UNIT - III

Phase rule

If the equilibrium between any number of phases is not influenced by gravity, or electrical or magnectic forces but is influenced only by pressure, temperature and concentration, then the number of degree of freedom (F) of the system is related to number of components (C) and number of phases (P) by the following phase rule equation

$$F = C - P + 2$$

Definition of terms with examples

* Phase (P)

Phase is defined as "any homogeneous physically distinct and mechanically separable portion of a system which is separated from other parts of the system by definite boundaries

Ex: 1. Gaseous phase - Air
2. Liquid phase - Benzene - water (Two immiscible)
3. Solid phase - $CaCO_3$

* Component (C)

Component is defined as, the smallest number of independently variable constituents by means of which the composition of each phase can be expressed in the form of a chemical equation.

Degree of freedom (F)

Degree of freedom is defined as the minimum number of independent variable factors such as temperature, pressure and concentration which must be fixed in order to define the system completely

Phase Diagram :-

Phase diagram is a graph obtained by plotting one degree of freedom against another.

Types

1. P–T diagram which is used for one component
2. T–C diagram which is used for two component.

Uses 1. It is possible to predict from the phase diagrams whether an eutectic alloy or a solid solution is formed on cooling a homogeneous liquid containing mixture of two metals

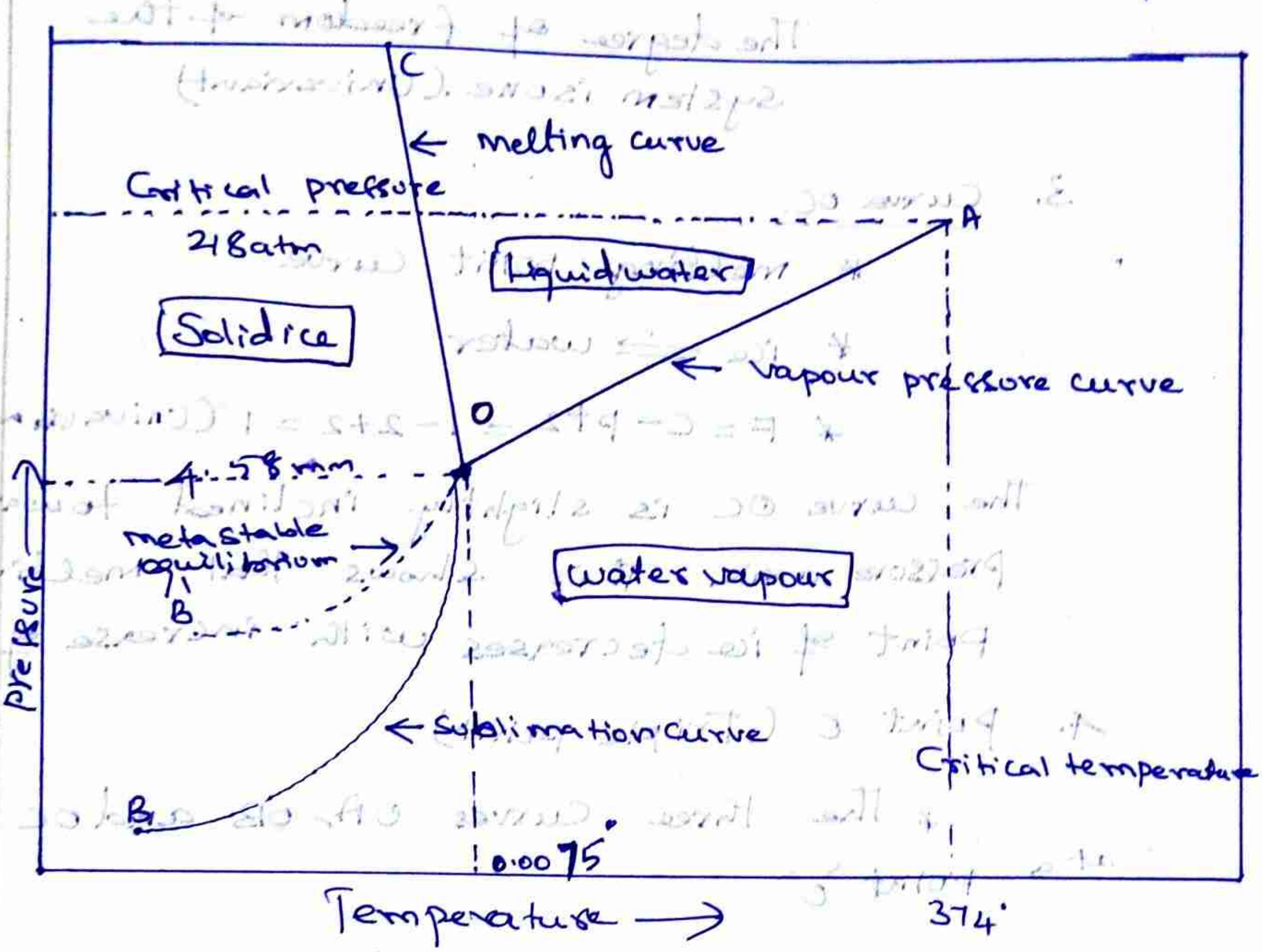
2. The phase diagrams are useful in understanding the properties of materials in the heterogeneous equilibrium system.

3 The study of low melting eutectic alloys used in soldering, can be carried out using phase diagrams.

ONE COMPONENT SYSTEM

Examples the water system

The water exists in three possible Phases namely, solid, liquid and vapour.



1. Curve OA

The curve OA is called vapourisation curve, it represents the equilibrium between water and vapour. At any point on the curve the following equilibrium will exist

$$\text{water} \rightleftharpoons \text{water vapour}$$

$$F = C - P + 2$$
$$= 1 - 2 + 2 = 1 \text{ (univariant)}$$

2. Curve OB

* Sublimation Curve

* ice ⇌ vapour

* $F = C - P + 2 = 1 - 2 + 2 = 1$
The degree of freedom of the system is one (Univariant)

3. Curve OC

* melting point Curve

* ice ⇌ water

* $F = C - P + 2 = 1 - 2 + 2 = 1$ (Univariant)

The curve OC is slightly inclined towards pressure axis. This shows that melting point of ice decreases with increase of pressure

4. Point O (Triple point)

* The three curves OA, OB and OC meet at a point 'O'

* $ice_{(s)} \rightleftharpoons water_{(l)} \rightleftharpoons vapour_{(g)}$

* $F = C - P + 2 = 1 - 3 + 2 = 0$

* Temperature and pressure at the point 'O' are 0.0075°c and 4.58mm respectively.

5. Curve OB' (Metastable)

* Super - Cool water ⇌ vapour

Sometimes water can be cooled below 0°C without the formation of ice this water is called super cooled water.

* Super cooled water is unstable and it can be converted into solid by seeding or by slight disturbance.

6. Areas

Area AOC, BOC, AOB represents water, ice, vapour respectively

$$F = C - P + 2$$
$$= 1 - 1 + 2$$
$$= 2 \text{ (Bivariant)}$$

Two Component systems

Reduced phase rule (or) Condensed system

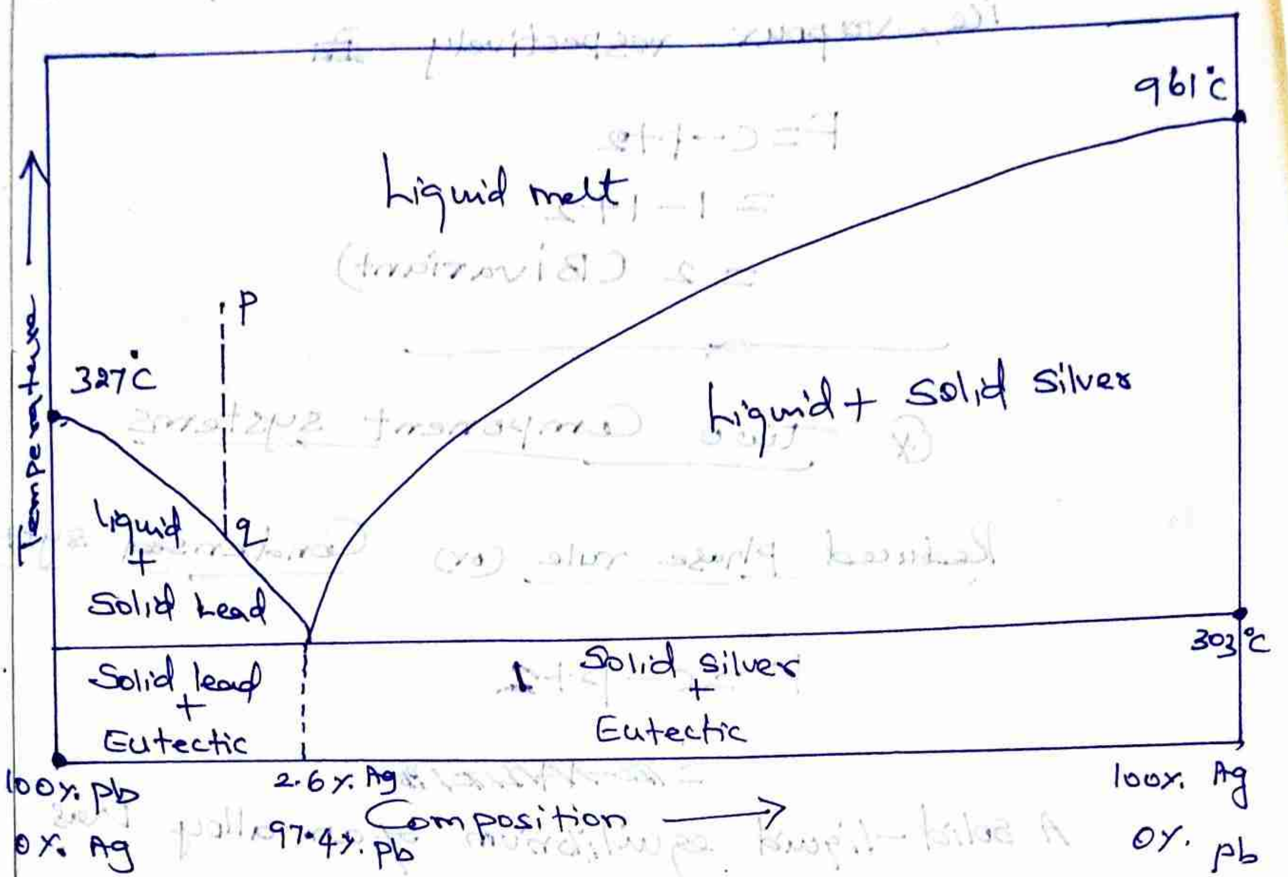
$$F = C - P + 1$$

A solid-liquid equilibrium of an alloy has practically no gaseous phase and the effect of pressure is negligible. Therefore, experiments are conducted under atmospheric pressure. Thus the system in which only the solid and liquid phases are considered and the gas phase is ignored is called a condensed system. Since the pressure is kept constant the phase rule becomes

$F = C - P + 1$ This eqn is called reduced phase rule.

