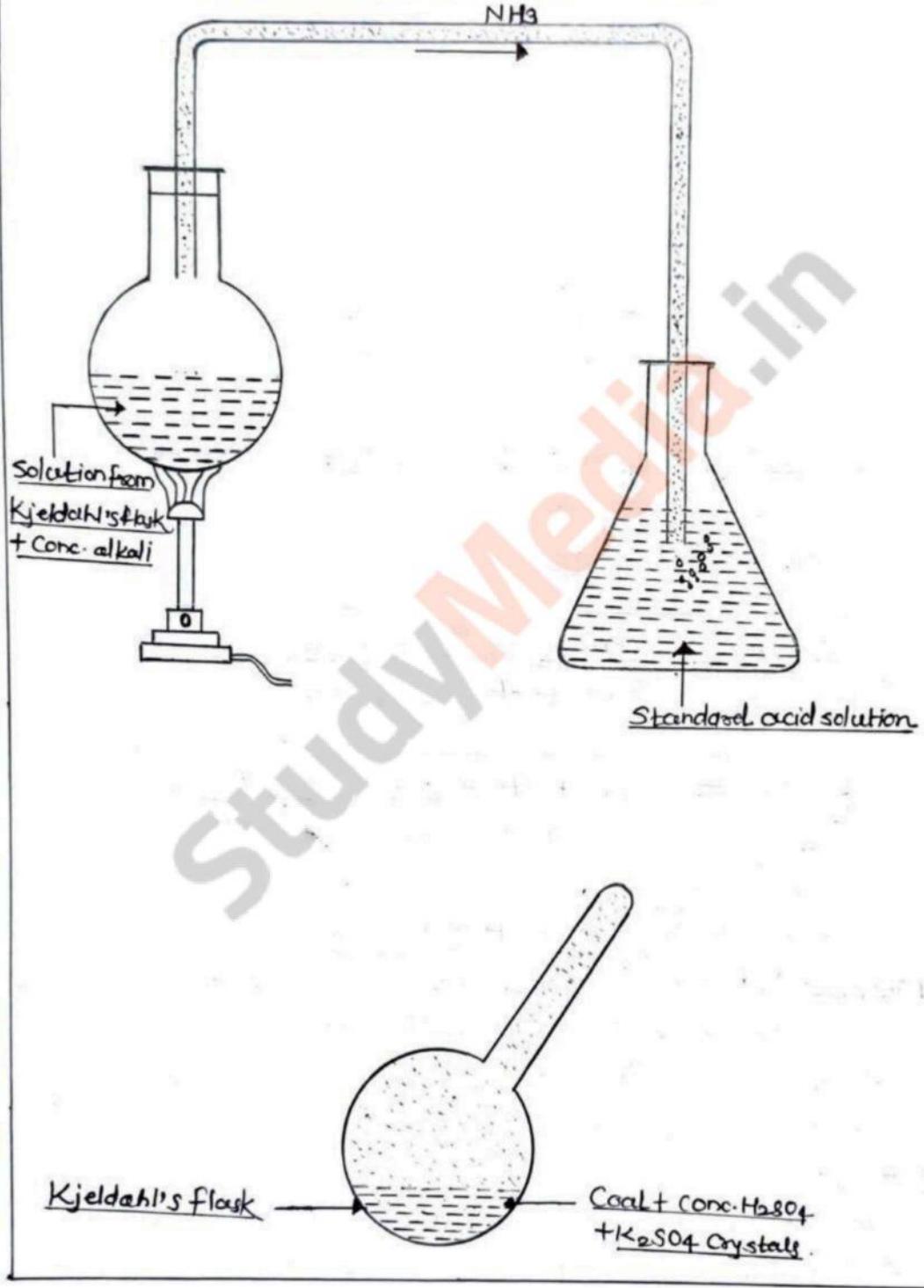
* Principle: Nitrogen in coal gets converted to ammonium sulphate, by action of hot concentrated H₂SO₄

and then on treatment with alkali solution, equivalent amount of NH₃ is liberated.

* Method:

- i) Estimation of nitrogen is carried out by Kjeldahl's method.
- ii) A known weight of powdered air dried coal is

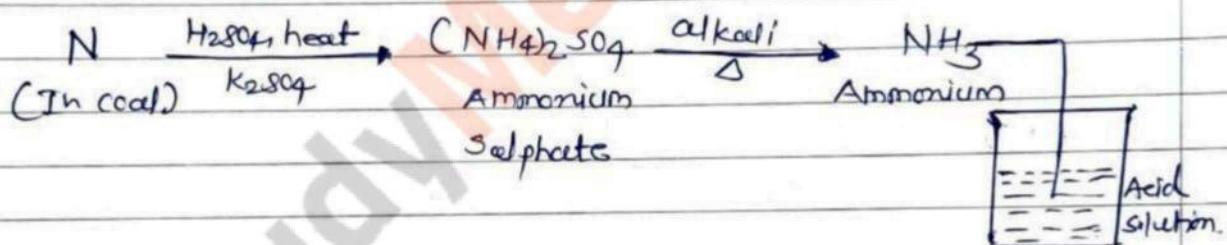
* Estimation of Nitrogen in Coal *



heated with conc. H_2SO_4 along with K_2SO_4 as a catalyst in a long necked Kjeldahl's flask till the soln. becomes clear.

- iii) Coal containing nitrogen is converted into $(NH_4)_2SO_4$ (Ammonium sulphate).
- iv) This solution of ammonium sulphate formed is then treated with alkali solution like $NaOH$ or KOH in a round bottom flask which liberates ammonia.
- v) This liberated ammonia is allowed to react with Std. acid solution of known volume.
- vi) From the volume of acid used by ammonia liberated, the percentage of Nitrogen present in coal is calculated.

* Reactions:



* Formula for calculation:

$$N \% = \frac{\text{Volume of acid consumed} \times \text{Normality of acid} \times 14}{\text{Weight of coal sample}}$$

iii) Determination of percentage of Sulphur.

