## Introduction:

"Fuel" is a substance, whose constituent particle is carbon., which on combustion produces a large amount of heat.

- The heat obtained by burning of fuels is utilized for industrial and domestic purposes., power generation in thermal power plants, transportation etc.

Ex: Wood, coal, Kerosene, petrol, diesel, natural gas, oil gas etc

The Combustion products mainly contain $CO_2$ & $H_2O$.

- The fuels like coal, crude oil, natural gas are fossil fuels. (ancient organic sediments) found in earth crust.

- The Nuclear fuels are not fuels in true sense as the energy obtained from the nuclear fission reactions and not by combustion process.

Nuclear fuels are most concentrated source of energy as 1 kg of $U^{235}$ produces

energy equivalent to 2000 tons of high grade coal.

- The fossil fuels, wood, vegetable oils etc. which produces the heat on burning are known as chemical fuels.

$$\text{Fuel} + \underset{(\text{air})}{O_2} \longrightarrow \text{Combustion Products} + \text{Heat}$$

## Comparision of Solid, Liquid & Gaseous fuel.

### Solid fuel.

- Combustion is slow
- Transportation is difficult sometimes.
- Storage is safe.
- Calorific value is less.
- Ash & smoke are produced and their disposal is problem.
- They can not be used in internal combustion engines.

## Liquid fuel:

- Combustion is Quick.
- It can be easily transported through pipes.
- There is a greater risk in storage.
- Calorific value is higher.
- There is no ash problem but it produces smoke.
- They can be used in internal combustion engines.

## Gaseous Fuel:

- Combustion takes place rapidly.
- Easy to transport through pipes and containers.
- Greater risk in storage.
- Calorific value is highest.
- Neither ash nor smoke is produced.
- Can be used in internal combustion engines.

## Types of fuels:

Fuels are of three types

i) Solid fuels : Ex: Wood, Coal, Charcoal etc

ii) Liquid fuels : Ex: Kerosene, Petrol, Diesel etc

iii) Gaseous fuels : Ex: CNG, LPG, Biogas, Hydrogen etc.

## Non-Conventional Sources of Energy:

1) Solar energy
2) Wind energy
3) Hydro energy
4) Geo-thermal energy
5) Biofuel
6) Biogas Energy

## Characteristics of Good Fuels:

1) High calorific values.
2) Moderate Ignition Temperature.
3) low Moisture content.
4) Low ash content.
5) Moderate velocity of combustion.
6) should not produce harmful products.
7) low cost.

- Easy storage & transportation.
- Easily controllable.

## Calorific Value :

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

"Total quantity of heat liberated on complete combustion of unit mass or unit volume of fuel completely".

## Units of Calorific values.

For Solid / Liquid
- Calori / gram — in C.g.s system
- K Cal / kg — in m.k.s. system.
- B.T.U / LLb — in British system.

For Gaseous — k cal / $cm^3$.

1 kCal = 3.968 B.T.U = 2.2 C.H.U.

## Types of Calorific Values:

1. **Gross Calorific value (G.C.V) or Higher Calorific value (H.C.V):**

Definition: "The total amount of heat produced when unit mass of fuel has been burnt completely and the combustion products are cooled to room temperature"

G.C.V / H.C.V - has only theoretical importance because in actual practice, we do not have any practice of cooling the products of combustion during combustion of a fuel in any engine.

2. **Net Calorific Value (N.C.V) / Lower Calorific value (L.C.V).**

The fuel containing hydrogen produces water, on combustion. Out of the total heat produced in combustion of fuel, the water takes away considerable portion of heat for evoporation & actually less heat is available for heating.

There is no any furnace, or device designed to collect the heat being taken away by the water vapours. Therefore practically we get lower calorific value than the theoretically expected.

Definition: " The amount of heat obtained ~~when~~ on complete combustion of unit mass of fuel and the products of combustion are allowed to escape with some heat".

GCV / HCV = CV of fuel + latent heat of water vapours formed.

LCV / NCV = CV of fuel

NCV / LCV = GCV - latent heat of water vapour.

= GCV - (Mass of hydrogen x 9 x latent heat of steam)

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$$

2 parts 18 parts

As 18 parts of $H_2O$ are formed by 2 parts of hydrogen ∴ Mass of steam will be 9 times mass of hydrogen.

Latent heat of water is 587 cal/gm or 2450 kJ/kg or 587 kcal/kg.

