UNIT V – ENERGY SOURCES AND STORAGE DEVICES

5.2 Nuclear Fission

When U235 is bombarded by thermal neutron (low energy neutron), it splits into two approximately equal parts with the liberation of large amount of energy.

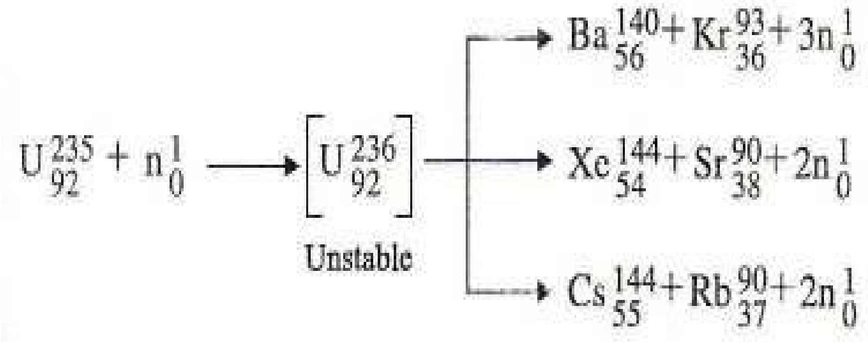
5.2.1 Definition

Nuclear fission is defined as "**the process of splitting of heavier nucleus into two (or) more smaller nuclei with simultaneous liberation of large number of energy**".

5.2.2 Mechanism of nuclear fission

When U^{235} is bombarded by thermal neutron (slow moving), unstable $U^{236}$is formed. The unstable

U^{236} then divides into two approximately equal nuclei with the release of neutrons and large number of energy



Illustration

During the nuclear fission a large amount of energy is released.

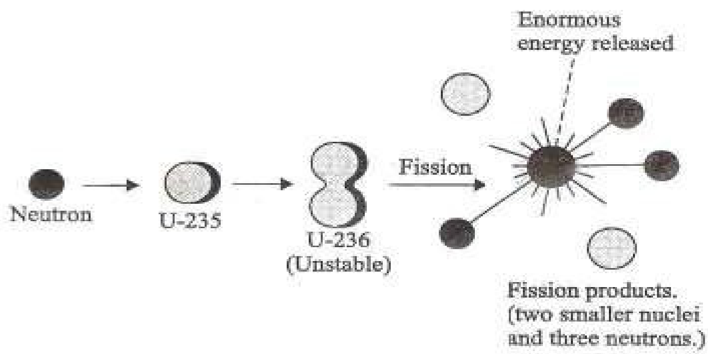


Fig. 5.1 The fission process illustrated

5.2.3 CHARACTERISTICS OF NUCLEAR FISSION

- A heavy nucleus such as (U^{235} (or) Pu^{239}) is bombarded by slow moving neutrons, split into two or more smaller nuclei.
- Two or more neutrons are produced by fission of each nucleus.
- Large quantities of energy are produced as a result of conversion of small mass of nucleus into energy.
- All the fission fragments are radioactive, giving off く and |ナ radiations.
- The atomic weights offission fragments range from about 70 to 160.
- All the fission reactions are a self-propagating chain-reactions fission products contain neutrons (secondary neutrons) which further cause fission in other nuclei.
- The nuclear chain reactions can be controlled and maintained steadily by absorbing a desired number of neutrons. This process is used in nuclear reactor.
- Every secondary neutron, released in the fission process, does not strike a nucleus, some escape into air and hence a chain reaction cannot be maintained.
- **Multiplication factor:** The number of neutrons, resulting from a single fission is known as the Multiplication factor. When the value of multiplication is less than 1, a chain reaction does not take place.

5.2.4 Advantages and disadvantages ofnuclear fission energy

Advantages of nuclear fission energy over fossil fuels energy

1. A small amount of nuclear fuel (U235) gives a large amount of energy while large quantity of fossil fuel is required to produce large amount of heat.
2. In a nuclear power plant, the nuclear fuel is inserted once to get energy over a long period of time. But, in a thermal power plant, fossil fuel is to be supplied continuously to get the energy.

Disadvantages of nuclear fission energy over fossil fuels energy

1. .Nuclear fission causes more serious pollution problems than burning fossil fuels.
2. The biggest problem of using nuclear fission energy is the safe disposal of nuclear waste. But no such problem is faced in the disposal of fossil fuels.

5.3 NUCLEAR FUSION

Nuclear fusion is defined as **"the process of combination of lighter nuclei into heavier nuclei, with simultaneous liberation of large amount of energy"**. Nuclear fusion occurs in sun.

Example:

$${}_1H^2 + {}_1H^2 \lesssim 2He^4 + \text{Energy}$$

$${}_1H^2 + {}_1H^3 \lesssim 2He^4 + {}_0n^1$$

Fig. 5.2 The fusion process illustrated

5.3 .1 CHARACTERISTICS OF NUCLEAR FUSION

1. Unlike nuclear fission, there is no limit on the amount of nuclear fusion that can occur.
2. It is possible only when the distance between the nuclei is of the order of one Fermi.
3. The amount of energy in fusion is 4 times more compared to that of fusion.

5.3.2 Difference between nuclear fission and fusion

S.No	Nuclear fission	Nuclear fusion
1.	It is the process of breaking of heavier nucleus.	It is the process of combination of lighter nuclei.
2.	It emits radioactive rays	It does not emit any kind of radioactive rays.
3.	It occurs ordinary temperature.	It occurs high temperature(>10^6)
4.	The mass number and atomic number of new elements are lower than that of parent nuclei.	The mass number and atomic number of product is higher than that of starting elements.
5.	It gives rise to chain reaction	It does not rise to chain reaction
	It emits neutrons	It emits positrons
6.	It can be controlled	It cannot be controlled

5.4 NUCLEAR CHAIN REACTION

In the nuclear fission reaction the neutrons emitted from the fission of U^{235}atom may hit another U^{235} nuclei and cause fission producing more neutrons and so on. Thus, a chain of self-sustaining nuclear reactions will set up with the release of enormous amount of energy. But the amount of energy released will be less than expected. Thus the fission of U^{235} by slow moving neutrons is a chainreaction.