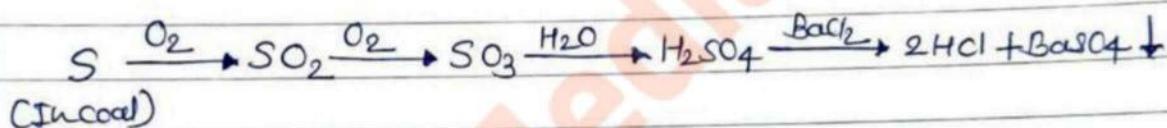
* Principle:

Sulphur present in coal converts to first SO_3 which is soluble in water forming H_2SO_4 . H_2SO_4 is then converted to $BaSO_4$ precipitate when treated with $BaCl_2$.

* Method / Procedure:

- i) Take about 10 ml of distilled water in the Bomb pot. Burn the known weight of powdered and air dried coal sample in the bomb calorimeter experiment.
- ii) Then collect the washings of the Bomb pot in a beaker. Add BaCl_2 solution in it.
- iii) Filter the precipitate of BaSO_4 , dry it and weight the precipitate of BaSO_4 . From the weight of BaSO_4 precipitate, percentage of sulphur can be calculated.

* Reaction:



* Formula:

$$\text{S \%} = \frac{\text{Weight of BaSO}_4 \text{ ppt.}}{\text{Weight of Coal sample}} \times \frac{32}{233} \times 100$$

iv) Determination of percentage of oxygen:

Percentage of oxygen is determined by deducting the sum of total percentage of C, H, N, S and ash from 100.

$$\text{O \%} = 100 - (\text{C \%} + \text{H \%} + \text{N \%} + \text{S \%} + \text{ash \%})$$

[Ash% determination is carried out as in proximate analysis]

* Significance / Importance of Ultimate Analysis.

i) Carbon:

Calorific value of coal depends on carbon present in it. The percentage of carbon depends on type of coal and it increases from peat to anthracite.

Greater the % of carbon, better is the quality of coal and higher is its calorific value.

ii) Hydrogen and Oxygen:

Most of the H & O in coal is in the form of moisture & volatile matter. Only a small percentage of them is combustible. Hydrogen combines with oxygen in coal to form moisture which requires heat for changing it into steam. It decreases the calorific value of coal.

Therefore, lower the percentage of 'H' & 'O' then the quality of coal is good and better is the rank of coal.

iii) Nitrogen:

Nitrogen does not burn during coal combustion and therefore it has no calorific value.

Hence a good quality coal contains negligible N %.

iv) Sulphur:

Although Sulphur can burn and increases calorific value of coal but when it oxidized, produces corrosive gases like SO_2 & SO_3 , which have harmful effect and corrodes the equipments. It also pollutes the atmosphere & causes acid rain.

Hence, lower the % of S in coal, better is coal quality.

* Determination of Calorific Value:

I] Bomb Calorimeter

- Calorific value of solid and nonvolatile liquid fuels can be determined using Bomb calorimeter.

- Principle :

A known quantity of fuel is combusted in the calorimeter and the heat generated is allowed to absorb / acquire by known quantity of water. From rise in temperature of water, the calorific value of the combusted fuel can be determined by using the law of conservation of Energy.

- Construction:

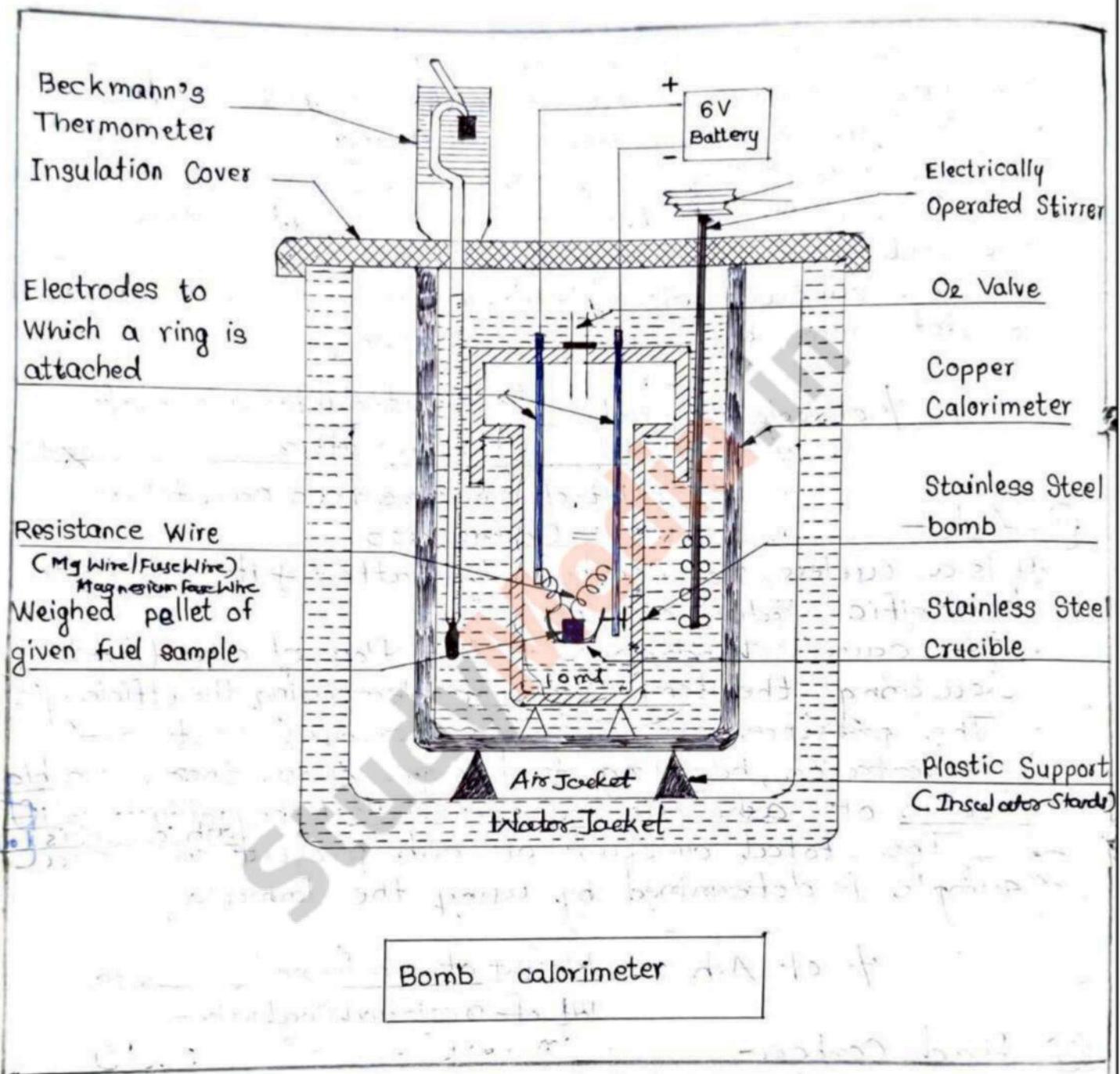
A Bomb calorimeter consists of main three parts:-

- ① Bomb Pot.
- ② Calorimeter.
- ③ Water and Air Jackets.