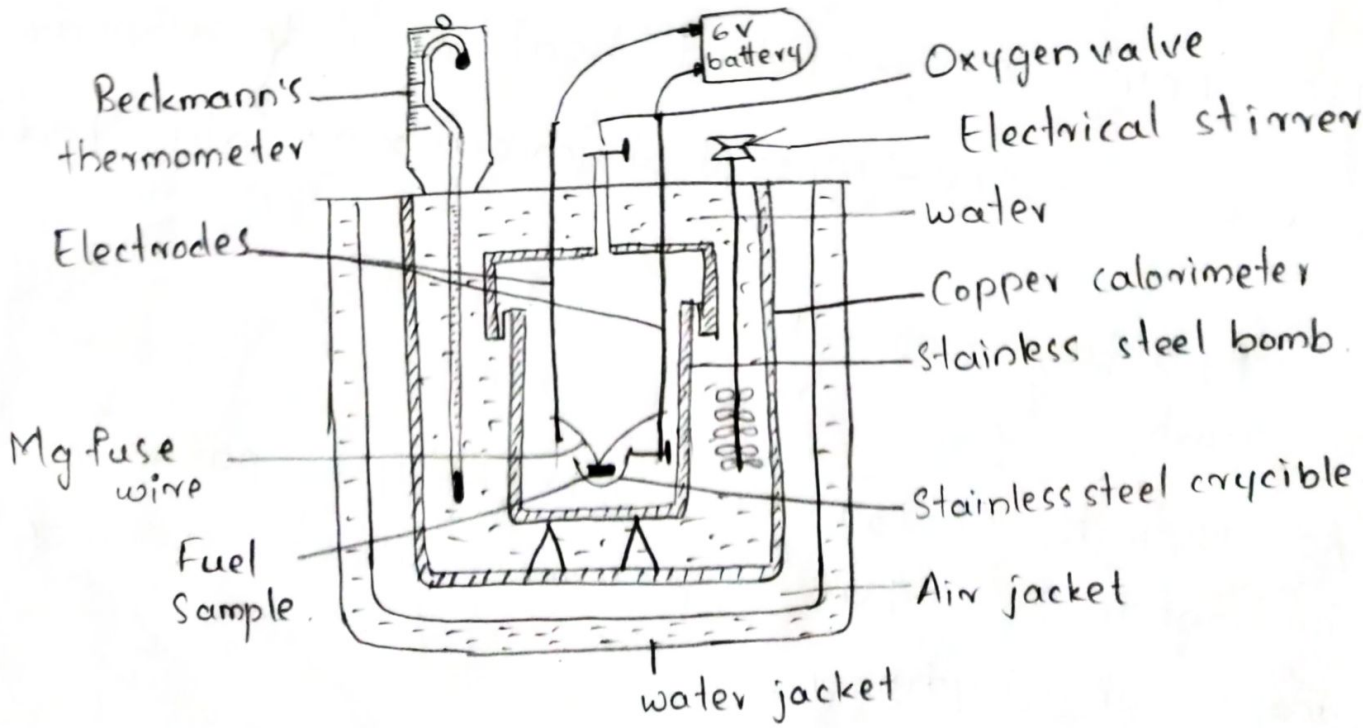
If the mass of hydrogen is expressed as % H, then mass of hydrogen per gram of fuel will be $\frac{H}{100}$.

$$\therefore NCV = GCV - \left(9 \times \frac{H}{100} \times 587\right) \text{ cal/gm or kcal/kg.}$$

$$NCV = GCV - 0.09H \times 587 \text{ cal/gm or kcal/kg.}$$

## Bomb Calorimetry:

Measurement of Calorific value of solid / liquid fuel can be done by using Bomb calorimeter.



Construction:

1. Bomb calorimeter consists of strong cylindrical stainless steel bomb in which fuel combustion is carried out.
2. Stainless steel bomb has gas tight lid screwed to the body.
3. The lid consists of two stainless steel electrodes and oxygen inlet valve.
4. A small ring is attached to one of the electrodes.
5. In this ring nickel or stainless steel crucible can be supported, in which fuel of known mass / volume is taken.
6. The entire bomb pot is placed in a copper calorimeter containing known mass of water.
7. Copper calorimeter is surrounded by air-jacket and water jacket to prevent heat losses due to radiation.
8. The calorimeter also contains electric stirrer and Beckmann's thermometer.