5.4.1 Definition

A fission reaction, where the neutrons from the previous step continue to propagate and repeat the reaction is called nuclear chain reaction.

Reason for less energy

Some of the neutrons, released in the fission of U^{235}, may escape from the surface to the surroundings or may be absorbed by U^{235} present as impurity. This will result in breaking of the chain and the amount of energy released will be less than expected.

5.4.2 Criteria for nuclear chain reaction

- For a nuclear chain reaction to continue sufficient amount of U^{235} must be present to capture the neutrons, otherwise neutrons will escape from the surface.

Critical mass

The minimum amount of fissionable material (U^{235}) required to continue the nuclear chain reaction is called critical mass.

The critical mass of U^{235} lies between 1 kg to 100kg.

(a) Super critical mass

If the mass of the fissionable material (U^{235}) is more than the critical mass, it is called super critical mass.

(b) Sub critical mass

If the mass of the fissionable material is smaller than the critical mass; it is called sub critical mass.

- Thus the mass greater or lesser than the critical mass will hinder the propagation of the chain reaction.

Illustration

When U^{235} nucleus is hit by a thermal neutron, it undergoes the following reaction with the release of three neutrons.

$${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba139 + {}_{36}Kr^{94} + 3{}_{0}n^{1}$$

Each of the three neutrons, produced in the above reaction, strikes another U^{235} nucleus causing 9 subsequent reactions. This 9 reaction further give rise to 27 reactions. This process of propagation of the reaction by multiplication in threes at each fission is called Chain reaction.

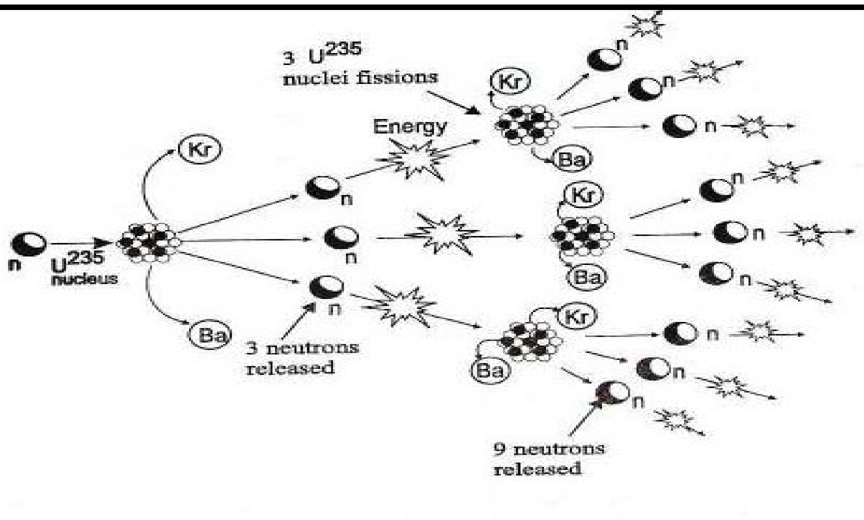


Fig. 5.3 U^{235} fission chain reaction illustrated

5.5 NUCLEAR ENERGY

The enormous amount of energy released during the nuclear chain reaction of heavy isotope like U^{235} or Pu^{239} is called nuclear energy.

5.5.1 DEFINITION

The energy released by the nuclear fission is called nuclear fission energy or nuclear energy.

Illustration

The fission of U^{235} or Pu^{239}occurs instantaneously, producing enormous amount of energy in the form of heat and radiation.

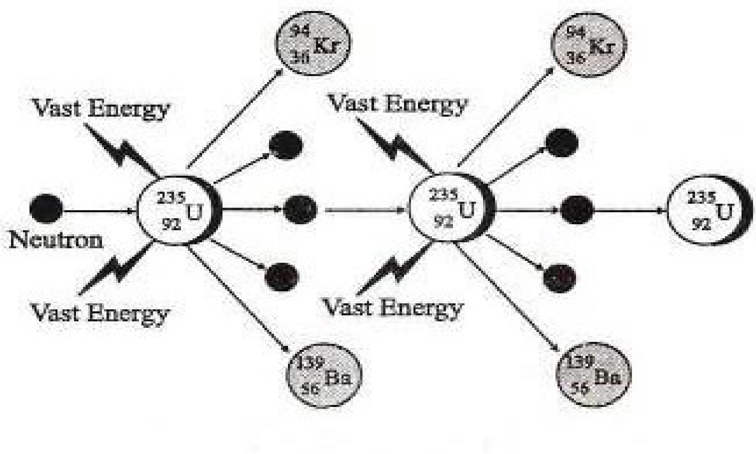


Fig. 5.4 Nuclear energy illustrated

5.5.2 CAUSE OF THE RELEASE OF ENERGY

The enormous amount of energy released during the nuclear fission is due to the loss in some mass, when the reaction takes place. It has been observed that during nuclear fission, the sum of the masses of the products formed is slightly less than the sum of masses of target species and bombarding neutron. The loss in mass gets converted into energy according to Einstein equation.

$E = mc^2$

Where,

c = velocity; m =loss in mass and E = energy

5.5.3 Hazards of using nuclear energy

The radiation is harmful to the living organisms. The long and constant exposure of living organisms to these radiations causes the following disease.

1. Damage the structure of cells in the human body.
2. Cancer and blindness.
3. Genetic disorder in a human body.
4. Sterility in young generation

5.5.4 Applications of nuclear energy

1. Electricity generation
2. Sources of pure water
3. Health care
4. Agriculture

5.6 TYPES OF NUCLEAR FISSION REACTION

5.6.1. Uncontrolled nuclear fission reaction

If a nuclear fission reaction is made to occur in an uncontrolled manner, then the energy released can be used for many destructive purposes.