- ① Bomb pot -

- It is a strong, cylindrical stainless steel pot which is corrosion resistant in which the combustion of fuel is made to take place.
- It has a lid, which can be screwed to the body of the bomb pot so as to make a perfect gas-tight seal.
- The lid is provided with two stainless steel electrodes and an oxygen inlet valve.
- To one of the electrode, a small ring is attached.

In this ring, a nickel or stainless steel crucible can be supported, in which fuel of known weight is taken.



② Calorimeter-

- The Bomb pot is placed in a copper calorimeter containing known quantity of water.
- Copper calorimeter is surrounded by Air-jacket and Water-jacket to prevent heat losses due to radiation.
- The calorimeter is provided with an electrically operated timer and Beckmann's thermometer which can read temperature difference upto $1/100$ th of a degree Celsius accurately.

③ Water and Air Jackets-

- A copper calorimeter is surrounded by Air-jacket and Water-jacket to prevent heat losses due to radiation.
- There are insulator stands between Water-jacket and Air-jacket.
- Working:
 - A known weight of the fuel (about 0.5g to 1.0g) is taken in a clean crucible. The crucible is then placed over the ring attached with an electrode.
 - A fine magnesium wire, touching the fuel sample, is then stretched across the electrodes. This system acts as a fuse.
 - Add about 50 ml of distilled water at the bottom of Bomb pot and fix the lid tightly to the Bomb pot by screwing.
 - Bomb pot is filled with oxygen at the pressure about 25 atm.
 - Then Bomb pot is placed in a copper calorimeter and known volume of water is added into the calorimeter so that Bomb pot get immersed in the water.

FOR EDUCATIONAL USE

- The calorimeter is then placed in the water-jacket over the plastic stands and the thermometer and stirrer is placed into the reactor of calorimeter.
- Plastic cover is kept on the top and electrical connections are made from battery to electrodes.
- The electrodes are connected to 6 Volts battery and current is passed for 5-10 seconds. This ignites the magnesium fuse wire which provides ignition to the fuel.
- The fuel sample burns completely and heat is liberated.
- The heat liberated by combustion of the fuel is absorbed by the water in the calorimeter. Stirring of water in calorimeter is continued for uniform distribution of heat and the maximum temp. attained is noted.

- Calculation:

Let,

' x ' g = Mass of fuel taken in crucible

' w_1 ' g = Mass of reactor in calorimeter

' w_2 ' g = Plate equivalent of calorimeter, stirrer, bomb pot, thermometer etc.

t_1 °C = Initial temperature of water in calorimeter

t_2 °C = Final temperature of water in calorimeter

' L ' cal/g = Gross/higher calorific value of the fuel.

- Heat liberated by fuel = $x \cdot L$

- Heat absorbed by water and apparatus = $M \times C_p \times (t_2 - t_1)$
[where M = Mass & C_p = Specific heat of water = 1 cal/g]

$$\therefore \text{Heat absorbed by water and apparatus} \\ = (W+w) \times 1 \times (t_2 - t_1)$$

And,

Heat liberated by fuel = Heat absorbed by water,
apparatus etc.

$$\therefore xL = (W+w) (t_2 - t_1)$$

$$\therefore \text{QCV of fuel (C)} = \frac{(W+w)(t_2 - t_1)}{\infty} \text{ cal/g or} \\ \text{kcal/kg}$$

or

$$\text{QCV (C)} = \frac{4.197 (W+w)(t_2 - t_1)}{\infty} \text{ J/g or} \\ \text{kJ/kg}$$

* Corrections :-

For accurate cal. of GCV, following correction are made:

1) Fuse Wire Correction (f) :-

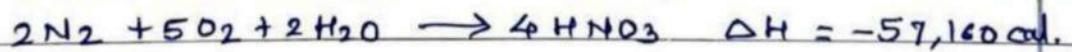
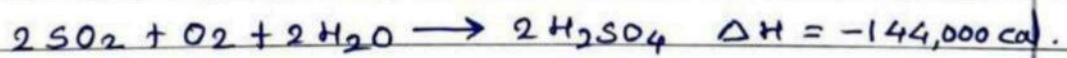
As Mg wire is used to start continuous combustion of fuel, some part of the heat generated by burning of Mg wire is also included in the higher calorific value. Hence, this amount of heat has to be subtracted from the total value.

2) Thread correction (t) :-

Cotton thread is used to tie the electrode, when GV battery is on, cotton thread burns & some part of heat is used to start the combustion of Fuel and the remaining heat is get added in CV of Fuel. Therefore, thread correction has to be subtracted from HCV of the fuel.

3) Acid correction (a) :-

During combustion, sulphur and nitrogen if present in the Fuel is oxidised to their corresponding SO & NO_x gases. When these gases mix with water forms acid under high pressure & temperature.



As acid formation reactions are exothermic in nature, therefore the heat produce by these reaction has to be subtracted from the HCV of the Fuel.