BINARY ALLOY SYSTEM
(or)
THE SIMPLE EUTECTIC SYSTEM

The Lead - Silver system



1. Curve AO

* Freezing point Curve of silver.

* Solid Ag ⇌ melt

* $F' = C - P + 1$
$= 2 - 2 + 1$
$= 1$

2. Curve BO

* Freezing point Curve of lead.

* $F' = C - P + 1 = 2 - 2 + 1 = 1$

* Solid pb ⇌ melt

3. Point O (Eutectic point)

The curves (AO and BO) meet at point 'O' at a Temperature of 303°c

* Solid pb + Solid Ag $\rightleftharpoons$ melt

* $F' = C - P + 1$

$= 2 - 3 + 1 = 0$ (non-variant)

4. Areas

The area above the line AOB has a Single phase.

$F' = C - P + 1 = 2 - 1 + 1 = 2$ (Bivariant)

The area below the line AO (solid Ag + liquid melt) below the line BO (solid pb + liquid melt) and below the point 'O' have two phases and hence the system is Univariant.

$F' = C - P + 1 = 2 - 2 + 1 = 1$

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* Uses of phase rule

1. It is applicable to both physical and Chemical equilibria.
2. It Indicates that the different systems having the same degrees of freedom behave Similarly.
3. It helps in deciding whether the given number of substances remain in equilibrium or not

Limitations of phase rule

1. Phase rule can be applied only for the systems in equilibrium.
2. Only three variables like P, T & C are considered, but not electrical, magnetic and gravitational forces.
3. All the phases of the system must be present under the same conditions of pressure and temperature.
4. Solid and liquid phases must not be in finely divided state, otherwise deviations occur.

UNIT – III

Composite materials

* Definition

a material system Consisting a mixture of two (or) more micro-Constituents which are mutually insoluble, differing in form (or) Composition and forming distinct Phases.

* NEED FOR COMPOSITES

1. As Composites never rust and have less fracture toughness than metals, we need different Composites.
2. To reduce maintenance cost and ensure long-term Stability Composites are essential.
3. It is essential because according to the needs using different fibres and matrix properties of Composites can be modified.
4. In telecommunication Industries, need of Power transmission along with data trans-mission is increasing so Composites are highly essential.
5. Composites are highly required because of its lower weight reduces fuel Consumption and emission.
6. As Carbon fibre weighs about 25% as much as Steel and 70% as much as aluminium and is much Stronger and Stiffer.

ADVATAGES of Composites

1) They posses higher specific strength and lower specific gravity.
2. They posses lower electrical Conductivity and thermal expanstion.
3. They posses better creep, fatigue strength, corrosion, and oxidation resistance.
4. They maintain very good strength, even upto high temperature.

CONSTITUENTS OF COMPOSITES

i) Matrix phase / resin
ii) Dispersed phase / Reinforcement.

(*) Matrix phase / resin.

i) MMC — metal matrix Composites
ii) CMC — Ceramic " "
iii) PMC — polymer " "

(*) Dispersed phase / reinforcement

i) Fibres
ii) Particulates
iii) Flakes
iv) whiskers.

Composites

Definition

A material system consisting a mixture of two or more micro-constituents, which are mutually insoluble differering in form (or) composition and forming distinct phases.

Need for Composites

* Composites never rust
* To reduce maintenance cost
* To ensure long-term stability
* According to the needs, the properties of composites can be modified.
* Composites are essential in tele communication industries because here power transmission along with data transmission was used.
* Because of its lower weight, it reduces fuel consumption and emission.
* As carbon fibre is much stronger and stiffer than steel and aluminium composites were essential.

Constituents of Composites

1. Matrix phase (or) matrix resin.
2. Dispersed phase (or) Reinforcement

1. Matrix phase (or) Matrix resin

Matrix phase is a continuous body

Constituent which encloses the composite matrix phase may be metal, ceramics (or) polymers.

i) Metal matrix Composites (MMC)
ii) Ceramic Matrix Composites (CMC)
iii) polymer matrix Composites (PMC)

2. Dispersed phase (or) Reinforcement

Dispersed phase is the structural Constituent, which determines the internal Structure of Composite

Ex: Fibres, Particulates, Flakes, whiskers.

Reinforcement

* It means addition of Plastic matrix with some reinforcing agents (organic (or) inorganic) to improve the characteristics

* The reinforcing agents may be In the form of powder, flakes, fibres.

* These reinforcing agents are highly resistance to Corrosion and posses high Strength and ease of fabrication.

1. Fibres

Fibres are long and thin filment of any macromolecular substance such as polymer metal (or) ceramic having high length to diameter ratio at least 100:1

Characteristics of fibre

i) Fibre possessed high tensile strength
ii) Have high stiffness
iii) Lowers overall density.

Classification of fibres.

* Natural fibres – derived from naturally available sources.
  Ex. Cotton, wool, silk etc.
* Semi synthetic fibres – produced by modifying natural fibres
  Ex. Rayon.
* synthetic fibres – made in laboratory
  Ex: Polyester, glass fibre
* Aramid fibres – Aromatic polyamides
  Ex. Kevlar.

Important Natural fibres

a) Cotton fibre – It is a vegetable fibre and is made of Cellulose molecule.

b) Wool fibre – It is an animal protein fibre these are made of α-aminoacids

c) Silk – Natural protein fibre derived from insect, silkworm, these fibre posses qualities such as softness, strength elongation etc.

d) Sisal – low cost fibrous material

e) Jute and coir – low cost fibrous material it can be used as woven cloth.

(B) <u>Synthetic fibres.</u>

a) Poly ethylene Terephthalate (PET) produced by the condensation of ethylene glycol and terephthalic acid.

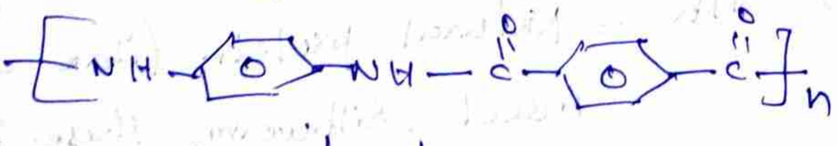
b) Polypropylene – produced by the polymerisation of propylene. They possess better hardness strength and used in making carpets, blankets, bags etc.

c) Carbon fibres – At high temperature they possess good strength and stiffness.

d) Nylon – used as reinforcements for epoxide resin to give flexible laminates with abrasion and chemical resistance.

c) <u>Aramid fibres.</u>

The aromatic polyamides are called as aramids



Kevlar.

Properties

* Possess high tensile strength
* Stable at higher temperatures
* Excellent toughness

Uses

* used in reinforcements
* bullet proof clothing
* astronauts suits.

2. Particulates.

These are small pieces of hard Solid materials they may be mettalic (or) Non metallic

Effect of particulate in Composite

* surface hardness gets increased
* wear and abrasion resistance are increased
* Performance at elevated temperature is improved
* Electrical thermal Conductivities are modified

3. Flakes

These are very thin Solid like materials Ex! mica flakes.

* They imparts equal strength in all direction in a Plane
* Flakes can be packed more efficiently than fibres

* Mica flakes can be used in electrical and thermal insulating applicances.

4. <u>whiskers</u>

It is a strong fibre like material Ex:, Graphite, Silicon Carbide Silicon nitride

* perfect whiskers posses high strength
* They posses high elastic modulus and high degree of crystallinity.
* These are costly and difficult to incorporate in matrix, so they find limited use.

Properties and applications

A. Polymer Composites or Fibre Reinforced Polymer Composites.

These are widly used Composites in various industries.

	Properties	applications
1) Glass FRP	* lower densities and dielectric Constants * Higher tensile Strength * Excellent Corrosion and Chemical resistance	Automobile Parts Pipes Storage tanks etc.
2) Boron FRP	* Excellent stiffness and Strength * manufacturing of B-FRP is difficult	Horizontal and vertical tail in aeroplane Stiffening spars ribs etc.
3) Carbon FRP	* light density Resist Corrosion Retention of desired properties (even at higher temperature	Structural Components of aircraft and helicopters sports Materials, Solar Panel etc.
4. Aramid FRP	They are ductile Stable at Compression Stresses	Structural Component in aircraft helicopter parts.
5. Alumina FRP	Good abrasion resistance Creep resistance Posses dimentional Stability	used in making engine parts and Component of turbine engine

2) <u>Metal Matrix Composites.</u>

<u>Properties</u>

* exhibit good thermal stability high strength and good stiffness.
* They are ductile and exhibit good performance at elevated temperature
* They can with stand at elevated temperature in corrosive environment than polymer composites.

<u>Applications</u>

* MMCs are suitable alternatives with Al, Ti, Ni alloys as one of the matrix material.
* used in engine blades combustion chambers etc.
* Al and Mg MMCs are used in automotive industry
* They improve fuel efficiency because of weight reduction
* MMCs are also used in bio medical and sports equipment industry.

3. Ceramic matrix Composites.

Properties

* They possess good Corrosion resistance, Stable at elevated temperature
* Possess good oxidation resistance
* The matrixes used are glass ceramics, carbides, nitrides, oxides and borides, the reinforcements are Al_2O_3, BC, SiC, and SiO_2

Applications

* used as thermal shields in space vehicles pump seal, brake linings etc.

Hybrid Composites.

Hybrid Composites are new class of materials composed of a suitable polymer matrix reinforced with two different fibres.

Properties

* They possess strong, tough and higher impact resistance
* They possess balanced strength and stiffness
* They exhibit Superior mechanical properties.

Types

1. Structurally hybridized composites
2. Materials hybridized in Chemical bond
3. Functionally hybridized Composites.

Uses

* used in light-weight transparent Structural Components.
* used in light weight Sports goods
* used to make furniture
* used in railway Coach interiors.

Unit - IV

Fuels

* A fuels is a combustible substance containing carbon as the main constituent which on burning gives large amount of heat.