Ex: Atom Bomb

5.6.2. Controlled nuclear fission reaction

If a nuclear fission reaction is made to occur in an controlled manner, then the energy released can be used for many constructive purposes.

Ex: Nuclear Reactor

5.7 NUCLEAR REACTOR (OR) PILE: If a nuclear fission reaction is made to occur in a controlled manner, then the energy released can be used for many constructive purposes.

5.7.1 DEFINITION

The arrangement or equipment used to carry out fission reaction under controlled conditions is called a nuclear reactor.

Example:

The energy released (due to the controlled fission of U^{235} in a nuclear reactor) can be used to produce steam which can run turbines and produce electricity.

5.7.2 Classification of nuclear reactors

I. Based on neutron energy and moderator

1. Thermal neutron reactors

In these reactors, nuclear fission reaction is brought out by slow moving neutrons. These are further classified into various types

(a) Light water moderated reactors (LWR)

In these reactors, ordinary water is used as moderators and coolant. These are cheaper and have excellent safety and stability when compared to other nuclear reactors.

These are further classified into

(i) Boiling water reactors (BWR)

(ii) Pressurized water reactors (BWR)

(iii) Supercritical water reactors (BWR)

(b) Heavy water moderated reactors (HWR)

Heavy water is used as a moderator

(c) Graphite moderated reactors (GMR)

Graphite is used as a moderator

(i) Gas cooled reactors

(ii) Water cooled reactors

2. Fast neutron reactors

In these reactors nuclear fission is brought out by unmoderated fast moving (high energy) neutrons. These are generally cooled by liquid metal.

II. Based on fuel used

1. Burner

Here, nuclear fuel is burnt to produce heat or electrical energy.

2. Convertor (or) Breeder type reactors

II. Based on purpose

(a) Power reactor

(b) Breeder reactor

(c) Materials testing reactor

5.7.3 COMPONENTS OF A NUCLEAR REACTOR

The main components of the nuclear reactor are

1. **Fuel rods**

The fissionable materials used in the nuclear reactor are enriched U^{235} or Pu^{239}. The enriched fuel is used in the reactor in the form of rods or strips.

Example: $\mathbf{U^{235}}$**;** $\mathbf{Pu^{239}}$ **(obtained from** $\mathbf{U^{238}}$**)**

Function: It produces heat energy and neutrons which initiates the nuclear chain reaction. The heat should be removed efficiently during the fission process.

2. **Control rods**

To control the fission reaction (rate), movable rods, made of cadmium (or) boron, are suspended between fuel rods. These rods can be lowered or raised. They control the fission reaction by absorbing excess neutrons. If the rods are deeply inserted inside the reactor, they will absorb more neutrons and the reaction become very slowly. On the other hand, if the rods are pushed outwards, they will absorb less neutrons and the reaction will be very fast.

Example:

$$\mathbf{Cd_{43}^{113}} \text{ and } \mathbf{{}_5B^{10}}$$

$$\mathbf{Cd_{43}^{113} + {}_n0^1 \rightarrow Cd_{43}^{114} + \gamma \text{ ray}}$$

$$\mathbf{B_5^{10} + {}_n0^1 \rightarrow B_5^{11} + \gamma \text{ ray}}$$

Function: It controls the nuclear chain reaction and avoids the damage of the reactors.

3. **Moderators**

The substance used to slow down the neutrons is called moderates.

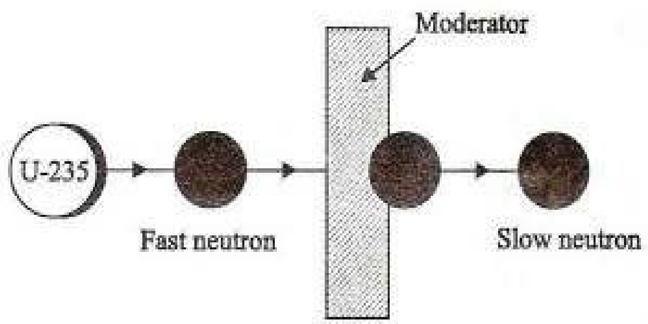


Fig. 5.5 Function of a moderator

When the fast moving neutrons collide with moderator they lose energy and gets slow down.

Example:Ordinary water, Heavy water, Graphite, Beryllium

Function: The kinetic energy of fast neutrons (1Mev)is reduced to slow neutrons (0.25eV)

4. **Coolants**

In order to absorb the heat products during fission, a liquid called coolant is circulated in the reactor core. It enters the base of the reactor and leaves at the top. The heat carried by out-going liquid is used to produce steam.

Example:Water and heavy water, Liquid metals like Na, K and Air

Function: It cools the fuel core.

5. **Pressure vessel**

It encloses the core and also provides the entrance and exit passage for coolant. Holes at the top of the vessel are provided to insert or pull out the control rods.

Function: It withstands the pressure as high as 200 kg/cm2.

6. **Protective shield**

The nuclear reactor is enclosed in a thick massive concrete shield (more than 10 meters thick).

Function: The environment and operating personnel"s are protected from destruction in case of leakage of radiation.

7. **Turbine**

The steam generated in the heat exchanger is used to operate a steam turbine, which drives a generator to produce electricity.

5.7.4 LIGHT WATER NUCLEAR REACTOR

Light-water nuclear -power plant is the one, in which U^{235} fuel rods are submerged in water. Here the water acts as coolant and moderator.