4) Cooling Correction (t_{dt}) :-

As the temperature rises above the room temperature, because of cooling, actual rise in temperature is lowered. Therefore, cooling correction is to be added in the observed rise in temperature.

$$\text{cooling correction} = (t \times dt)$$

t = time taken to cool the water in the calorimeter from the maximum temperature to room temperature in minutes.

dt = rate of cooling

$$\text{Higher calorific value} = \frac{(W+w)(t_2 - t_1 + t_{dt}) - (a+F)}{CHCV} \times \text{cal/g}$$

or

$$\text{Higher calorific value} = \frac{4.184(W+w)(t_2 - t_1 + t_{dt}) - (a+F)}{CHCV} \times \text{J/kg}$$

* Determination of calorific value :- Boy's gas Calorimeter :-

- Principle of Boy's Calorimeter :-

A gaseous fuel is burnt at a known constant rate in the calorimeter under such condition that entire amount of heat produced is absorbed by circulation water.

- Construction of Boy's Calorimeter :-

It consists of following parts:

- i) Gas burner :-

There is a gas burner in which a known volume of gas is burnt at a known pressure. The gas is burnt at the rate of 3 to 4 lit. per minute.

- ii) Combustion chamber (chimney) :-

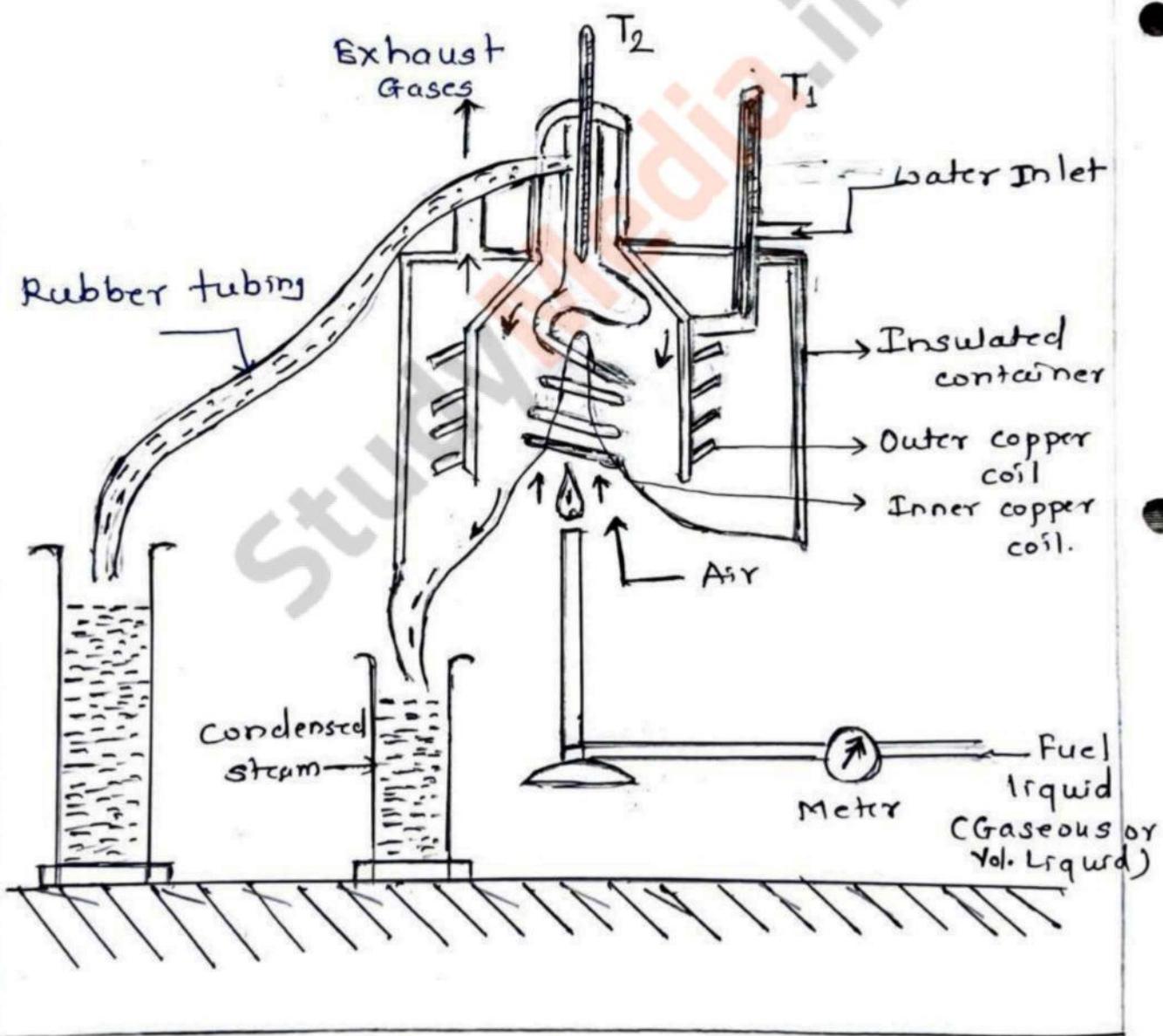
Around the burner there is a combustion chamber which has a copper tubing coiled inside as well as outside of it. Water enters from top of the outer coil, moves to bottom of chimney and then goes up through the inner coil to the exit at top.

- iii) Thermometers :-

There are two thermometers to measure temp. of inlet water and outlet water.

- iv) Insulating cover :- The assembly is covered with an insulator to detach combustion chamber from

Fig: Boy's gas calorimeter



atmosphere. There is a hole on top for exhaust gas, water inlet and condensed steam comes out from bottom outlet.

* Working of Boy's calorimeter:-

- i) Start burning the gas at suitable pressure and adjust the rate of water flow such that the temperature of outgoing water remains constant.
- ii) Burn the gas for 5-10 min. to have the steady temperature of outgoing water.
- iii) After the steady conditions of outgoing water temperature, constant water circulation & gas flow rate reached, simultaneously note the following,
 - a) Volume of gas burnt at given temperature & pressure in certain time period.
 - b) Quantity of water passed through coil during this period.
 - c) Mass of water condensed from product gas during the period.
 - d) The steady rise in temp. of water ($t_2 - t_1$)

* Calculations:-

First convert the volume of gas burnt to volume of gas at STP.

Let this STP volume be ' V ' m³.

Let,

W = mass of cooling water used in the period of observation, in kg.

m = mass of water condensate in kg.

L = G.C.V. of the Fuel.