CHARACTERISTICS OF A GOOD FUEL

1. It should be cheap and readily available.
2. It should be safe and economical for storage and transport
3. It should not undergo spontaneous combustion.
4. It should have higher calorific value.
5. It should have moderate ignition temperature
6. The combustion should be easily controllable
7. It should have low moisture content because the moisture content reduces the calorific value.
8. The products of combustion should not be harmful
9. It should have low non-combustible matter or ash content.

CLASSIFICATION OF FUELS

- Based on occurrence
  - primary fuels — Ex. Coal, Petroleum
  - Secondary fuels — Coke, gasoline.
- based on their physical State
  - Solid — Ex. Coal
  - liq — diesel
  - gases — coal gas

* COALIFICATION

The process of Conversion of vegetable matter to anthracite is called Coalification or metamorphism of Coal.

Classification of Coal.

wood → peat → Lignite → Bituminous Coal → Anthracite

The progressive transformation of wood to anthracite results in.

1. decrease in moisture content.
2. decrease in Volatile Content.
3. decrease in H, O, N, S Content
4. Increase in Carbon Content.
5. Increase in hardness.
6. increase in Calorific value

% of fixed Carbon in coal =

100 − % of (moisture Content + volatile matter + ash Content)

Significance

1) High percentage of fixed Carbon is desirable because higher the % of fixed Carbon in a coal, greater is its calorific value.

2) the percentage of fixed Carbon helps in designing the furnace and the shape of the fire-box.

Ultimate analysis

1. Carbon and Hydrogen Contents

A Known amount of the Coal Sample is burnt in a Current of O_2 in a Combustion apparatus. The Carbon and Hydrogen present in the Coal Sample, are Converted into CO_2 and H_2O respectively according to the following equations.

$$C + O_2 \longrightarrow CO_2 \uparrow$$

$$H_2 + \tfrac{1}{2}O_2 \longrightarrow H_2O \uparrow$$

Ash Content

After the analysis of volatile matter, the crusible with residual coal sample is heated without lid at 700 ± 50°c for ½ an hour in a muffle furnace. The loss in weight of the sample is found out and the % of ash content is calculated as.

$$\% \text{ of ash content in coal} = \frac{\text{wt of ash formed}}{\text{wt of air-dried coal}} \times 100$$

Significance

i) It reduces the calorific value of coal
ii) ash causes hindrance to heat flow as well as produces clinkers, which blocks the air supply through the fuel.
iii) it increases the transporting, handling and storage costs.
iv) it involves additional cost in ash disposal.

Fixed Carbon

It is determined by substracting the sum total of moisture volatile and ash contents from 100.

Volatile matter

After the analysis of moisture content the crucible with residual coal sample is covered with a lid and is heated at 950 ± 20°C for 7 minutes in a muffle furnace. The loss in weight of the sample is found out and the % of volatile matter is calculated as

$$\% \text{ of volatile matter in coal} = \frac{\text{loss in wt of the coal}}{\text{wt of air-dried coal}} \times 100$$

Significance

i) It reduces the calorific value of coal.

ii) Large proportion of fuel on heating will distill over as vapour which escapes out unburnt.

iii) Coal with high percentage of volatile matter burns with a long flame with high smoke

iv) The coal containing high % of volatile matter do not coke well.

ANALYSIS OF COAL

i) Moisture Content
ii) Volatile "
iii) Ash "
iv) Fixed Carbon in Coal.

i) Moisture Content

About 1gm of powdered air-dried Coal sample is taken in a Crucible, and is heated at 100 – 105°c in an electric hot air oven for 1 hour The Loss in weight of the Sample is found out and the % of moisture is Calculated as

$$\%\text{ of moisture in Coal} = \frac{\text{loss in wt of the Coal}}{\text{wt of air-dried Coal}} \times 100$$

Significance / importance

1) it reduces the Calorific value of Coal.
2) moisture in coal Consumes more heat in the form of latent heat of evaporation and hence more heat is to be supplied to the ~~heat~~ Coal.
3) it increase the transport cost.

Various fractions Compositions and their uses

Sno	Name of the fraction	Boiling Range °C	Range of C-atoms	uses.
1.	Un condensed gases	Below 30	$C_1 - C_4$	As a fuel under the name of LPG.
2	Petroleum ether	30-70	$C_5 - C_7$	As a solvent
3.	Gasoline or petrol	40-120	$C_5 - C_9$	Fuel for IC engines.
4.	Naphtha or Solvent spirit	120-180	$C_9 - C_{10}$	As a solvent in paints and in dry cleaning
5.	Kerosene oil	180 - 250	$C_{10} - C_{16}$	fuel for stoves and jet engine
6.	~~Heavy~~ Diesel oil	~~250~~ 250-320	$C_{15} - C_{18}$	Diesel engine
7.	Heavy oil	320 - 400 °C	$C_{17} - C_{30}$	fuel for ships and for production of gasoline by cracking

Heavy oil refractionation gives

1. SNo	Name of the fraction	uses
1.	Lubricating oil	As Lubricants.
2.	Petroleum jelly (or) Vaseline	used in medicines and Cosmetics.
3.	Grease	used as Lubricant.
4.	Paraffin wax	used in Candles boot Polishes.
5.	Pitch	used for making roads.

hot vapours are then passed into the bottom of a fractionating column The fractionating column is a tall cylindrical tower containing a number of horizontal stainless steel trays at short distances. Each tray is provided with small chimney covered with a loose ~~cap~~ cap.

when the vapours of the oil go up in the fractionating column, they become cooler and get condensed at different trays The fractions having higher boiling points condense at lower trays whereas the fractions having lower boiling points condense at higher trays. The gasoline obtained by this fractional distillation is called straight run gasoline. various fractions obtained at different trays are given in table.

The middle oil is further hydro[genated] in vapour phase to yield more gas. The heavy oil is recycled for making paste with fresh coal dust. The yield of gasoline is about 60% of the coal used.

Petroleum Refinery Process

Step 1. Separation of water (Cottrell's process)

The crude oil from oil well is an extremely stable emulsion of oil and salt water. The crude oil is allowed to flow between two highly charged electrodes, where colloidal water droplets combine to form large drops, which is then separated out from the oil.

Step 2 Removal of harmful sulphur compounds

Sulphur compounds are removed by treating the crude oil with copper oxide. The copper sulphide formed is separated out by filtration.

Step-3

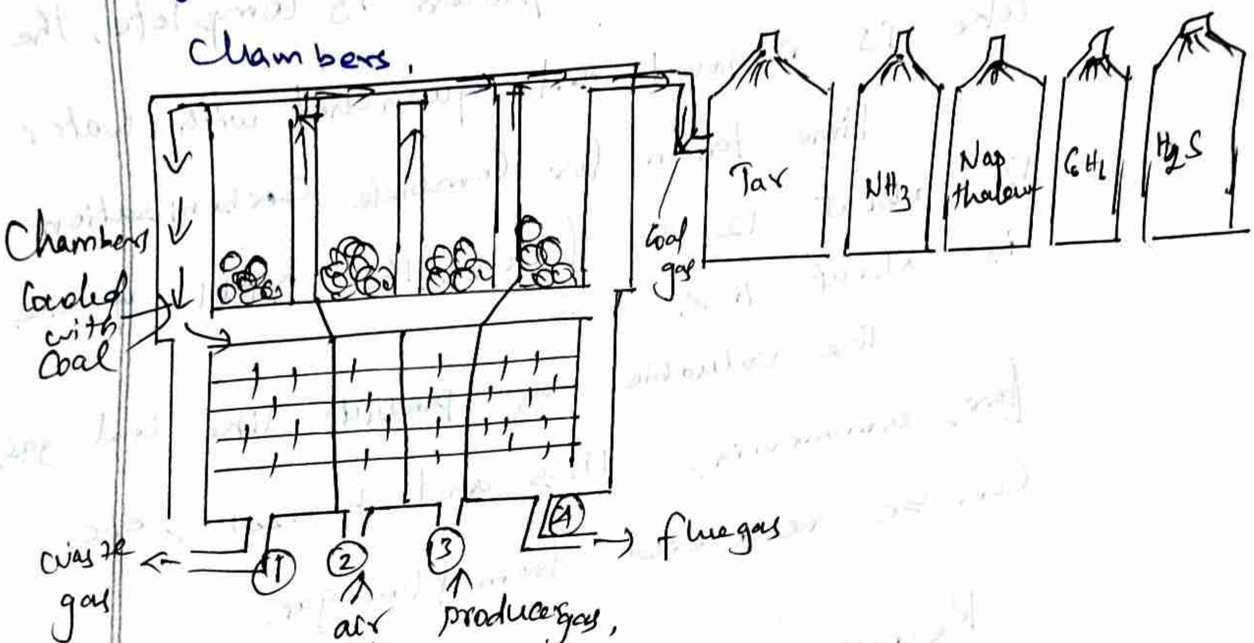
The purified ~~oil~~ crude oil is then heated to about 400°C in iron retort where the oil gets vapourised. The

Otto - Hoffman method.

The oven consist of a number of silica chambers. Each chamber is provided with a charging hole at the top

Coal is introduced into the silica chamber and the chambers are closed.

The chambers are heated to 1200°c by burning the preheated air and the producer gas mixture in the interspaces between the chambers.



The air and gas are preheated by sending them through 2nd and 3rd hot regenerators. Hot flue gases produced during combustion are allowed to pass through 1st and 4th regenerators until the temperature has been raised to 1000°c while 1st and 4th regenerations are heated by hot flue gases the 2nd and 3rd regenerators are used for heating the incoming air and gas mixture.

For economical heating, the direction of inlet gases and flue gases are changed frequently. The above system of recycling the flue gases to produce heat energy is known as the regenerative system of heat economy. When the process is complete, the coke is removed and quenched with water.

Time taken for complete carbonisation is about 12-20 hours. The yield of coke is about 70%.

The valuable by products like coal gas, tar, ammonia, H_2S and benzol, etc, can be recovered from flue gas.

Recovery of by-products,

i) Tar - The coal gases are first passed through a tower in which liquor ammonia is sprayed. Tar and dust get dissolved and collected in a tank below, which is heated by steam coils to recover back the ammonia sprayed.

ii) Ammonia : The gases are then passed through another tower in which water is sprayed. Here ammonia gets converted to NH_4OH

iii) Naphthalene: The gases are again passed through a tower, in which cooled water is sprayed, Here naphthalene gets condensed.

iv) Benzene: the gases are passed through another tower, where petroleum is sprayed, Here benzene gets condensed to liquid.

v) Hydrogen Sulphide: The remaining gases are then passed through a purifier packed with moist Fe_2O_3, Here H_2S is retained,

The final gas left out is called pure Coal gas which is used as a gaseous fuel.