## Working:

1. A known mass of about 0.5 to 1.0 gm of fuel is taken in a crucible. This crucible is placed over the ring.
2. A fine magnesium wire is streched across the electrodes, touching the fuel sample.
3. The lid of the bomb pot is tightly screwed and the bomb pot is filled with oxygen to 25 atmospheric pressure.
4. The bomb pot is then placed in the copper calorimeter containing known mass of water.
5. Stirrer is worked and initial temperature of water is noted.
6. The electrodes are connected to 6 V. battery. Circuit is completed. This provides ignition to the magnesium fuse wire. It burns and in turn provides ignition to the fuel.
7. The fuel sample burns and heat is liberated.
8. The heat liberated by fuel combustion is absorbed by the water in the calorimeter.

Stirring of water is continued for uniform distribution of heat. The temperature of water rises. The maximum temperature attained is recorded. (6)

Heat liberated by fuel = Heat absorbed by calorimeter.

Heat absorbed by calorimeter means heat absorbed by water.

$$X \cdot L = (M+m)(t_2-t_1)$$

m = Water equivalent of calorimeter.

X = mass of fuel taken in crucible.

L = Calorific value of fuel.

M = Mass of water in copper calorimeter.

$$\text{GCV of fuel} = \frac{(M+m)(t_2-t_1)}{X} \text{ Cal/gm.}$$

or

L

Example 1: Calculate the HCV (in kJ/kg) of 0.75 gm of a containing 80% carbon, when burnt in a bomb calorimeter of water increased the temperature from 27.3 to 29.7°C. The calorimeter contains 250 gm of water & its water equivalent is 150 gm.

Sol2: $x$ = wt. of fuel = 0.75 gm

$W$ = wt of water = 250 gm.

$w(m)$ = water equivalent = 150 gm.

$t_1 = 27.3^\circ C$

$t_2 = 29.7^\circ C$

$$HCV(L) = \frac{(W+m)(t_2-t_1)}{x} \text{ cal/gm or k cal/kg.}$$

$$= \frac{(250+150)(29.7-27.3)}{0.75}$$

$$= 1280 \text{ cal/gm}$$

$$= 1280 \text{ k cal/kg.}$$

1 Cal = 4.187 Joule

$$= 1280 \times 4.187 \text{ kJ/kg.}$$

$$= \underline{5359.36 \text{ kJ/kg.}}$$

## Corrections for Accurate results:

1) **Fuse wire correction $t_f$:** CV of fuel includes the heat given out by burning of fuse wire and should be substracted.

2) **Cotton thread correction $t_c$:** CV of fuel includes the heat given out by burning of cotton thread & should be substracted.

3) Acid correction $t_a$: Fuel containing S & N are oxidized to $H_2SO_4$ & $HNO_3$. Thus should be substracted from CV.

4) Cooling correction $t_c$: Actual combustion of fuel occurs in bomb & heat is transferred to water and then to thermometer. During this time temperature of water falls & this amount should be added to C.V.

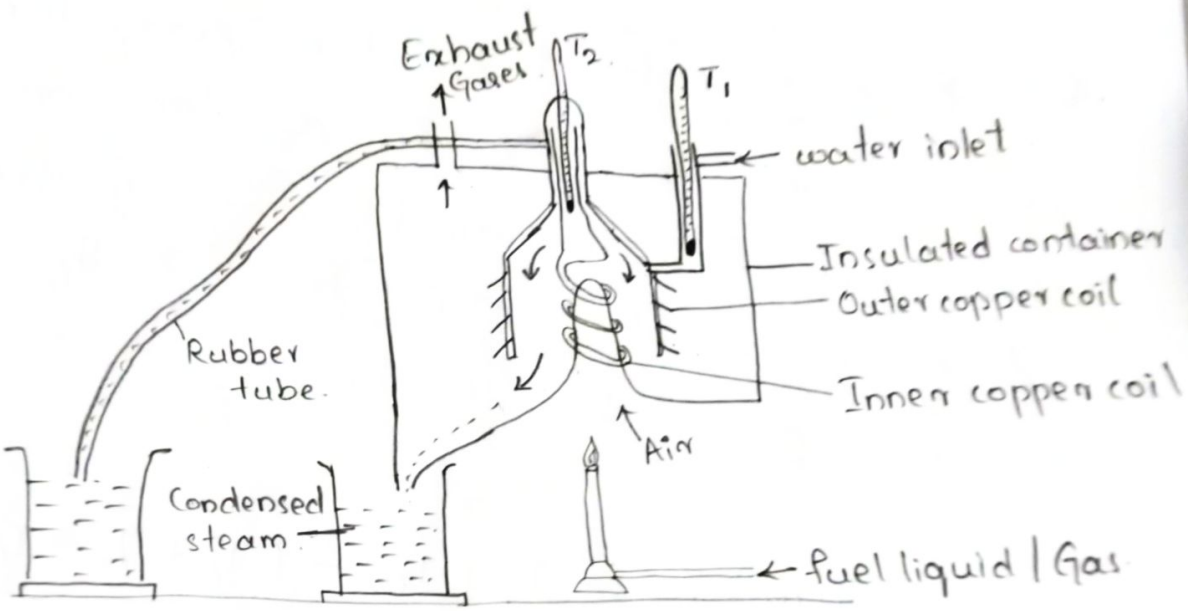
$$L = \frac{(M+m)(T_2 - T_1 + T_c) - (T_f + T_t + T_a)}{x} \text{ callgram}$$