\therefore Heat produced by combustion of Fuel = heat absorbed by cooling water (assuming no heat loss)

$$\therefore VL = W(t_2 - t_1)$$

$$\therefore b = \frac{W(t_2 - t_1)}{V} \text{ kcal/m}^3$$

\therefore The mass of condensate water per m^3 of gas will be, $\frac{m}{V}$ kg/m³

\therefore If this water had left as steam in product gases, it would have taken away.

$$\therefore \text{Heat} = \frac{m}{V} \times 587 \text{ kcal/m}^3$$

$$\therefore NCV = GCV - \frac{m}{V} \times 587$$

$$\therefore NCV = \frac{W(t_2 - t_1)}{V} - \frac{m \times 587}{V} \text{ kcal/m}^3$$

* Numericals :-

1) Observations in the Boy's gas calorimeter experiment on a gaseous fuel are given below, Find the G.C.V. & N.C.V of the fuel, Volume of gas burnt (STP) = 0.08 m^3
Mass of cooling water used = 29.5 kg

Rise in temperature of circulating water = 9.1°C
mass of steam condensed = 0.04 kg .

Given

- i) $V = 0.08 \text{ m}^3$, ii) $W = 29.5 \text{ kg}$ (Mass of water used)
- iii) $m = \text{Mass of steam condensed} = 0.04 \text{ kg}$.

* Alternative Fuels :-

- Increasing industrialization of the world has led to rapid depletion of the non-renewable fossil fuel. Also, the combustion of fossil fuels leads to lot of harmful emission.
- Power alcohol, biodiesel are the emerging alternative fuels.

1) Power alcohol :-

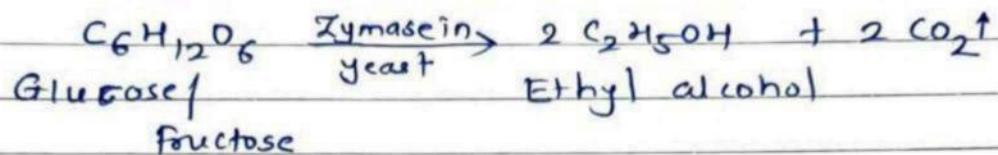
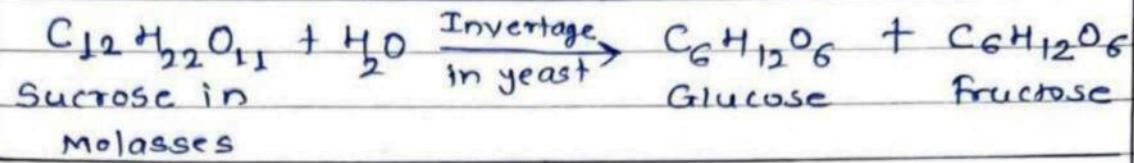
When ethyl alcohol is blended with petrol and is used as a fuel for internal combustion engines, it is known as power alcohol.

Alcohol is considered as an excellent alternative motor fuel for petrol engines, as it contains oxygen which contributes to combustion. Gasoline (petrol) blended with alcohol gives comparable performance as that of 100% unleaded gasoline with superior antiknocking properties.

• Production of ethyl alcohol :-

In India, ethyl alcohol is obtained from molasses which contains sucrose. Sucrose is converted into glucose & Fructose by means of enzyme Invertase from yeast at 30°C.

The enzyme zymase (from yeast) converts glucose and Fructose into ethyl alcohol and carbon dioxide by fermentation.



- Ethyl alcohol obtained contains 95.5% alcohol and 4.5% water.
- Water from alcohol separated by use of suitable dehydrating agents or by distilling along with benzene.

* Advantages of power alcohol :-

- High octane number O.N = 90, Petrol O.N = 65
- Saves currency
- Cheap, burns clean.
- It contains oxygen - help for complete combustion & reduces the release of harmful gases.
- It has property of absorbing any traces of water if present in petrol.
- Alcohol reduces chances of overheating of engine thus extending engine life.

* Disadvantages of power alcohol :-

- Low calorific value.
- Engine needs to be modified.
- Ethyl alcohol may undergo oxidation to form acetic acid which corrodes engine parts.

* Biodiesel :-

Definition :- Biodiesel is a biofuel obtained from renewable source of energy such as vegetable oil or animal oils by transesterification.

- It is mainly used as a fuel for diesel engine.
- Vegetable oils like soyabean oil, palm oil, Sunflower oil, peanut oil, cottonseed oil etc can be used for preparation of biodiesel.

* Chemical nature and Preparation of Biodiesel :-

- Vegetable or animal oil are mainly triglycerides of Fatty acids [ester of glycerol & 3 Fatty acids]. These oils have high viscosity, high flash point and low calorific value hence can not be used as such in conventional diesel engine.
- Vegetable / animal oils can be converted into biodiesel by the process known as transesterification.

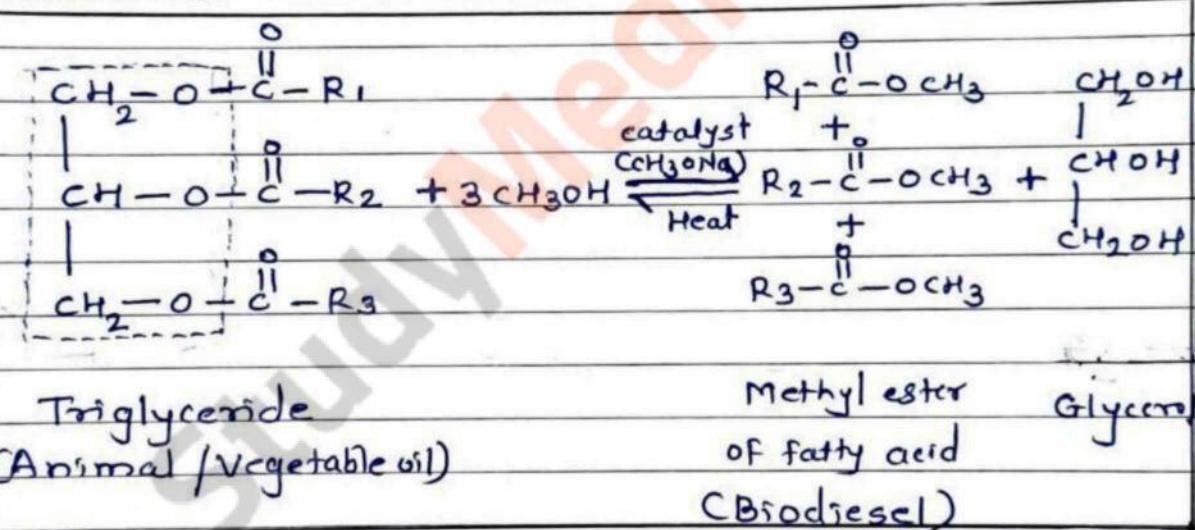
- 1) Take filtered, clean non edible vegetable oil in reaction vessel & heat to about 11°C to remove moisture.
- 2) Add about 2% Sodium methoxide ($\text{NaOH} + \text{Methanol}$) and 20% methanol in the vessel.
- 3) The mixture is refluxed at $60-70^{\circ}\text{C}$ for about 1 to 2 hrs.
- 4) mixture is cooled and mixed with water is dissolved glycerine formed in the reaction. If soap is formed, that will dissolved in water phase.
- 5) Water insoluble biodiesel phase is then separated