Synthetic petrol

Bergius process

If Coal is heated with Hydrogen to high temperature under high pressure It is converted to gasoline. The preparation of liquid fuels from solid coal is Called Hydrogenation of Coal (or) Synthetic petrol.

Bergius process (or) direct method

In this process, the finely Powdered coal is made into a paste with heavy oil and a Catalyst powder is mixed with it. The Paste is pumped along with hydrogen gas into the Converter, where the paste is heated to 400 – 450°C under a pressure of 200 – 250 atm,

During this process hydrogen Combines with coal to form saturated higher Hydro Carbons, which Undergo further decomposition at higher temperature to yield mixture of lower hydro Carbons. The mixture is led to a Condenser, where the Crude oil is obtained

The Crude oil is then fractionated to Yield i) Gasoline ii) middle oil iii) Heavy oil

Flue gas Analysis:

(ORSAT Method)

The mixture of gases (like CO_2, O_2, CO etc) Coming out from the Combustion chamber is called flue gases.

Flue gases analysis give an idea about the Complete or incomplete Combustion process.

Description

* It Consist of a horizontal tube.
* One end of the tube - U tube with fused $CaCl_2$ other end - graduated burette.
* The lower end of burette Connected with water reservoir.
* The horizontal tube is also Connected with different absorption bulbs 1, 2, and 3 for absorbance CO_2, O_2 and CO.

Bulb	Reagent	function
1	KOH soln	Absorbs only CO_2.
2	alkaline pyrogallol soln.	Absorbs CO_2 and O_2.
3	Ammoniacal cuprous Chloride soln	absorbs CO_2 / O_2 and CO.

Working

The 3-way stop cock is opened to the atmosphere reservoir is raised, so That air is excluded from the burette. Then the 3-way stop cock is connected to flue gas supply (100 cc)

i) Absorption of CO_2

- Bulb 1 - KOH Soln.
- It absorbs CO_2 present in flue gas
- The decrease in the volume of flue gas in the burette volume of CO_2 in 100 CC of flue gas.

Unit-5

Energy sources and Storage Devices

Stability of Nucleus

Mass Defect

The difference between the calculated and experimetal masses of nucleus is called mass defects. It is denoted by Δm

Δm = {Total mass of the Protons, neutrons and electron} − {Experimental mass of the nucleus.}

Calculation of mass defects

Consider an isotope

Let its atomic number = Z

mass number = A

If its atom contains

Z - protons Z - electrons (A−Z) neutrons

Let m_p = mass of proton m_n = mass of neutron

m_e = mass of electron

Calculated mass of isotope

$$M' = Zm_p + Zm_e + (A-Z)m_n = Zm_H + (A-Z)m_n$$

M = Actual experimental mass of nucleus

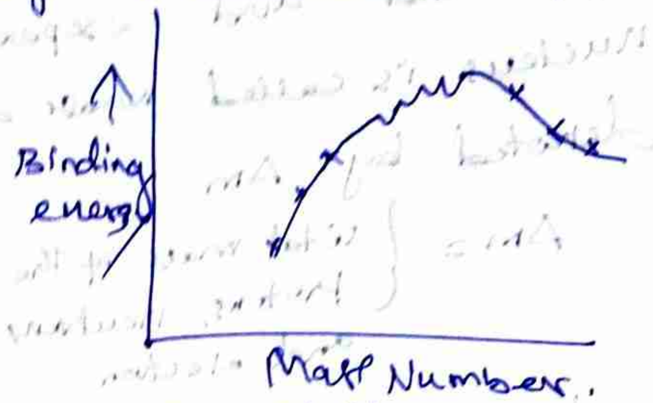
$\Delta m = M' - M$ $m_p + m_e = m_H$ (mass of H atom)

Binding Energy

Definition

The energy released when a given number of proton and neutrons come together to form nucleus.

Binding energy Vs Nuclear Stability.



* From the graph the stability of nucleus upto a mass number of 65 and decreases thereafter

* Some subsidiary peaks in the plot at $_{2}He^{4}$, $_{6}C^{12}$, and $_{8}O^{16}$ indicating stable Nuclear Configurations.

* This is probably due to the presence of equal number of protons and neutrons.

Calculation of binding energy.

It is calculated from the mass defect using the relation $E = \Delta mc^2$

$$E = [Zm_H + (A-Z)m_n - M] \times c^2$$

* Wind mill

- It Consist of wheel Contain no. of blades
- wheel rotates about an axle on a pole.
- wind energy rotates the wheel electricity was produced.
- Here the kinetic energy of the wind is Converted into electrical energy.

2. Wind farm

* To produce electricity on a large Scale, a large no. of wind mills are Connected

3. Other methods

* Kite Ship (large free flying sails)
* Sky wind power (flying electric generator)
* Briza technologies (wind turbine)

Advantages of wind energy

-> It does not Cause any pollution.
-> It is very Cheap.
-> Renewable.

7. Solar distillation.

It can harvest solar energy, if there is an integrated membrane distillation attachment.

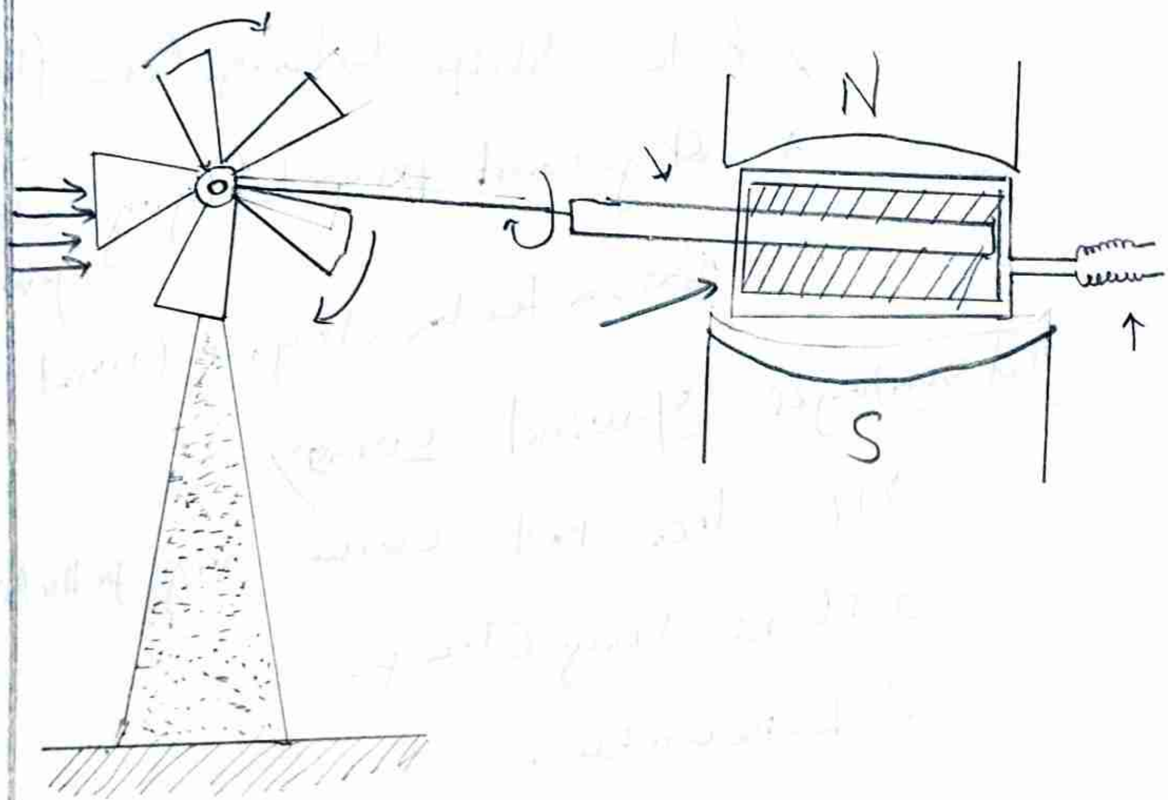
Wind energy

Energy recovered from the force of wind is called wind energy.

Methods of harvesing wind energy.

1. Wind mill

Wind energy. → Kinetic energy → Mechanical energy → Electrical energy.



efficiency 21 %.

2. Artificial geysers

In some places, we can artifically drill a hole upto the hot region, and by sending a pipe init we can make the hot water or steam to rush out through the pipe with very high pressure

Thus the hot water (or) steam coming out from the natural (or) artifical geysers, is allowed to rotate the turbine of a generator to produce electricity

Significance of geothermal energy,

⇒ The power generation level is higher

⇒ Geothermal powerplants can be constructed easily.

⇒ These are efficiency used as hot water bath resorts, aquaculture etc.

Disadvantages

- ⇒ Noise pollution
- ⇒ wind turbine interfere with electromagnetic signal.

Uses

- ⇒ It is used to operate water pumps
- ⇒ used to produce electricity.

Geo – Thermal energy

Temperature of the earth increases at a rate of 20–75°c per km, when we move down the earth surface. The energy harnessed from the huge temperature present inside the earth is called geothermal energy.

Natural geysers.

In some places, the hot water (or) steam comes out of the ground through cracks naturally in the form of natural geysers.

1. Crystalline Si

* It is the most used semi conducting material in solar panels.

* But, though it efficiency is only 30%.

* Now, high efficiency solar cells are emerging.

Ex: i) III - V multijunction materials (efficiency > 30%)

ii) Six - Junction III - V) Solar cells

Under Concentrated light efficiency > 47%

Thin films

These Solar cells are growing as one of the most promising PV technologies because of their narrow design. (light weight, flexibility and ease of installation)

Eg i) Cd - telluride (CdTe)

ii) Copper - Indium - Gallium - Selenide (CIGS)

efficiency 21%.

3. Perovskite solar cells.

These are low price, thinner design, low temperature processing and posses excellent light absorption properties

Eg. Combined perovskite and Si-pv materials shows efficiency upto 28%.