Determination of Water Equivalent:

$$m = \frac{xL - W}{T_2 - T_1} \quad \text{callgm.}$$

## Boy's Gas Calorimeter:

Measurement of calorific value of volatile liquid or gaseous fuels.




## Construction:

1) The apparatus consists of a suitable gas burner in which a known gas at known pressure can undergo combustion at a uniform rate of 3-4 litres per minute.

2) Around the burner, there is a combustion chamber with a copper tubing coiled inside as well as outside.

3) Water is passed through this coil at constant

Working:

1) A definite volume of gas is taken in the gas burner at definite pressure.

2) Gas burns at constant rate to produce large amount of heat. The rise in temperature in water circulation is recorded with the help of thermometer.

3) When the steady situation with respect to rate of fuel burning & water circulation is attained., then the following observations are taken.

1) The volume of gas burnt in given time.
2) The quality of water circulated through the coil.
3) Mass of water condensed during the time.
4) The rise in temperature.

Calculation: Assuming there is no loss in heat, we can write, Heat liberated by fuel = Heat absorbed by calorimeter.

$$V \cdot L = W (T_2 - T_1)$$

V = Volume of gas burnt for time period T

L = Calorific value of fuel

W = Mass of water circulated in time T.

GCV of fuel $L = \frac{W(T_2 - T_1)}{V}$ kcal / $m^3$.

G.C.V / $L = 4.187 \frac{W(T_2 - T_1)}{V}$ J/gm (or) kJ/kg.

NCV / LCV = GCV - latent heat of water produced.

N.CV / L.CV = $L - \left(\frac{m}{V} \times 587\right)$ kcal / $m^3$.

m = mass of water condensed during time 't'.

Numerical :

1. Observations in Boy's gas calorimeter experiment on gases fuel as given below, find the G.C.V & N.C.V. of the fuel.

Given: Volume of gas burnt (STP) V = 0.08 $m^3$

Mass of cooling water used = W = 29.5 kg.

Rise in temperature of circulating water = $T_2 - T_1$ = 9.1°C

mass of steam condensed = m = 0.04 kg.

$$GCV = \frac{W(T_2 - T_1)}{V} \text{ kcal/m}^3$$

$$= \frac{29.5 (9.1)}{0.08}$$

$$G.C.V = 3355.625 \text{ kcal/m}^3$$

$$NCV = GCV - \frac{m}{V} \times 587 \text{ kcal/m}^3$$

$$= 3355.625 - \frac{0.04}{0.08} \times 587$$

$$N.C.V. = \underline{3062.12 \text{ kcal/m}^3}$$

## Geothermal Energy:

Geo - Earth

Thermal - Heat

It is the energy derived from the natural heat of earth contained in hot rocks, hot water, hot brine or streams.