by using separating funnel.

a) Biodiesel so obtained is further proceed by adding suitable antioxidants to avoid oxidation and increase stability.

* Reaction :-

In this process, animal / vegetable oils are heated with excess of methanol in presence of catalysts like sodium methoxide, Potassium methoxide, NaOH / KOH. Catalyst should be free from moisture.



- R₁, R₂ and R₃ are the fatty acid alkyl groups. They can be same or different, depending on the type of oil.

Biodiesel can be used as an alternative fuel for diesel or it can be blended with petroleum diesel.

* Advantages of Biodiesel :-

- i) Biodiesel is cheaper, as it is manufactured from cheap, non-edible or waste oil or animal fats.
- ii) It has high cetane numbers 46 to 54 and high C.V. of about 40 kJ/gm.
- iii) It is regenerative and environment friendly.
- iv) It does not give out particulate and CO pollutants, as 'O' atoms in biodiesel help for complete combustion.
- v) It has certain extent of lubricity, due to higher oiliness of the esters.
- vi) Its use provides good market to vegetable oils and reduces our dependence on diesel on foreign countries saving currency.
- vii) It is clean to use biodiesel in diesel engines.

* Limitations of Biodiesel :-

- i) Cloud and pour points of biodiesel are higher than diesel and can cause problem in fuel flow line so it cannot be used in cold regions.
- ii) Biodiesel may have dissolving action on rubber hoses & gaskets.
- iii) There is shortage of vegetable oils and the starting material if costly, the biodiesel will be costly.
- iv) Biodiesel strongly adheres on metals and can become gummy.

* Hydrogen Gas as a Future Fuel :-

Hydrogen gas is considered as the fuel of 21st century, as the conventional energy sources available are very less. Hydrogen gas is considered as fuel as it can be synthesized of the future from variety of material available.

- Hydrogen is often considered as a future fuel because -

- i) It is non-toxic and clean burning
- ii) It has high calorific value as compared to fossil fuel.
- iii) It is the most abundant element on earth.

- The major problems associated with hydrogen are :

A) Its Production of hydrogen

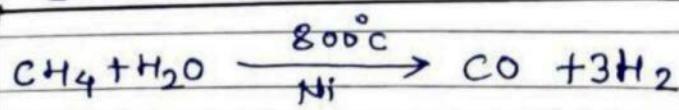
B) Its storage and transport of hydrogen.

A) Production of Hydrogen :-

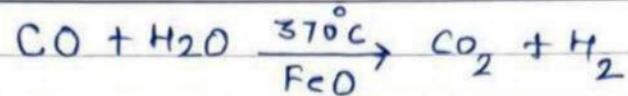
H_2 production is expensive and inefficient. Hydrogen can be produced from electrolysis of water, by water splitting using solar energy. However, the most cost-efficient method is the steam reforming of hydrocarbon and coke.

1) Steam reforming of hydrocarbon (Methane) :-

- Methane from natural gas is mixed with steam & passed over Nickel catalyst at $800^\circ C$ to produce water gas (mixture of $CO + H_2$).

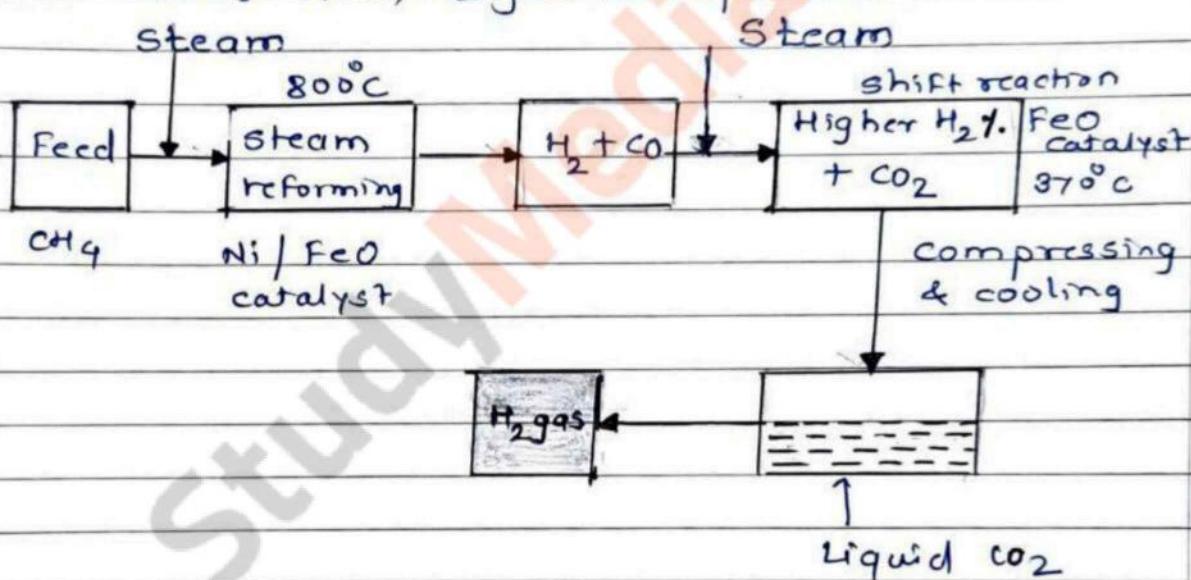


- Water gas on further reaction with steam at 370°C in presence of FeO catalyst produces additional H_2 .