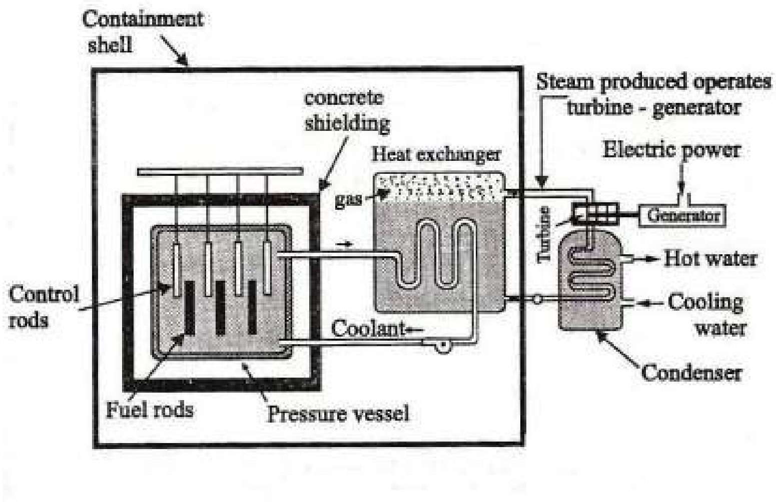


Fig. 5.6 Light water nuclear power plant

Working

The fission reaction is controlled by inserting or removing the control rod of B^{10} automatically from the spaces in between the fuel rods. The heat emitted by fission of U^{235} in the fuel core is absorbed by the coolant (light water). The heated coolant (water at 300°C) then goes to the heat exchanger containing sea water. The coolant here, transfers heat to sea water, which is converted into steam. The steam then drives the turbines, generating electricity.

Pollution

Though nuclear power plants are very important for production of electricity, they will cause a serious danger to environments.

Problem on disposal of reactor waste

Disposal of reactor waste is another important problem because the fission products viz., Ba^{139} and Kr^{92} are themselves radioactive. They emit dangerous radiation for several hundred years. So waste is packed in concrete barrels, which are buried deep in the sea.

5.8 BREEDER REACTOR

Breeder reactor is the one which convert non-fissionable material (U^{238}, Th^{232}) into fissionable materials (U^{258}, Th^{239}). Thus the reactor produces more fissionable materials than it consumes.

$$U_{92}^{238} + {}_0n^1 \rightarrow Pu_{94}^{239} + 2e^-$$

Non – fissionable **Fissionable**

$$Pu_{94}^{239} + {}_0n^1 \rightarrow \text{Fission products} + 3\,{}_0n^1$$

In breeder reactor, of the three neutrons emitted in the fission of U^{235}, only one is used in propagating the fission chain with U^{235}. The other two are allowed to react with U^{238}. Thus, two fissionable atoms of U^{235} are produced for each atom of U^{235} consumed. Therefore, the breeder reactor produces more fissionable material than it uses. Hence Pu^{239} is **a man-made nuclear fuel** and is known as **secondary nuclear fuel**.

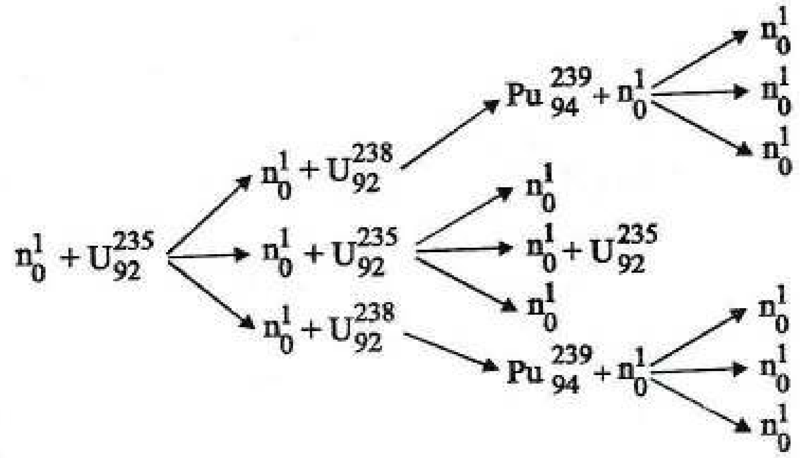


Fig. 5.7 Principle of breeder reactor

Significance

- The non-fissionable nucleides, such as U^{238} and Th^{232}called **fertile nucleides**, are converted into fissile nucleides.
- The fissionable nucleides such as U^{235} are called **fissile nucleides**.
- As regeneration of fissile nucleided takes place, its efficiency is more.

5.9 Solar energy conversion

Solar energy conversion is the process of conversion of direct sunlight into more useful forms. This solar energy conversion occurs by the following two mechanism.

- Thermal conversion
- Photo conversion

5.9.1 Thermal conversion

Thermal conversion involves absorption of thermal energy in the form of IR radiation. Solar energy is an important source of low-temperature heat, which is useful for heating building, water and refrigeration.

Methods of thermal conversion

✓ Solar heat collectors.

✓ Solar water heater.

1. **Solar heat collectors**

Solar heat collectors consists of natural materials like stones, bricks or materials like glass, which can adsorb heat during the day time and release it slowly at night.

Uses

- It is generally used in cold places, which houses are kept in hot condition using solar heat collectors.

Solar water heater

It consists of an insulated box inside of which is painted with black paint. It is also provided with a glass lid to receive and store solar heat. Inside the box it has black painted copper coil, through which cold water is allowed to flow in, which gets heated up and flows out into a storage tank. From the storage tank water is then supplied through pipes.