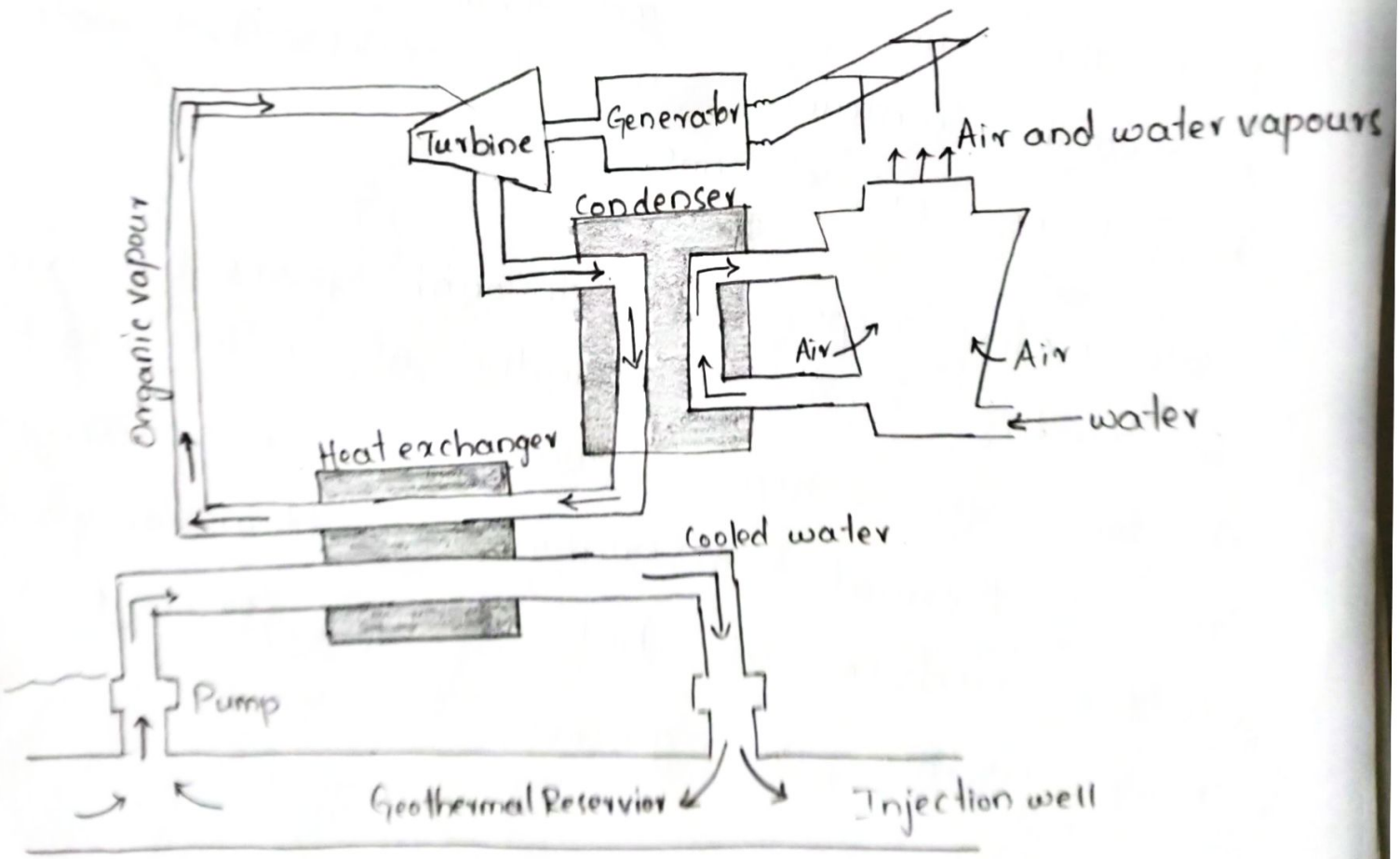
Rain water seeps down through pores & cervices in earth's crust to depths of miles & gets heated. This heated water either stored in geothermal reservoirs or flows upwards to the surface as hot springs, or boil near surface as geysers.

Advantages:

1. A reilable source of renewable energy.
2. Has high efficiency
3. No environmental impact.

Disadvantages:

1. High installation cost.
2. Cannot be transported to great distances.
3. Withdrawal of large amount of steam or water may disturb the ecosystem.



## Hydrothermal Energy:

Hydrothermal is the commercial geothermal source.

It uses hot water or steam directed to a steam turbine either on direct or indirect basis.

## Hydro power plants:

- In hydropower plants, water from rivers are stored by constructing dams.
- Micro hydro systems typically produce up to 100 kW of power.
- They are often used in water rich areas as a remote-area power supply.
- Run-off the river hydroelectricity systems derive kinetic energy from rivers and oceans without using dam.

Ex: Grand Coulee Dam in Washington

The Akosombo Dam in Ghana.