4. Solar paints.

It can be coated over the polymer films

Eg Quantumdote,

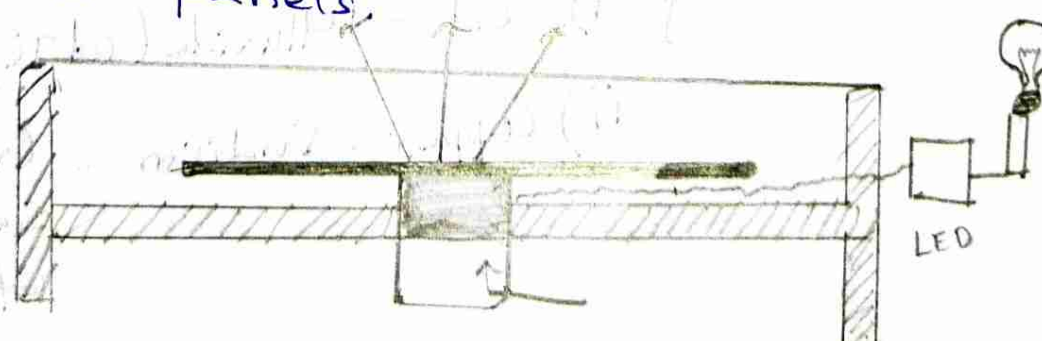
Perovskite - based paints.

5. Transparent solar windows

They posses highly innovative applications. Their solar to electricity conversion efficiency is 10%. more.

6. Thermoradiative pv devices (or) Reverse solar panels.

It can generate electricity at night by using the heat irradiated from the panels.



2. Solar water Heater.

* It Consist of an insulated box (painted in black Colour)

* At the top, there is a glass lid (receive and store Solar heat)

* Inside it black Painted (Cu coil through which cold water is allowed to which gets heated and stored in a Storage tank.

* Then the water is supplied through pipes.

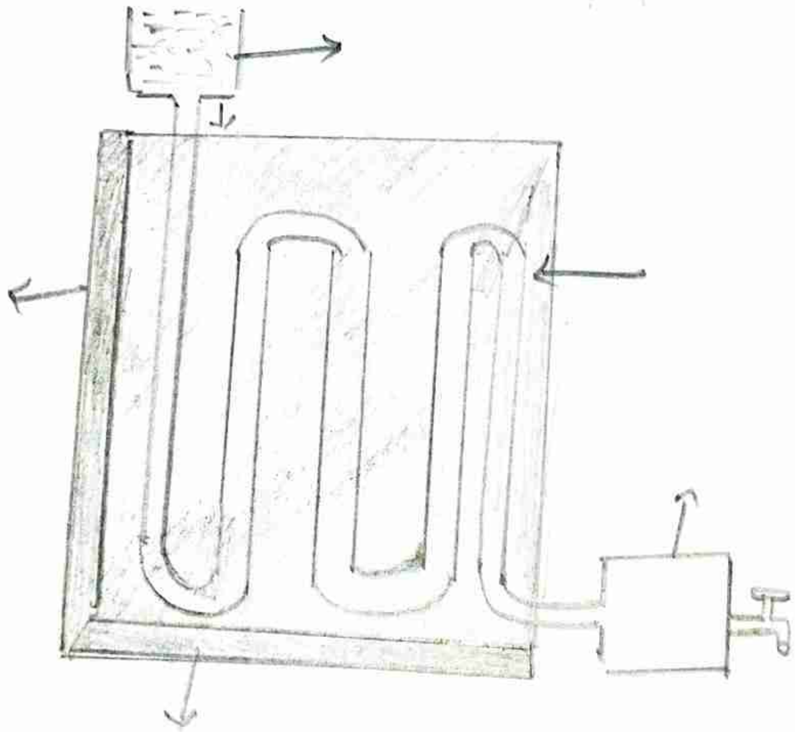


Photo Conversion

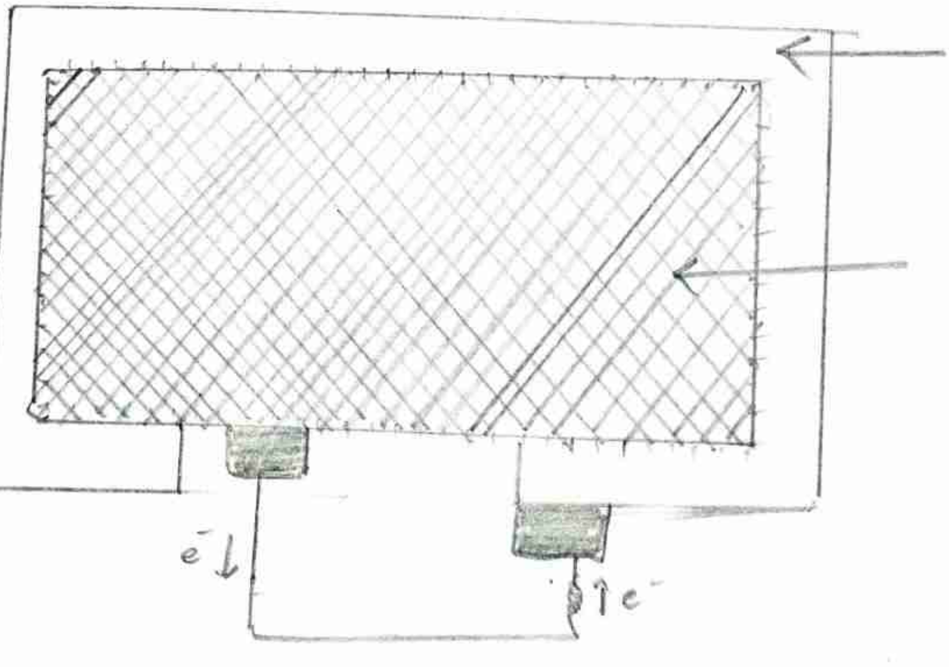
Light energy (sun) → Electrical energy,

Photo galvanic cell (or) Solar cell

photogalvanic cell Converts Solar energy directly into electrical energy,

principle

when the solar rays falls on a two layers of Semi Conductor devices a potential difference between two layer is produced. This potential difference Causes flow of electrone and produces electricity,



It Consist 7

P type Semi Conductor (Si doped with B)

n type Semi Conductor (Si doped with P)

Working

* Solar rays fall on the top layer of P-type Semi Conductor

* The e^-ns from the valence band get promoted to the Conduction band Cross. p-n junction into n-type Semi Conductor.

* So there is Potential difference between two layers

* Hence, there is a flow of e^-ns, and Current is produce,

Applications of Solar cells,

* Solar Cells Can be used for lighting purpose.

* Solar batteries produces more electricity which is enough to run water pump.

* Solar Cells are used in Calculators electronic watches radios and TVs,

Advantages

* maintenance cost low.
* Solar cells are noise and pollution free.
* Their life time is long

Disadvantages.

* Capital cost is higher.
* Storage of solar energy is not possible.

Recent developments in Solar cell materials

Types of highly investigated solar cell materials.

1. Crystalline Si
2. Thin films
3. Next generation perovskite solar cells.
4. Solar paints.
5. Transparent solar windows.
6. Thermoradiative pv devices.
7. Solar distillation.

where

E = binding energy of the nucleus

Δm = mass defect

c = velocity of light.

Nuclear energy

The energy released by the nuclear fission (or) nuclear fusion reaction is called nuclear energy.

Nuclear Reactor (or) pile

Components of a nuclear reactor

1. Fuel rods

The fuel (fissionable material) used in the reactor in the form of rods (or) stripes.

Ex: U^{235}, Pu^{239}.

function

* It produces heat energy and neutrons.

2. Control Rods

To control the fission reaction movable rods are placed between fuel rods. These rods can be raised (or) lowered and control the fission reaction

$$Cd^{113}_{43} + {}_0n^1 \longrightarrow Cd^{114}_{43} + \gamma\text{-ray}$$

$$B^{10}_5 + {}_0n^1 \longrightarrow {}_5B^{11} + \gamma\text{-ray}$$

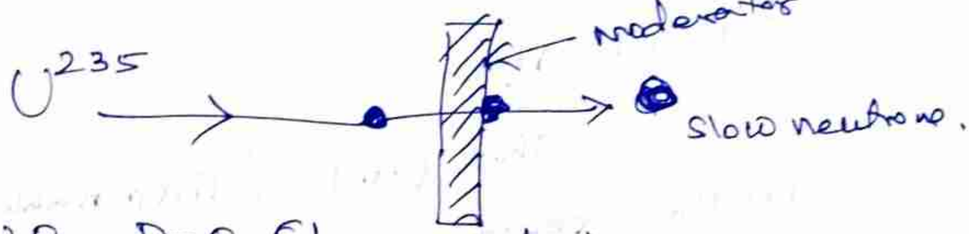
Ex: Cd^{113}, B^{10}

<u>function</u>

* It Controls the nuclear chain reaction.

3. <u>Moderator</u>

these are substance used to slow down the neutrons,



Eg. H_2O, D_2O (heavy water)

Function

* The Kinetic energy of fast moving neutrons (1 mev) is reduced to 0.25 mev.

4. <u>Coolant</u>

The liquid (used to absorb heat produced) is Circulated in the reactor Core is Known as Coolant

Eg: H_2O, D_2O.

5. Pressure Vessel

It enclose the reactor core and provide entrance and exit for the passage of coolant.

Function

It with stand the pressure as high as 200kg/cm²

6. Protective Shield.

The nuclear reactor enclosed with a Concrete Shield (more than 10m thick.)