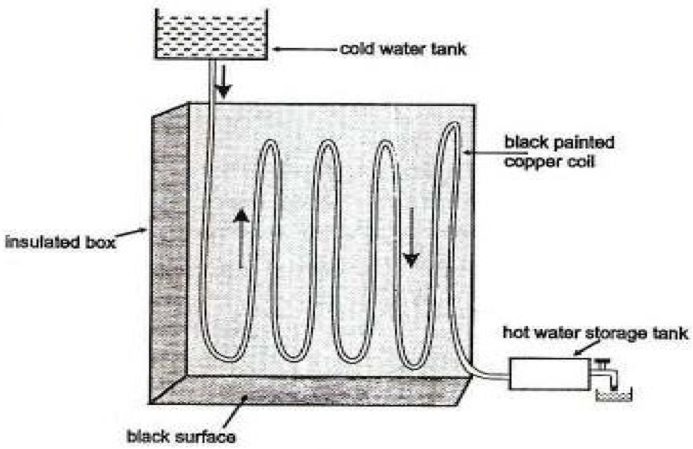


Fig. 5.8 Solar water heater

5.9.2 Photo conversion

Photo conversion involves conversion of light energy directly into electrical energy.

Methods of photo conversion

- Photo conversion can be made by the following method.
- Photo galvanic cell or Solar cell.

5.10 PHOTO GALVANIC CELL OR SOLAR CELL

Definition

Photo galvanic cell is the one, which converts the solar energy (energy obtained from sun) directly into electrical energy.

Principle

The basic principle involved into the solar cell is based on the photovoltaic (PV) effect. When the solar rays fall on a two layer of semi-conductor devices, a potential difference between the two layers is produced. This potential difference causes flow of electrons and produces electricity.

Construction

A solar cell consists of a p-type semiconductor (such as Si doped with B) and n-type semiconductor (such as Si doped with P). They are in close contact with each other.

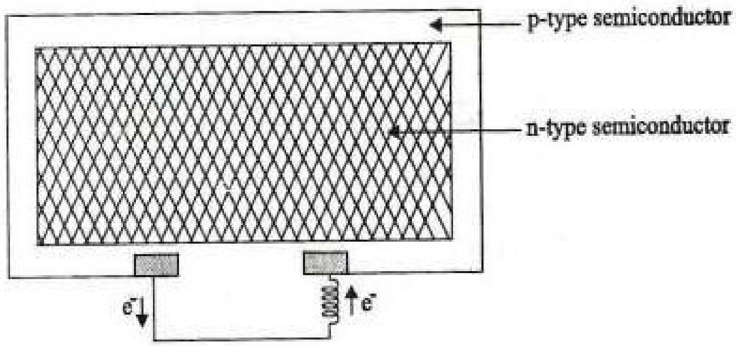


Fig5.9 Solar cell

Working

When the solar rays fall on the top layer of p-type semiconductor, the electrons from the valence band get promoted to the conduction band and cross the p-n junction into n-type semiconductor. There by potential difference between two layers is created, which causes flow of electrons (ie., an electric current). The potential difference and hence current increases as more solar rays falls on the surface of the top layer. Thus when this p and n layers are connected to an external circuit, electrons flow from n-layer to p-layer, and hence current is generated.

5.10.1 Applications of solar cells

1. **Lighting purpose**

   Solar cells can be used for lighting purpose. Nowadays electrical street lights are replaced by solar street lights.

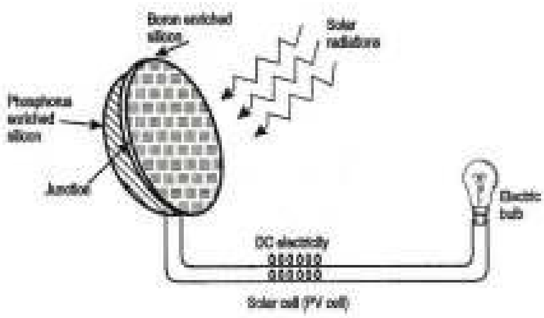


Fig. 5.10 Solar light

2. **Solar pumps run by solar battery**

   When a large number of solar cells are connected series it form a solar battery. Solar battery produces more electricity which is enough to run, water pump, street-light etc. They are also used in remote areas where conventional electricity supply is a problem.

Solar cells are used in calculators, electronic watches, radios and TVs.

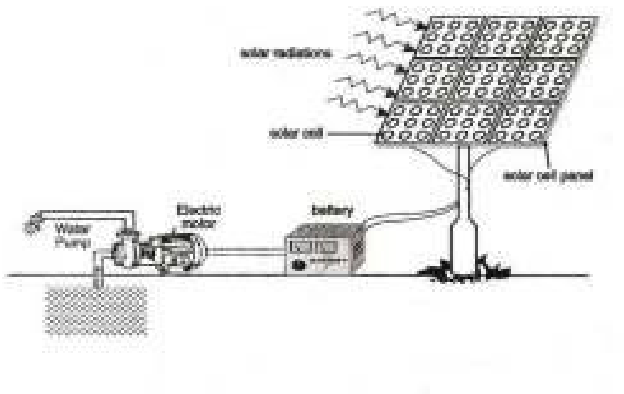


Fig. 5.11 Solar pump run by solar cells (Battery)

3. Solar cells are superior to other type of cells, because these are non-polluting and eco-friendly.

4. Solar energy can be stored in Ni-Cd batteries and lead acid batteries.

5. Solar cells can be used to drive vehicles.

6. Solar cells, made of silicon, are used as a source of electricity in space craft and satellites.

5.10.2 Advantages of solar cells

1. Solar cells can be used in remote and isolated area, forests and hilly regions.
2. Maintenance cost is low.
3. Solar cells are noise and pollution free.
4. Their lifetime is log.

Disadvantages

- ✓ Capital cost is higher.
- ✓ Storage of energy is not possible.

5.11 WIND ENERGY

Moving air is called wind. Energy recovered from the force of the wind is called wind energy. The energy possessed by wind is because of its high speed. The wind energy is harnessed by making use of wind mills.

5.11.1 Methods of harnessing wind energy

1. Wind mills

The strike of blowing wind on the blades of the wind mill makes it rotating continuously. The rotational motion of the blades drives a number of machines like water pump, flour mills and electric generators.