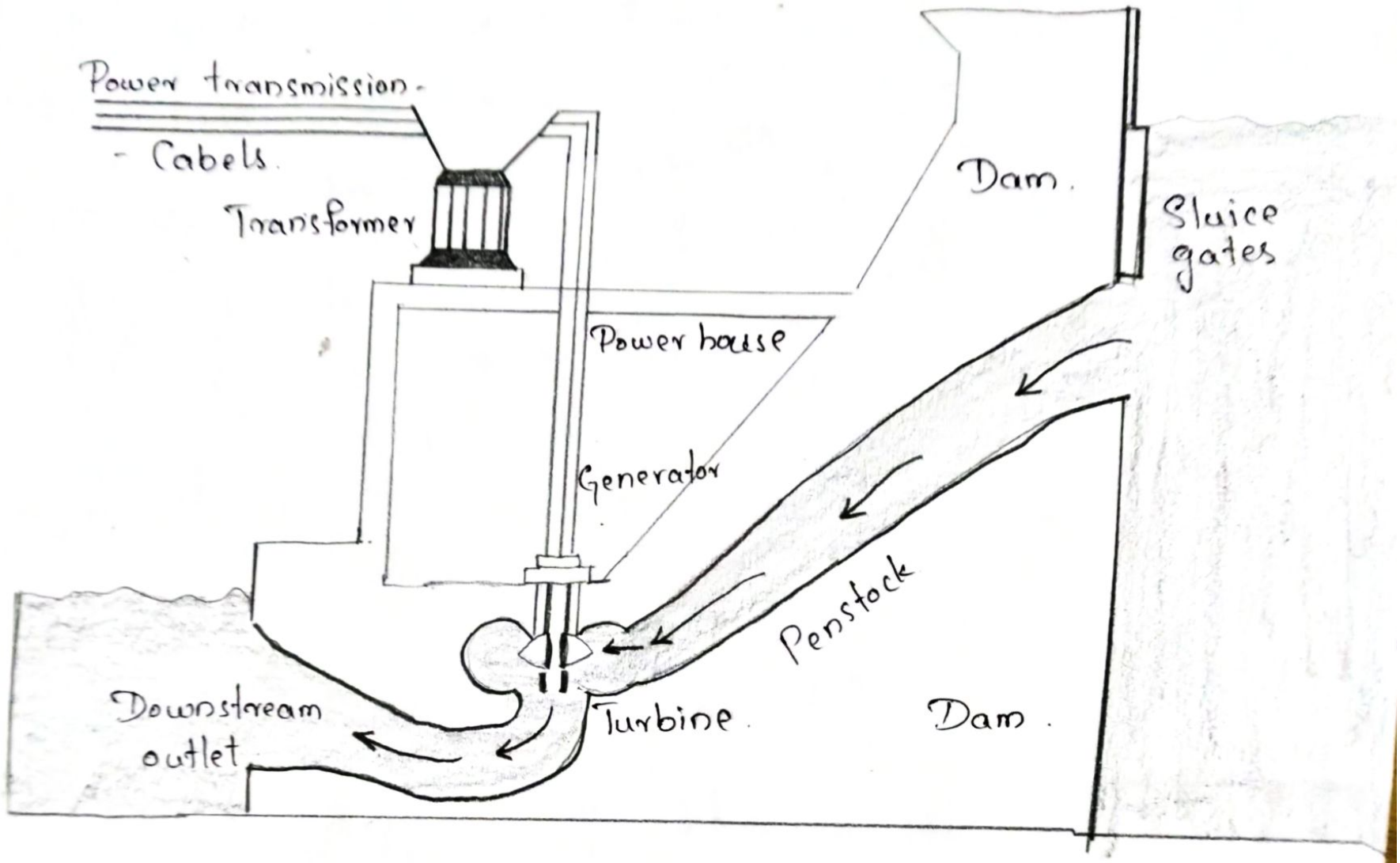
## Advantages:

1. Flowing water is renewable source of energy.
2. The electricity produced does not cause pollution.
3. The water stored in dams can also be used to control floods and for irrigation.
4. Once the dam is constructed, electricity can be produced at a constant rate.
5. Often large dams become tourist attractions.

## Disadvantages:

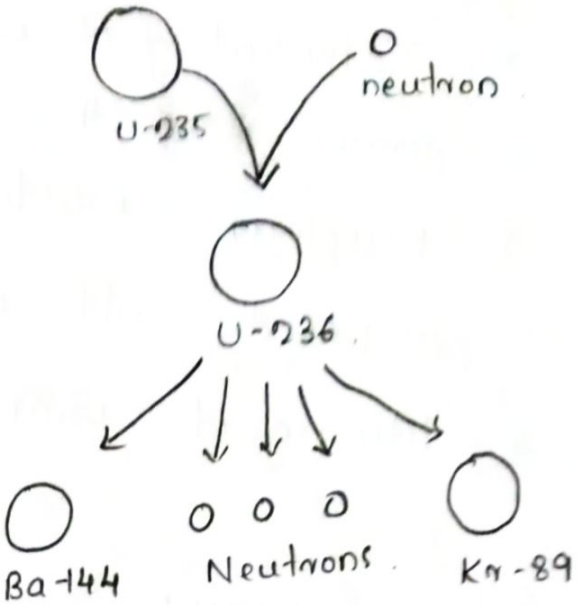
1. Initial cost is high.
2. Large areas of land gets submerged & the decomposition of vegetation produces methane gas which is a green house gas.
3. Disturbs the ecosystem.