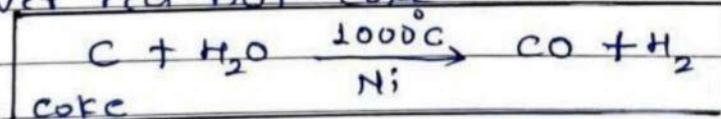
- Removal of CO_2 :-

The $\text{CO}_2 + \text{H}_2$ mixture is compressed and cooled to get liquid CO_2 & H_2 gas. CO_2 can also be removed by dissolving in water under pressure or by reacting with K_2CO_3 . Thus, H_2 gas is separated.



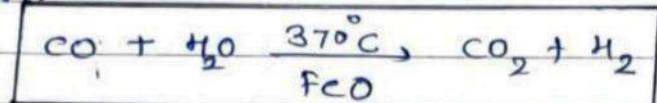
⇒ Steam reforming of coke :-

- Coke is obtained by carbonisation of coal.
- Hydrogen can be prepared by passing steam over red hot coke.



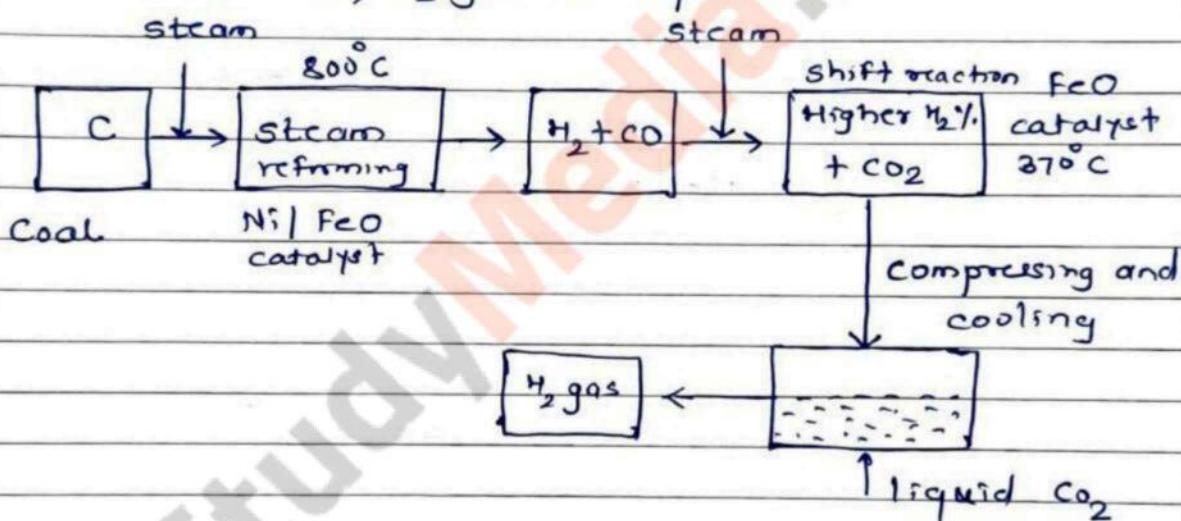
- The gaseous mixture ($\text{CO} + \text{H}_2$) is mixed with more steam at 370°C & passed over FeO catalyst to

produce additional hydrogen by water gas shift reaction.



Removal of CO₂ :-

The CO₂ + H₂ mixture is compressed & cooled to get liquid CO₂ & H₂ gas. CO₂ can also be removed by dissolving in water under pressure or by reacting with K₂CO₃. Thus, H₂ gas is separated.



B) Storage and transport of hydrogen :-

Current method of H₂ storage include :

i) Physical storage :-

a) In form of compressed H₂.

b) In the form of liquefied H₂.

c) By adsorption on porous carbon materials.

ii) Chemical storage :- a) In the form of metal hydrides. b) In the form of sodium alanates

• The difficulties in the storage & transportation of hydrogen are :

- 1) Hydrogen is the lightest gas i.e. 2 gms of H₂ occupy a volume of 22.4 lit. at STP. Hence, it has to be stored in cylinders in compressed form. The cost of compression is high.
- 2) Hydrogen gas is highly inflammable.
- 3) High pressure H₂ gas in steel cylinders leads to decarbonisation because of which steel become brittle.

c) Use of H₂ as a Fuel :-

- H₂ can be used as a rocket fuel.
- It can be used as a fuel in an internal combustion engine or in fuel cell.
- A hydrogen internal combustion engine is similar to a petrol engine in which hydrogen react with oxygen to produce hot gases which move the engine parts.
- A fuel cell is a device that uses H₂ (hydrogen rich fuel) and oxygen (oxidant) to generate electricity by an electrochemical reaction.
- A single fuel cell consist of two electrodes (anode and cathode) separated by an electrolyte.
- Hydrogen is supplied to the anode where a catalyst splits it into protons & electrons.
- The electrons cannot pass through the electrolyte to the cathode & move to it through an external circuit.
- Fuel cells are arranged in stacks to generate sufficient electricity to power a vehicle.