Now a day"s wind mill uses large sized propeller blades and is connected to a generator through a shaft. Wind mills are capable of generating about 100 kW electricity.

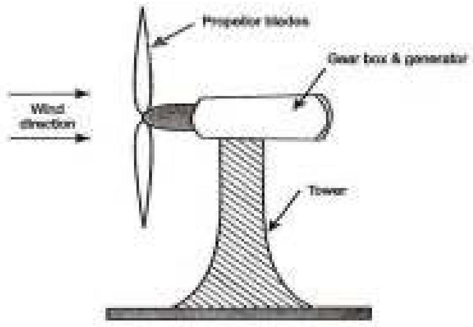


Fig. 5.12 Wind mill

2. Wind farms

When a large number wind mills are installed and joined together in a definite pattern it forms a wind farm. The wind farms produce a large amount of electricity.

Condition

The minimum speed required for satisfactory working of a wind generator is 15 km/hr.

3. Others methods

Other methods adopted for harnessing wind energy are

(a) Sky sail.

(b) Ladder mill.

(c) Kite ship (Large free flying sails.)

(d) Sky wind power (Flying electric generator.)

(e) Briza technologies (Hovering wind turbine)

(f) Sequoia automation (The kite wind generator).

5.11.2 Advantages of wind energy

(i) It does not cause any air pollution.

(ii) It is very cheap and economic.

(iii) It is renewable.

(iv) It does not cause any pollution.

Disadvantages

- ✓ Public resists for locating the wind forms in polluted areas due to noise generated by the machines and loss of aesthetic appearance.
- ✓ Wind forms located on the migratory routes of birds will cause hazards.
- ✓ Wind forms produce unwanted sound.
- ✓ Wind turbines interfere with electromagnetic signals(TV, Radio signals).

5.11.3 Use of wind energy

1. Used to move the sail boats in lakes, rivers and seas.

2. Used to operate water pumps.

BATTERIES AND FUEL CELLS

6.1 INTRODUCTION

In electrochemical cells, the chemical energy is converted into electrical energy. The cell potential is related to free energy change. In an electrochemical cell, the system does work by transferring electrical energy through an electric circuit. Thus free energy change for a reaction is a measure of the maximum useful work that can be obtained from a chemical reaction.

i.e., $\triangle G$ = maximum useful work

But we know that

Maximum useful work = nFE

→hen a cell operates, work is done on the surroundings (flow of electricity).

$\boxed{\triangle G = \_- nFE}$ OR $\boxed{\triangle G < 0}$

Decrease in free energy is indicated by negative sign.

One of the main uses of the galvanic cells is the generation of portable electrical energy. These cells are known as batteries.

6.1.1 Battery

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 anode and cathode.

6.1.2 Requirements of a battery

A useful battery should fulfil the following requirements.

- It should be light and compact for easy transport.
- It should have long life both, when it is being used and when it is not used.
- The voltage of the battery should vary appreciably during its use.

6.2 TYPES OF BATTERY

1. **Primary Battery (or) Primary cells (or) Non-reversible Battery**

In these cells, the electrode and the electrode reactions cannot be reversed by passing an external electrical energy. The reactions occur only once after use they become dead. Therefore, they are **not chargeable. Examples:Dry cell, mercury cell.**

2. **Secondary Battery or Secondary cells or Reversible Battery**

In these cells, the electrode reactions can be reversed by passing an external electrical energy. Therefore, they can be chargeable by passing electric current and used again and again. These are also called **Storage cell** or **Accumulators.**

Examples: Lead acid storage cell, Nickel-cadmium cell.

3. **Flow Battery or Fuel cell**

In these cells, the reactants, products and electrolytes are continuously passing through the cell. In this chemical energy gets converted into electrical energy.

Example: Hydrogen-Oxygen fuel cell.

6.3 Dry Cell or Leclache‟s Cell

Description

A dry cell consists of a zinc cylinder, which acts as anode. This zinc cylinder is filled with an electrolyte consisting of NH_4Cl_2, $ZnCl_2$ and MnO_2 in the form of paste using starch and water.

A carbon rod acts as cathode, is immersed in the electrolyte in the cell. The zinc cylinder has an outer of cardboard case. During use, the zinc cylinder gets consumed and the end, it will develop holes which are responsible for leakages.

Working

When the cell is working, zinc losses electrons and Zn^{2+} ions gets dissolved in the electrolyte. The electrons pass through the circuit and are consumed at cathode .This causes discharge of NH^{4+} ions from the electrolyte.

Cell reactions

Anode:

$$\mathbf{Zn \rightarrow Zn^{2+} + 2e^-}$$

Cathode:

$$\mathbf{NH^{4+}_{(aq)} + MnO_{2(s)} + 2e^- \rightarrow MnO(OH)^- + NH_3}$$

Overall reaction:

$$Zn + NH^{4+}_{(aq)} + MnO_{2(s)} \rightarrow Zn^{2+} + MnO(OH)^- + NH_3$$

In cathode reaction,Mn is reduced from +4 oxidation state to +3 oxidation state. The liberation of NH_3gas,which disturbs the current flow, is prevented by a reaction of $NH_3$with Zn^{2+}.

$$ZnCl_2 + 2NH_3 \rightarrow [Zn(NH_3)_2]Cl_2$$

6.3.1 Advantages of alkaline battery over dry battery

- This dry cell do not have an indefinite life, because NH_4Cl being acidic corrodes the zinc container, even if it is not used.
- When current is drawn rapidly from it, produces build up on the electrodes, so voltage drop occurs.

Uses: It is used in calculators, watches etc.

6.4 LEAD ACID STORAGE CELL OR LEAD ACCUMULATOR OR ACID STORAGE CELL

Storage cell

A lead acid storage cell is secondary battery, which can operate both as a voltaic cell and as an electrolytic cell. →hen it acts as a voltaic cell, it supplies electrical energy and becomes "run down". →hen it is recharged, the cell operates as an electrolytic cell.