: Hydroelectric Power Generation:

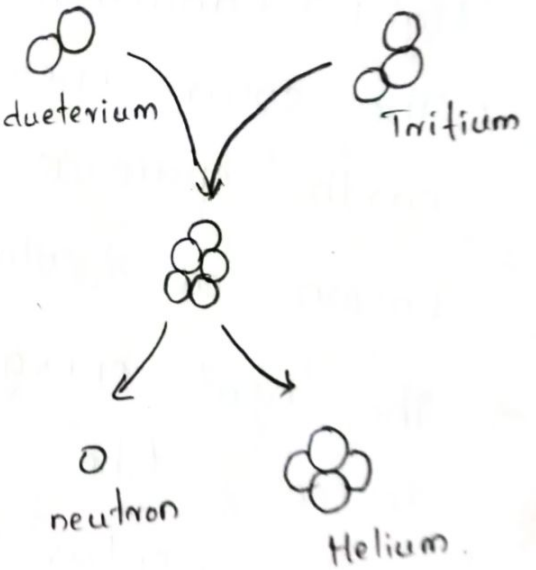


## Nuclear Energy Power Plant:

In nuclear fission $U_{235}$ combines with a neutron to form unstable $U_{236}$ which quickly disintegrates into Barium-144 & Krypton-89 plus 3 neutrons with release of high energy.




In nuclear fusion deuterium & tritium combine to form helium and neutron with lots of energy.




### Advantages

1) Low operative cost.
2) Low green house gases emission.
3) Power output is maximum.
4) Reliable source of energy.

Disadvantages:

1. Initial investment is high.
2. Potential of nuclear accident leading to major health issues.
3. Nuclear waste is radioactive & has to be disposed off with great care.
4. Mining of uranium adds to cost.

Solar Energy:

- Energy obtained from sun in form of heat & light. (Radiation).
- The solar energy received by the near earth space is approximately 1.4 kilojoules/sec known as solar constant.
- The heat energy is used in solar heating devices like solar cooker, solar water heater, solar furnaces etc.
- The light energy is used in solar cells.

Various Technologies in which solar energy used.

1. Solar cookers
2. Solar hot water systems
3. Solar dryers
4. Solar air heaters
5. Solar desaltination system
6. Solar batteries.

## Advantages:

1. Solar power is pollution free & causes no greenhouse gases.
2. Reduced dependance on foreign oil & fossil fuels.
3. Renewable clean power that is available every day of the year, even cloudy days, to produce some power.
4. Return on investment unlike paying for utility bills.
5. Virtually no maintance as solar panels last over 30 years.
6. Creates jobs by employing solar panel manufacturers, solar installers etc. & in turn helps the economy.
7. Excess power can be sold back to the power company if the grid inner tied.

Disadvantages:

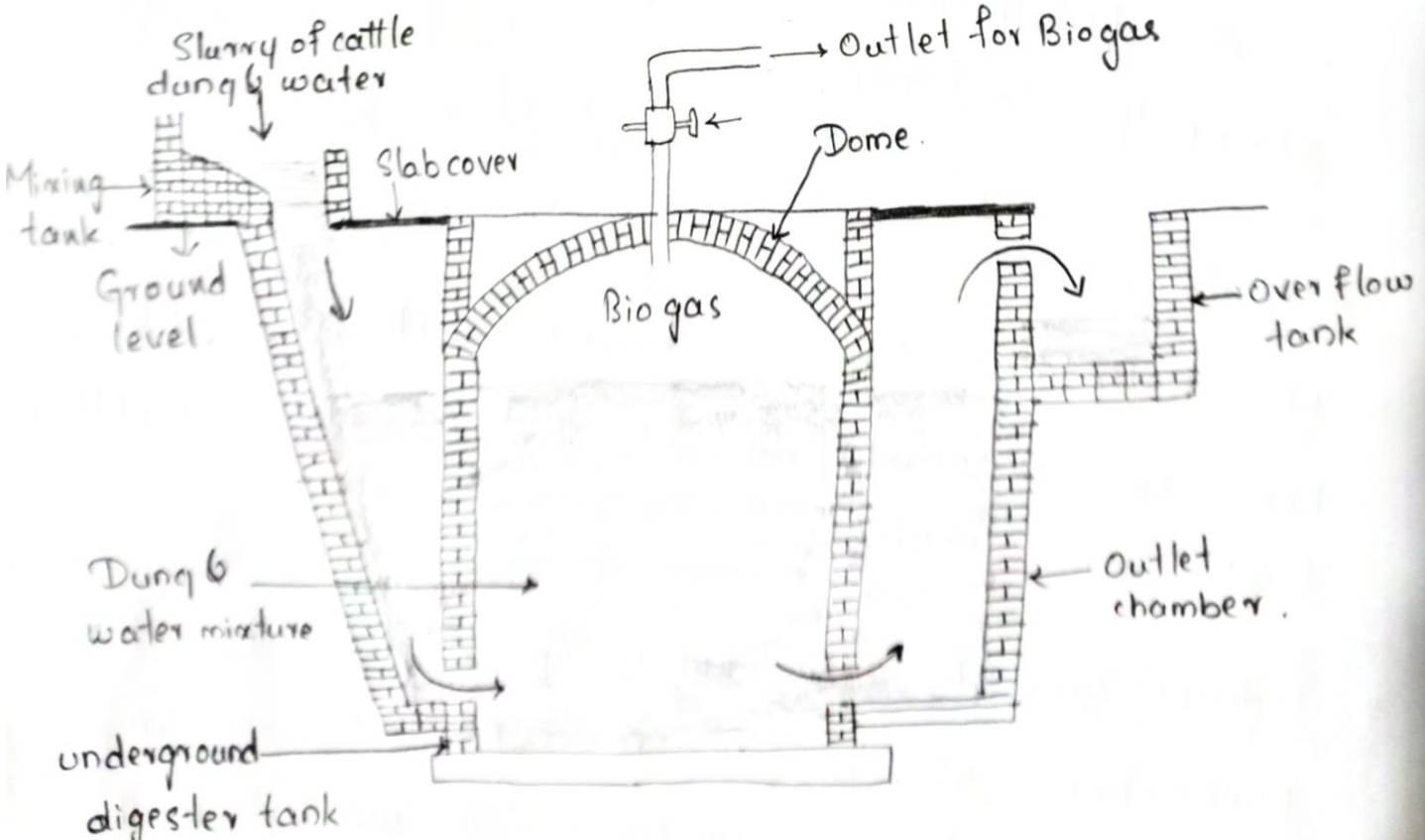
1. High initial cost for material & installation & long ROI. [However, there is reduction in cost of solar over the last 10 years, solar is becoming more cost feasible every day).
2. Needs lot of space as efficiency is not 100% yet.
3. No solar power at night. so there is a need for battery back up.
4. Depending on the geographical location the size of the solar panels vary for the same power generation.
5. Cloudy days do not produce as much energy.
6. Solar panels are not being produced due to a lack of material & technology to lower the cost enough to be more affordable (this is started to change).

## Biogas:

* Biogas refers to a mixture of gases produced by the anaerobic decomposition of organic matter such as agricultural waste, municipal waste, plant residue, food waste etc.

* Biogas consists of methane, carbon dioxide along with the small amount of hydrogen sulphide & moisture.

"Anaerobic decomposition = Means break down of organic matter by bacteria in the absence of oxygen."



* It consists of a dome like structure.
* Organic material like discarded food material, fats, sludge, cow dung etc. are mixed with water & fed to the digester through the inlet.
* The digester is sealed chamber where anaerobic decomposition of organic matter takes place.
* After few days organic matter completely decomposes to produce gases like $CO_2$, $H_2$ & $H_2S$.
* These gases are drawn through pipes from the storage tank above the digester and distributed through decentralized channels for use.

Advantages:

1. Non-polluting: Biogas burns without smoke, hence no harmful gases such as $CO_2$, CO, $NO_2$, & $SO_2$ are evolved.

2. Reduces landfills: The slurry produced after the production of biogas is used as manure in fields, hence no space is wasted in the form of landfills.

3. Cheaper technology: Biogas plants require very little installation cost and become self-sufficient in a span of 3-4 months.

4. Generates employment: Work opportunity for thousands of people is created, especially in rural areas.

5. Renewable source of energy: It is considered as a renewable source of energy because the production is dependent on the generation of waste which is an endless process.

Disadvantages:

1. Not efficient enough on large scale: Since it is difficult to enhance the efficiency of biogas. It is not economically viable to use biogas on a large scale.

2 Contains Impurity: Biogas when compressed, to be used as fuel, proves to be highly corrosive to the container due to presence of impurities that are difficult to remove.

3. Unstable & hazardous: When methane comes in contact with oxygen it reacts violently. to produce $CO_2$. The highly inflammable nature of methane makes it prone to explosions.