* Lithium Ion Battery :-

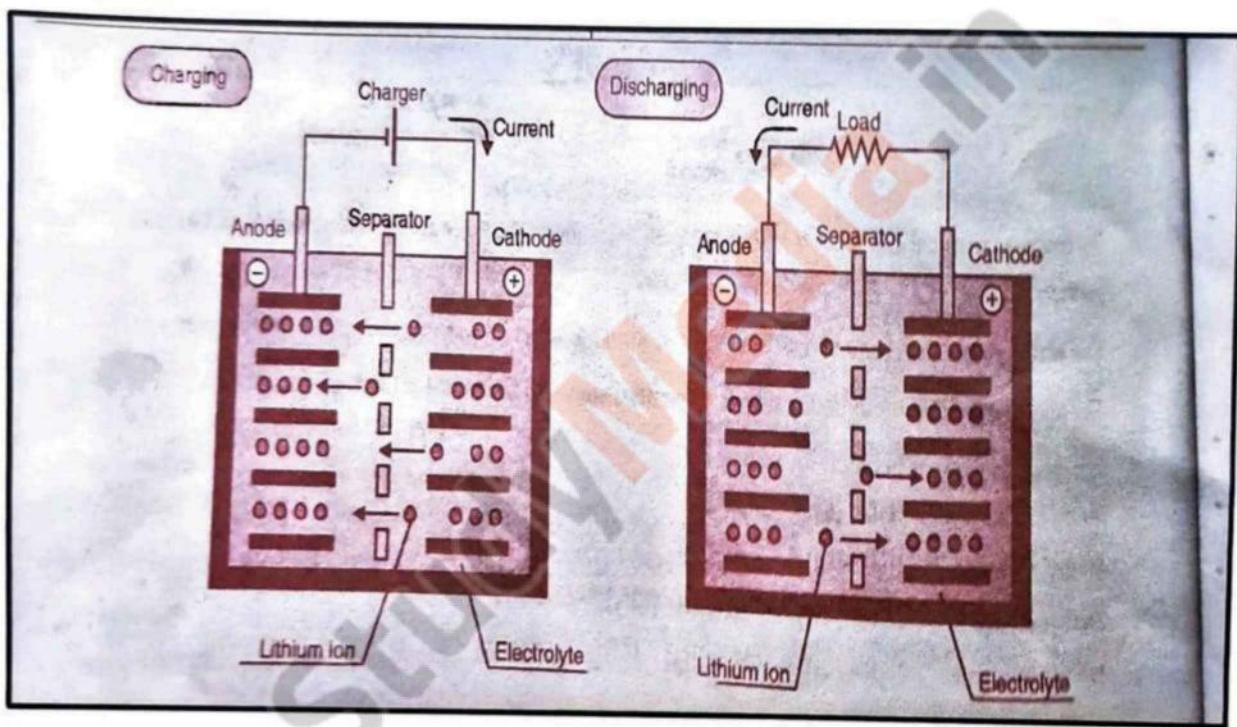
Lithium is the lightest of metal. It floats on water. It also has the greatest electrochemical potential device, which directly converts chemical energy into electrical energy.

Lithium-ion battery is a very good option for rechargeable batteries for portable devices such as laptops, mobile phones, Bluetooth, Camera & minibus etc.

* Defn :- The batteries in which lithium ions are used instead of lithium metal and movement of lithium ion through electrolyte takes place from one electrode to another electrode, such batteries are called lithium-ion batteries.

e.g. Lithium Cobalt Oxide $[LiCoO_2]$ battery.

- Lithium-ion battery uses metal oxide as a cathode (+ve electrode), porous carbon as an anode (-ve electrode) & electrolyte as conductor.
- During discharge, lithium ions flow from the anode to the cathode through the electrolyte & separator, whereas charging reverse the direction & the ion flow from cathode to the anode.
- The cell reaction in - Li-ion battery is migration of Li-ion between +ve & -ve electrode. No chemical changes are observed in the two electrode.



* Construction :-

Lithium-ion batteries use a chemical reaction between lithium ion & electrode materials to store and release energy. The electrolyte in a lithium-ion battery carries positively charged lithium ion between the battery anode & cathode creating an electrical current.

• Anode :-

The negative side of the battery, typically made of graphite.

• Cathode :-

The positive side of the battery, typically made of a lithium-based compound like lithium cobalt oxide (LiCoO_2) or lithium iron phosphate (LiFePO_4).

• Electrolyte :-

A chemical solution that conducts electricity by moving ions. In a lithium-ion battery, the electrolyte carries lithium ions between the anode & cathode.

• Separator :-

A thin layer of insulating material that microporous polyethylene film, which separate electrode when lithium ion exchanges from one side to another.

• Current Collectors :-

Positive & Negative collectors that connect the battery to a device being powered.

* Working :-

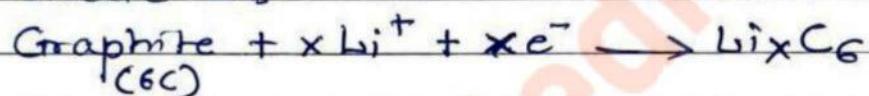
When a lithium-ion battery is charging, lithium ions move from the cathode to the anode through the electrolyte.

When the battery is discharging, the lithium ions move back to the cathode, releasing energy as electricity.

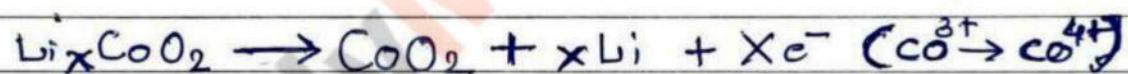
* Reaction :-

→ Charging Process (Non-Spontaneous)

• Anode :-

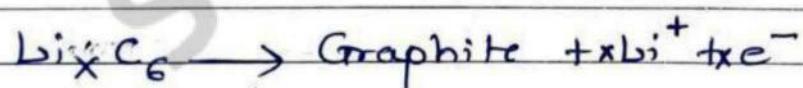


• Cathode :-

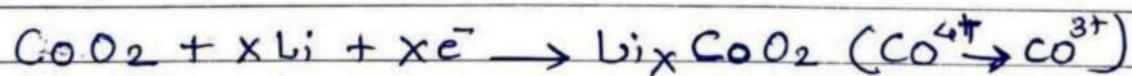


→ Discharging Process (Spontaneous)

• Anode :-



• Cathode :-



* Advantages :-

- 1) It is light in weight compare to the same size other batteries.
- 2) It takes less time for charging.
- 3) Lithium-ion batteries are having long life.
- 4) They have improved safety i.e. more resistance to overcharge.

* Disadvantages :-

- 1) They are expensive.
- 2) It requires to be charged regularly.
- 3) They are not available in standard cell types.

* Applications :-

- 1) The Li-ion batteries are used in camera, calculators.
- 2) Used in remote areas.
- 3) They are used in cardiac pacemakers & other implantable device.
- 4) They are used in telecommunication equipment, instruments portable radios & TVs.
- 5) They are used to operate laptops, computers and mobile phones & aerospace application.

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