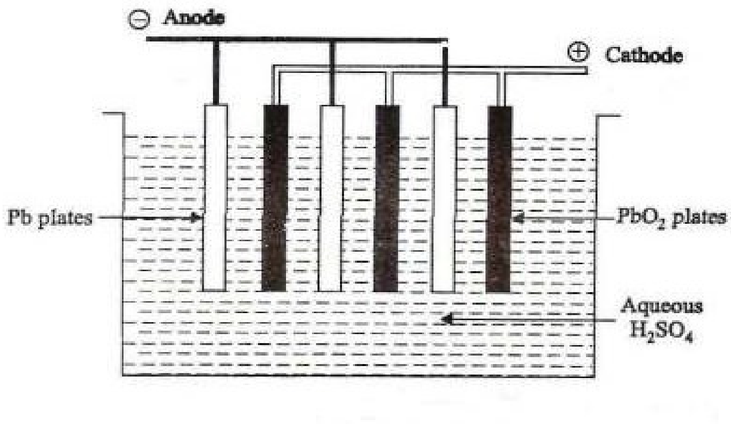


Fig. 6.2 Lead storage cell

Description

A lead acid storage battery consists of a number of (3 to 6) voltaic cells connected in series to get 6 to 12 V battery. In each cell, the anode is made of lead. The cathode is made of lead dioxide or a grid made of lead, packed with lead dioxide. A number of lead plates (anodes) are connected in parallel and a number of lead dioxide plates (cathodes) are also connected in parallel. Various plates are separated from the adjacent ones by insulators like rubber or glass fibre. The entire combinations is then immersed in dil.sulphuric acid (38 percentage by mass) having a density of 1.30 gm/ml. The cell may be represented as;

Cell representation:

$Pb, PbSO_4 \mid H_2SO_{4(aq)}\ PbO_2, Pb$

Working (Discharging)

When the lead acid storage battery operates, the following reaction occurs.

Anode

Lead is oxidized to Pb^{2+} ions, which further combines with SO_4^{2-} forms insoluble $PbSO_4$.

$$Pb_{(s)} + SO_4^{2-}{}_{(aq)} \longrightarrow PbSO_{4(s)} + 2e^-$$

Cathode

PbO_2 is reduced to Pb^{2+} ions, which further combines with SO_4^{2-} forms insoluble $PbSO_4$

$$PbO_{2(s)} + 4H^{+} + SO_4^{2-} + 2e^{-} \rightleftharpoons PbSO_{4(s)} + 2H_2O$$

Overall reaction:

$$PbO_{2(s)} + Pb_{(s)} + 4H^{+}_{(aq)} + O_{4}2^{-}_{(aq)} \rightleftharpoons 2PbSO_{4(s)} + 2H_2O_{(l)} + Energy$$

From the above cell reactions it is clear that, lead sulphate is precipitated at both the electrode and sulphuric acid is used up. As a result, the concentration of sulphuric acid decreases and hence the density of sulphuric acid falls below 1.2 gm/ml. So the battery needs recharging.

Recharging the Battery

The cell can be charged by passing electric current in the opposite direction. The electrode reaction is reversed. As a result, Pb is deposited on anode and lead dioxide on the cathode. The desity of sulphuric acid also increases.

The net reaction during charging is,

$$2PbSO_{4(s)} + 2H_2O + Energy \rightleftharpoons Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)}$$

Advantages of lead acid battery

- It is made easily.
- It produces very high current.
- The self-discharging rate is low when compared to other rechargeable batteries.
- it also acts effectively at low temperature.

Disadvantages of lead acid batteries

- Recycling of this battery causes environmental hazards.
- Mechanical strain and normal bumping reduces battery capacity.

Uses

- Lead storage cell is used to supply current mainly in automobiles such as cars, buses, trucks, etc.,
- It also used in gas engine ignition, telephone exchanges, hospitals, power stations, etc.,

6.6 LITHIUM BATTERY

Lithium- ion battery is a secondary battery. As in lithium cell, it does not contailmetallic lithium as anode. As the name suggests, the movement of lithium ions are responsible for charging and discharging. Lithium -ion cell has the following three components.

- Cathode-Lithium metal oxide
- Anode-Porous carbon
- Electrolyte- Polymer gel

Construction

The positive electrode is typically made from a layers of chemical compound called lithium-cobalt oxide ($LiCoO_2$)

The negative electrode is made from layers of porous carbon.

Both the electrodes are dipped in a polymer gel electrolyte and separated by a separator, which is a perforated plastic and allows the lithium ions to pass through.

Working (Charging)

During charging Li^+ ions flow from the positive electrode to the negative electrode through the electrolyte. Electrons also flow from the positive electrode to the negative electrode through the wire. The electrons and Li^+ ions combine at the negative electrode and deposit there as Li.