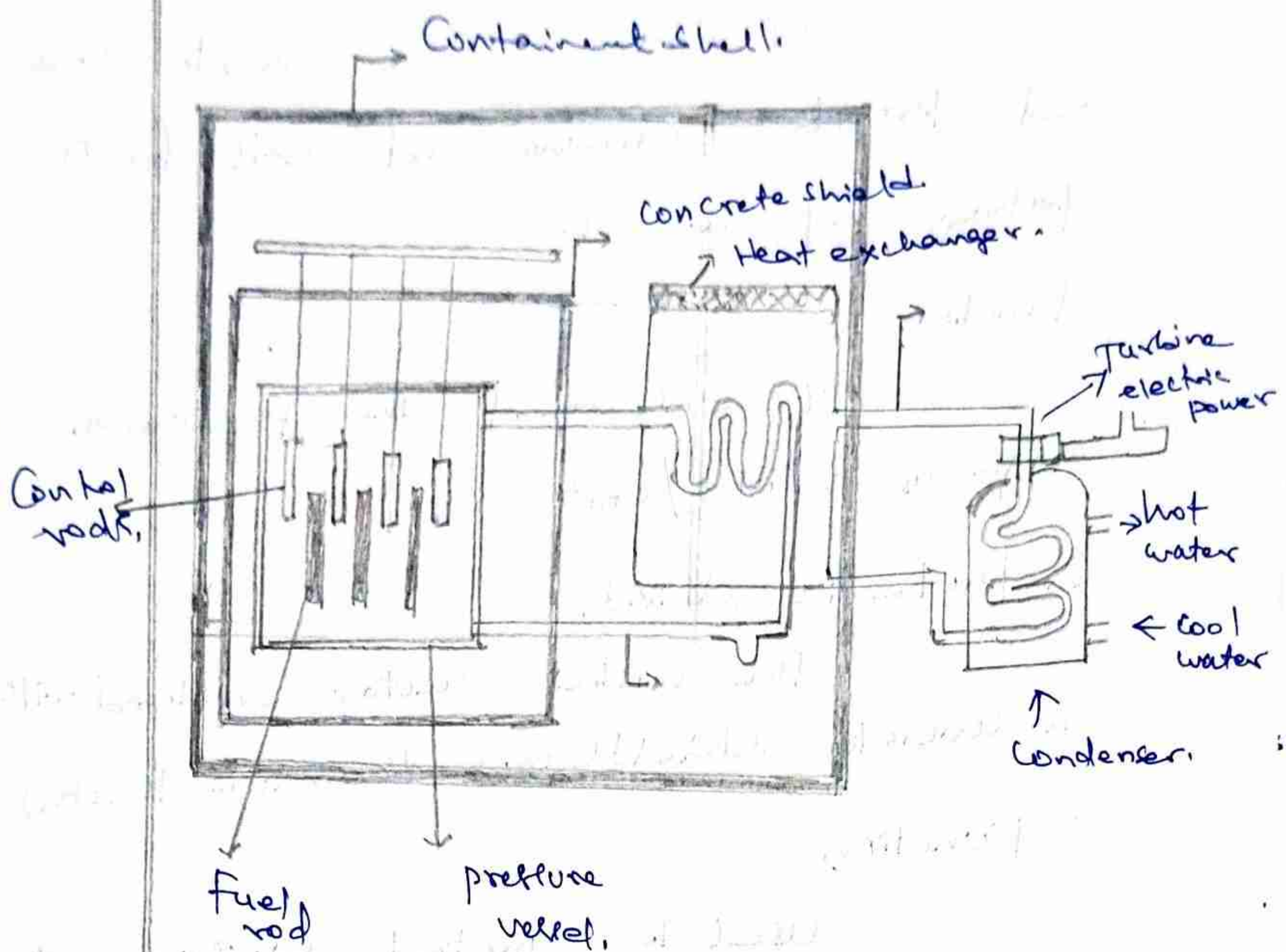
Function

Used to protect environment from radiation

7. Turbine

The steam is used to operate steam turbine which drives a generator to produce electricity.

In light water nuclear Power Plant U^{235} fuel rods are submerged in water, Here water acts as coolant and moderator.



Working

* The fission reaction is controlled by ~~inter~~ inserting (or) removing control rods of B^{10}.

* The heat produced from nuclear fission reaction is absorbed by the coolant (water)

* The heated coolant (water at 300°c) then goes to the heat exchanger containing sea water.

* The coolant here transfer heat to sea water which is converted into steam,

* The steam drives the turbine, generate electricity,

Problem on disposal of reactor waste

The fission products are radioactive. They emit dangerous radiation for several hundred years.

So the waste is packed in Concrete barrels, which are buried deep in the sea.

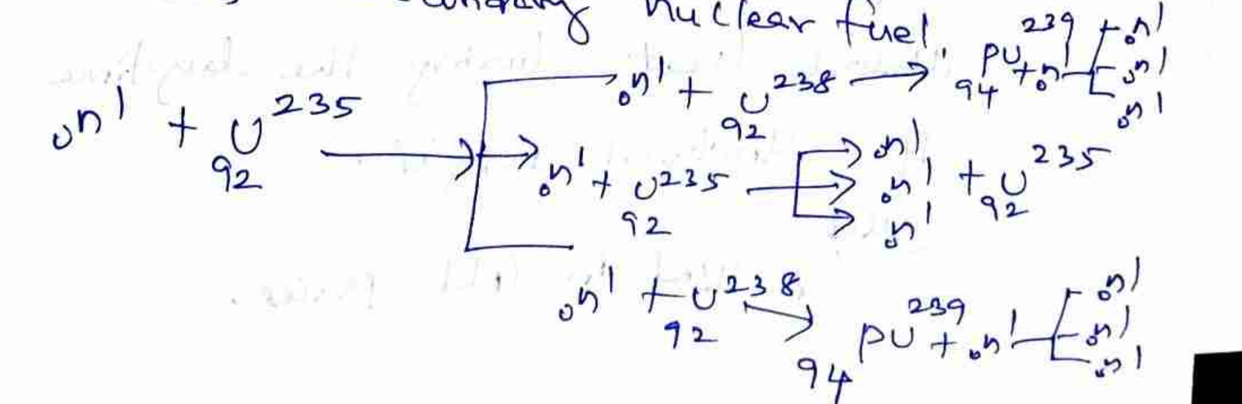
Breeder Reactor

Breeder reactor is the one which converts non-fissionable material (U^{238}, Th^{232}) into fissionable material (U^{235}, Pu^{239})

$$_{92}U^{238} + {}_0n^1 \longrightarrow {}_{94}Pu^{239} + 2e^- \xrightarrow{{}_0n^1} \text{Fission pdt} + 3\,{}_0n^1$$

In Breeder reactor of the 3 neutrons one is used to react with U^{235}, two is used to react with U^{238}

P^{239} is a man made nuclear fuel, and it is known as secondary nuclear fuel.



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Significance

* The non-fissionable nucleides (fertile nucleides) like U^{238}, Th^{232} Converted into fissile nucleides like U^{235}, Pu^{239}
* The efficiency of fissile nucleides are greater.

Solar Energy Conversion

It is the process of Conversion of direct sunlight into more useful forms

* Thermal Conversion.
* Photo Conversion.

Methods of thermal Conversion.

1. Solar heat Collectors.

These Consist of natural materials like stones bricks ~~co~~ glass, which can absorb heat during the daytime and release it slowly at night.

Uses

* used in Cold places.

UNIT - V

Batteries

* A battery is an arrangement of several electrochemical cells connected in series that can be used as a source of direct electric current.

A cell : It contains only one anode and cathode.

A Battery : It contains several anodes and cathodes.

TYPES OF BATTERY

1. Primary Battery / NON Reversible Battery

(*) NOT Chargeable — The electrode rxn cannot be reversed by passing an external electrical energy. The rxn occurs only once and after use they become dead. Ex: Dry cell, mercury cell

2. Secondary Battery / Reversible Battery

The electrode rxn can be reversed by passing an external electrical energy. It can be recharged by passing electric current used again & again and also called storage cell (or) Accumulators.
Ex: Lead acid storage cell.

3. Flow battery or Fuel cell.

In these cells, the reactants, products and electrolyte are continuously passing through the cell here chemical energy gets converted into electrical energy. Ex: $H_2 - O_2$ fuel cell.

Dry cell / Leclanche's cell.

It is a primary cell.

Anode: Zn

Cathode: graphite.

Electrolyte: $ZnCl_2 + NH_4Cl + MnO_2$ paste using starch & H_2O.

EMF : 1.5 V

It consists of Zn cylinder filled with electrolyte of paste ($ZnCl_2 + NH_4Cl + MnO_2$) as anode. Carbon rod acts as cathode.

Cell reactions:

At Anode: $Zn \rightarrow Zn^{2+} + 2e^-$

At Cathode: $NH_4^+ + MnO_2 + 2e^- \rightarrow MnO(OH)^- + NH_3$

$$Zn + NH_4^+ + MnO_2 \xrightarrow{(O)} Zn^{2+} + MnO(OH^-) + NH_3$$

Mn is reduced from +4 oxidation state to +3 oxidation state. The liberation of NH_3 gas is prevented by a reaction of $NH_{3(g)}$ with Zn^{2+} form $ZnCl_2$

If operates as voltaic cell and as an electrolytic cell. It consists of a number of voltaic cell connected in series. In each cell connected in series. In each cell pb is Anode and pbO_2 is Cathode which are alternatively placed. They are separated by insulators like rubber. They entire Combination is immersed in dil H_2SO_4 (13 g/ml)

Cell Representation

$$Pb(s) / PbSO_{4(s)} // H_2SO_{4(aq)} / PbO_2 / Pb(s)$$

Cell reactions (During discharging)

At Anode : $Pb + SO_4^{2-} \rightleftharpoons PbSO_4 + 2e^-$

At Cathode $PbO_2 + 4H^+ + SO_4^{2-} + 4e^- \rightleftharpoons 2PbSO_4 + 2H_2O$

$$Pb + PbO_2 + 2H_2SO_4 \rightleftharpoons 2PbSO_4 + 2H_2O$$

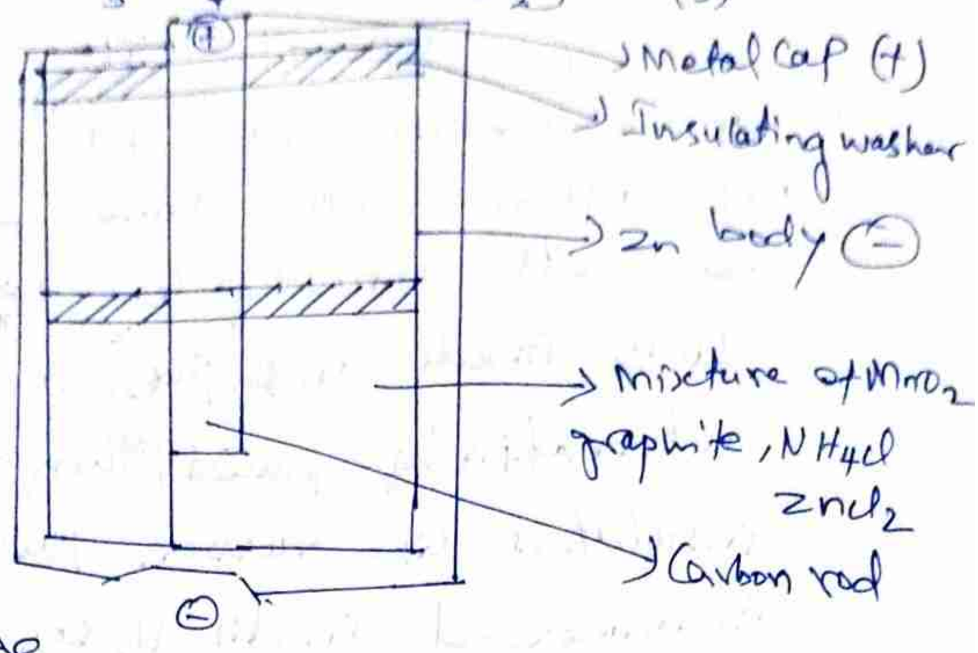
During charging

$$2PbSO_4 + 2H_2O \rightleftharpoons Pb + PbO_2 + 2H_2SO_4$$

Advantages
* It is made easily
* It produces very high current

Disadvantages
* Recycling Causes environmental hazards
* Mechanical Strain and normal bumping reduces battery Capacity

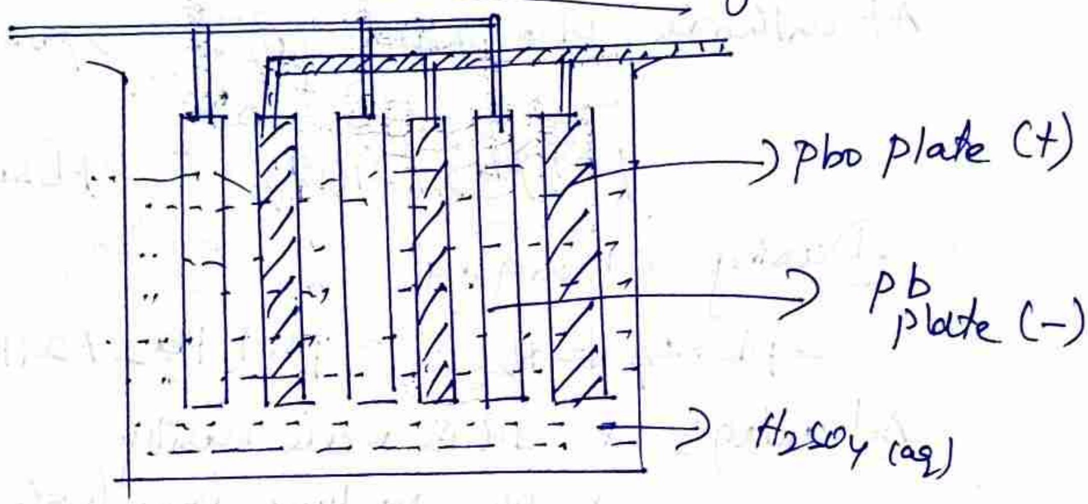
$ZnCl_2 + 2NH_3 \longrightarrow [Zn(NH_3)_2]Cl_{2(s)}$



Disadvantage

1. Life is short because NH_4Cl corrodes Zn container even if not used.
2. voltage drop occurs

Lead-Acid Battery

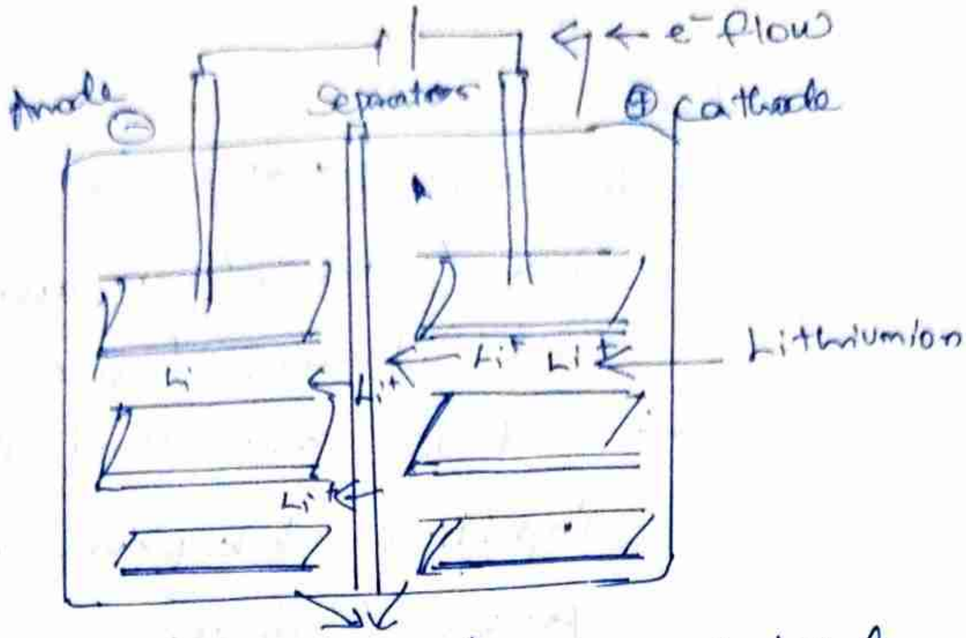


Anode: Pb

Cathode: PbO_2

Electrolyte: H_2SO_4

EMF $6 \times 2 = 12V$



Electrolyte gel polymer electrolyte

Li^+ cell during charging

<u>working Charging</u>

Li^+ ions flow from the positive electrode ($LiCoO_2$) to the negative electrodes (graphite) through the electrolyte Electrons also flow from the positive electrodes to the negative electrodes through the wire the electrons and Li^+ ion Combine at the negative electrode and deposit there as Li

$$LiCoO_2 + C \longrightarrow Li_{(1-x)}CoO_2 + CLi_x$$

<u>working discharging</u>

Li^+ ions flow back through the electrolyte from negative electrode to the positive electrode. electrons flow from negative electrode to the positive electrodes through the wire the Li^+ ions and electrons Combine at the positive electrode and deposit there as Li

$$Li_{(1-x)}CoO_2 + CLi_x \longrightarrow LiCoO_2 + C$$

Uses

1. Lead Storage Cell is used to supply Current mainly in automobiles such as Cars, buses, trucks
2. It is also used in gas engine ignition, telephone exchange, hospitals power Stations.

Lithium-ion Battery

* It is a Secondary battery
* The movement of Lithium ions are responsible for charging and discharging
* Lithium ion cells has three Components.

⇒ A positive electrode (Layers of Lithium metal, oxide) cathode

⇒ A negative electrode: (Layers of porous Carbon) anode

⇒ An electrolyte polymer gel - Separator

Constructions

Cathode : $LiCoO_2$ layers

Anode : graphite

Electrolyte : polymer gel electrolyte (organic Solvent)

The electrodes and electrolyte are separated by a separator which allow Li^+ ions to pass through.

Working principle

Electric vehicles works by storing electricity in rechargeable battery that power on electric motor which rotates the wheels.

Various steps of working

Step - I Controller takes and regulates electrical energy from battery to inverter.

Step II The inverter then sends a certain amount of electrical energy to the motor

Step III The motor converts electrical energy into mechanical energy (rotation)

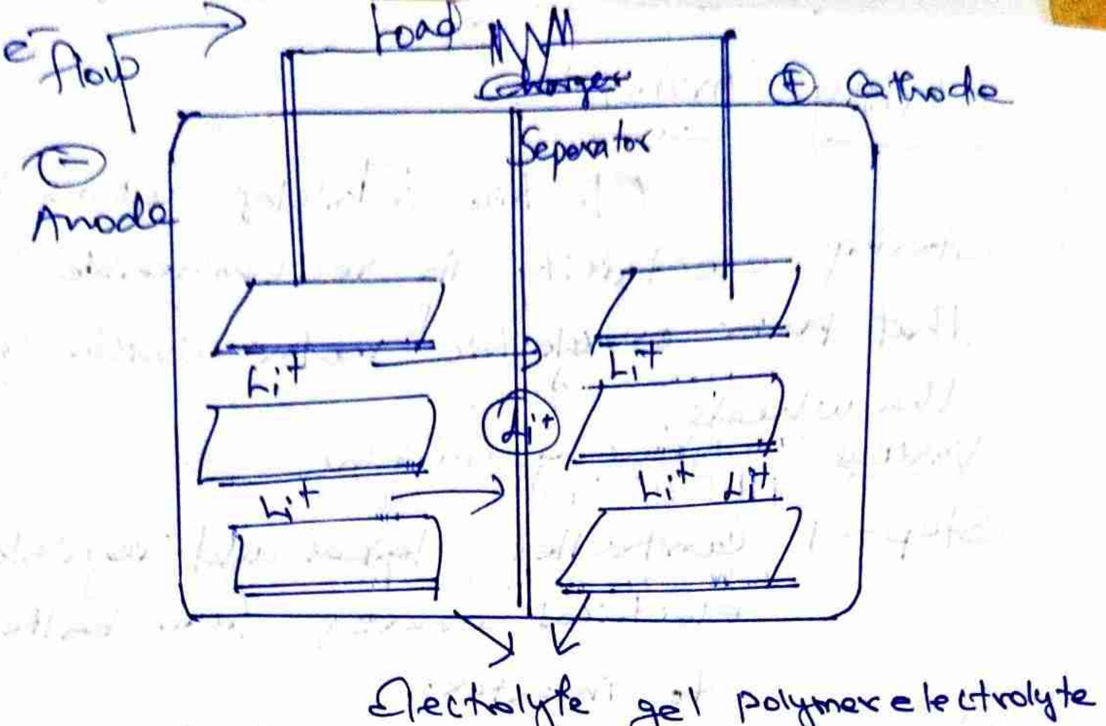
Step IV Rotation of the motor rotor rotates the transmission, so the wheels turn and then the vehicle moves

Step V When the brakes are pressed, the motor becomes an alternator and produces power which is sent back to the battery.

Types of plug - in electric vehicles

1. Battery Electric vehicles (BEV)

These are the vehicles powered by a battery. These batteries can be charged by plugging the vehicle into the charging equipment. Its typical driving ranges from 150 to 300 miles. This type of vehicles do not have an ICE.



Li^+ ion cell during discharging.

Advantages

1. Li^+ batteries are high voltage and light weight batteries.
2. It is smaller in size, it produce 3 times the voltage of Ni - Cd batteries.

Uses of Lithium cell,

It is used in cell phone, note PC, portable LCD TV Semi conductor driven audio

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Electric VEHICLES

Electric vehicles are the vehicles runs on electric power referred as battery electric vehicles. They have an electric motor instead of IC engine since it runs on electricity, the vehicle emits no exhaust gases.

Fuel Cell Electric Vehicles

Fuel cell technology is to generate electricity which is required to run the vehicle. Here Chemical energy of the fuel is Converted directly into electric energy The main advantage of this vehicle is it generates electricity required to run their vehicle on the vehicle itself.

Advantages

1. Electric cars are energy efficient.
2. It reduces emission.
3. Its performance is high and has low maintance.
4. It is more Convenient and easy to recharge.

Disadvantages

1. Electric Cars can travel less distance
2. Initial investment is very high.
3. It takes longer time to refuel (recharge)
4. These are more expensive and battery Packs may need to be replaced.

Hybrid Electric vehicle (HEV)

It has both an Internal Combustion engine (ICE) and an electric motor. In this type of electric cars. ICE gets energy from fuel while the motor gets electricity from batteries. It offers a mixture of battery and gasoline powers.

The gasoline engine and electric motor Simultaneously rotate the transmission, which drives the wheels Batteries in HEC can only be charged by ICE by the motion of the wheels The battery cannot be charged from out side the system.

Plug-in Hybrid Electric vehicle (PHEV)

This type of electric cars are powered by a Conventional fuel (gasoline) and by a rechargeable batteries pack. This battery can be charged up with electricity by plugging into an electrical plug. It can also be recharged by ICE.

It operates on electricity until their battery pack is depleted. Once the battery is empty the engine takes over and the vehicle operates as a Conventional non-plug in Hybrid vehicle.

Advantages

1. Fuel cells are efficient 75% and take less time for operations.
2. It is pollution free technique.

Disadvantages

1. Electrodes are expensive and short lived.
2. Storage and handling of H_2 gas in dangerous.
3. Electrodes are expensive and short lived.
4. Fuel cells can not store electric energy as other cells do.

Fuel cells ($H_2 - O_2$ fuel cells)

Fuel cell is a voltaic cell which converts the chemical energy ~~into~~ of the fuels directly into electricity without combustion

Fuel + O_2 ⟶ oxidised pdt + current.

Fuel - Hydrogen   Electrolyte KOH/NaOH

Oxidiser oxygen   Emf 0·8 – 1·0 V

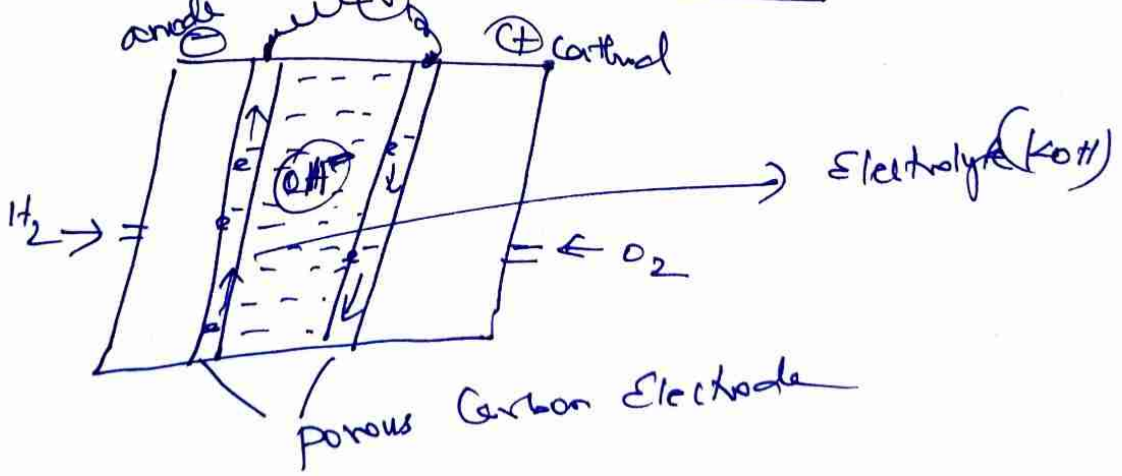
It consist of porous electrodes anode and cathode made up of compressed carbon containing catalyst Pt, Pd, Ag electrolyte is placed in between them two electrodes are connected to voltmeter H_2 gas is passed through anode and O_2 is passed through cathode.

Cell reactions.

Anode $2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$

Cathode $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$

$2H_2 + O_2 \longrightarrow 2H_2O$



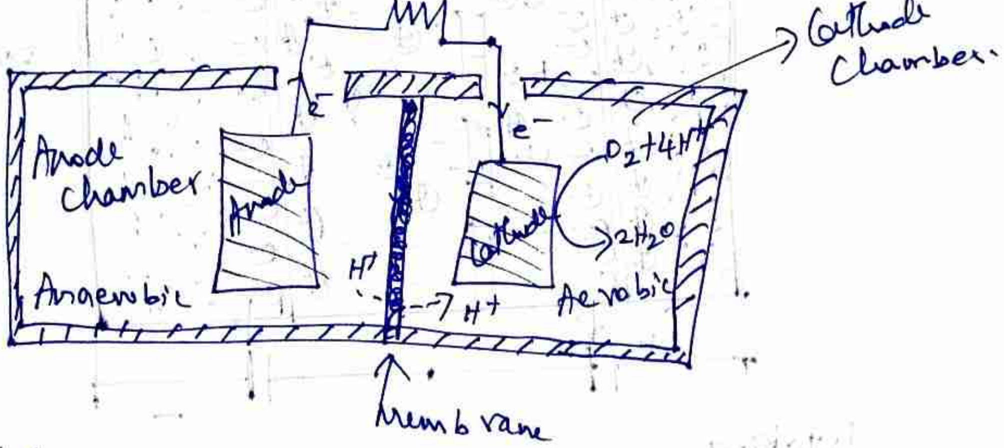
σ oxidation (at anode) ...

3. This electric field polarize the dielectric so its molecule line up in the opposite direction to the field and reduce it strength.

Advantages	Disadvantages	Applications.
* Highly safe	* Cost per watt is high	* Energy harvest
* Lifetime is high	* Cannot be a source for continuous power supply.	* Consumer electricity
* Can be charged in seconds	* High self discharge	* kitchen application
performance is excellent even at low temp (−40°C)		* switches, LED

Microbial fuel cells (MFCs)

MFCs converts chemical energy to electrical energy by the action of micro organisms under anaerobic conditions.



Principle

* MFCs are electro chemical cell - has bioanode and biocathode

* A membrane separates anode and cathode

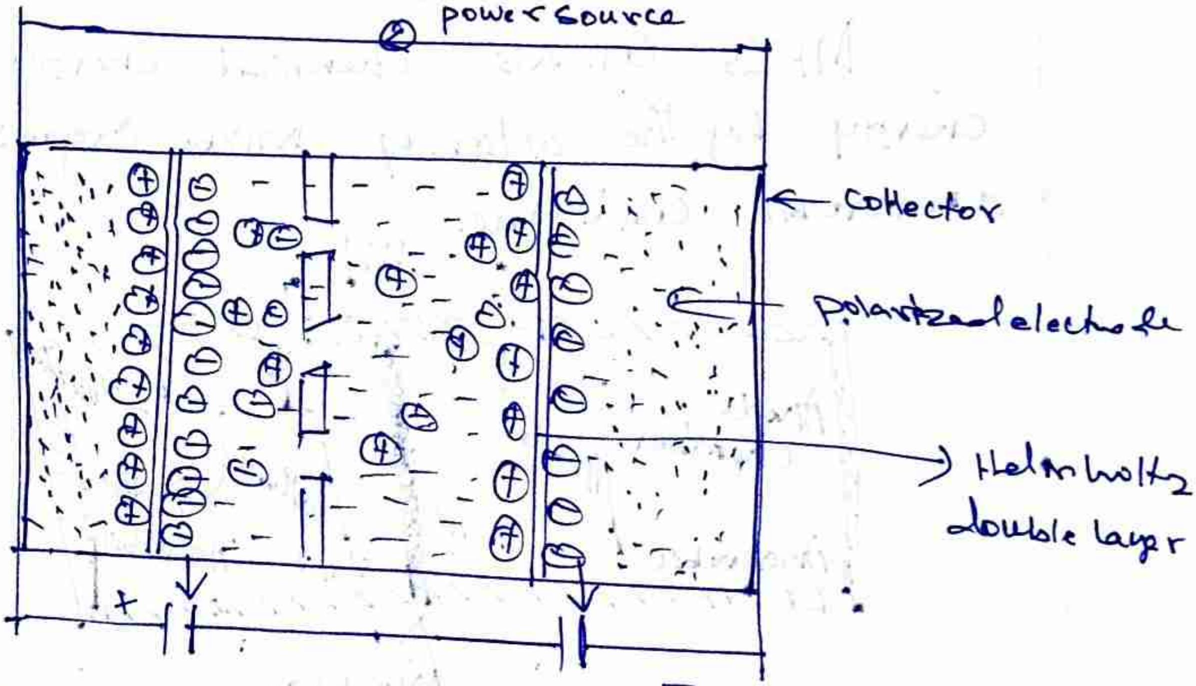
* The e^- produced during oxidation (at anode) transfer to cathode.

Super Capacitor

* It is a high Capacity Capacitor more Capacitance value
* Super Capacitors use electrostatic double layer

Design

It has two electrodes made from metal Coated with a porous substance like powdery activated Carbon, separated by an ion permeable Membrane (Separator) dipped in an electrolyte Containing positive and negative ions, Connecting both the electrodes.



Working

① When The electrodes are Connected to the power source, ions in the electrolyte forms electrical double layer.

① Electrode / Electrolyte interface (+)vely polarized electrode have a layer of -ve ions. -vely polarized electrode will have layer of +ve ions

Organic electron donors, oxidised to produce CO_2, protons and ~~elt~~ electrons are used in most MFCs

Components

i) Anodic Compartment - it Consists of microbes suspended under anaerobic Conditions.

ii) Cathodic Compartment - It Consist of electron acceptor CO_2

iii) Permeable membrane - Cationic and anionic Compartment seperated by Permeable Cation - specific membrane.

Working

* At anode oxidation occurs on Organic waste and e's were released.

* The electrons transferred directly to Cathode across external circuit.

* For every electron Conducted, a proton is transported across the membrane to the Cathodes.

* Finally O_2 present at Cathode Combines with Hydrogen and electron to produce water.

Applications:

* Used in waste water treatment
* used in deep water environments
* used to convert carbon rich waste water into methane
* Used in Space
* MFCs plays an important role in the field of micro biology and soil chemistry.