$$LiCoO_2 + C \rightleftharpoons Li_{1-x}CoO_2 + CLi_x$$

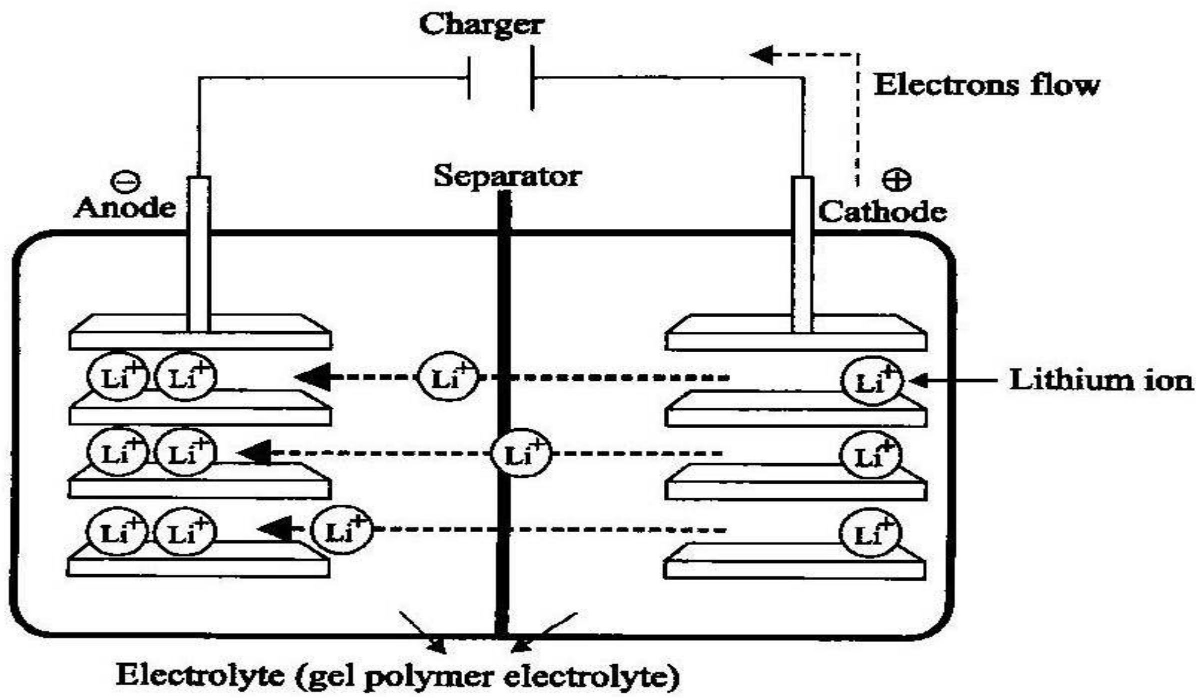


Fig. 9.3 Lithium-ion cell during charging

Fig. 6.4 Solid state lithium battery

Discharging

During discharging, the Li^+ ions flow back through the electrolyte from negative electrode to the positive electrode. Electrons flow from the negative electrode to the positive electrode through the wire. The Li^+ ions and electrons combine at the positive electrode and deposit there as Li.

$$Li_{1-x}CoO_2 + CLi_x \rightleftharpoons LiCoO_2 + C$$

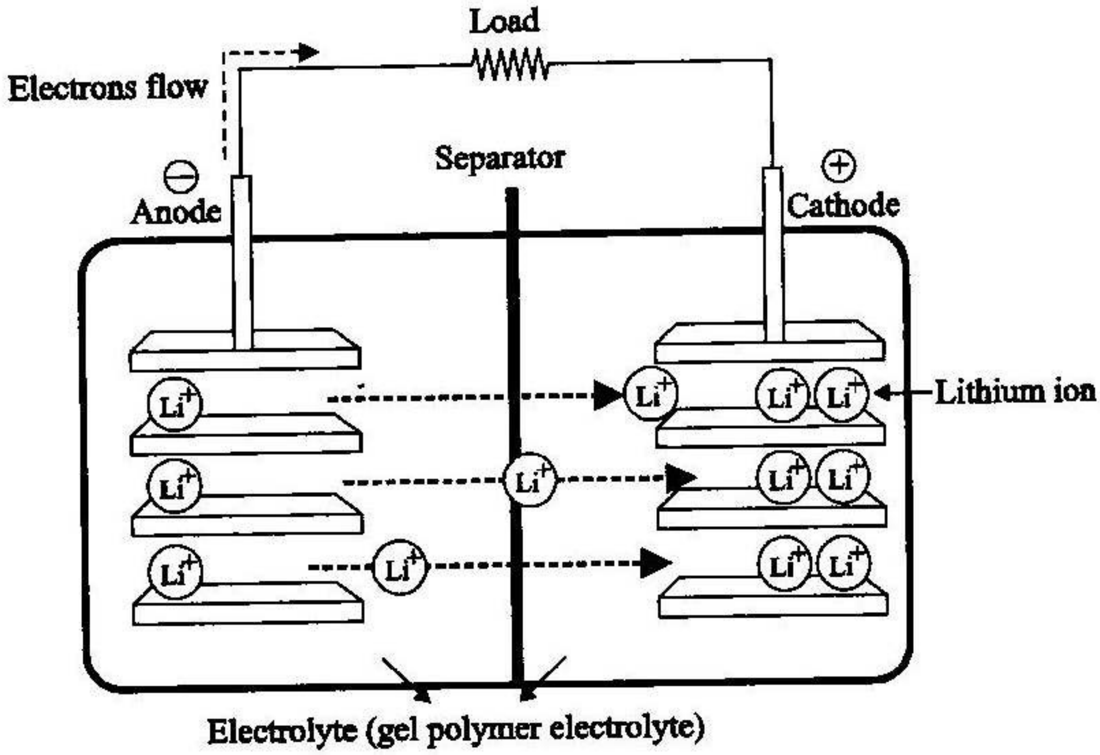


Fig. 9.4 Lithium-ion cell during discharging

6.6.1 Advantages

- Lithium - ion batteries are high voltage and light weight batteries.
- It is smaller in size.
- It produces three time the voltage of Ni-Cd batteries.

Uses

It is used in cell phone, note PC, portable LCD TV and semiconductor driven audio, etc.,

6.7 FUELL CELLS

Definition

Fuel cell is a voltaic cell, which converts the chemical energy of the fuels directly into electrical energy without combustion. It converts the energy of the fuel directly into electricity. In these cells, the reactants, products and electrolytes pass through the cell.

Fuel + Oxygen ⇌ oxidation products + Electricity.

Examples: Hydrogen-oxygen fuel cell: Methyl alcohol-oxygen fuel cell.

6.7.1 Hydrogen-Oxygen fuel cell

Hydrogen-Oxygen fuel cell is the simplest and most successful fuel cell, in which the fuel-hydrogen and the oxidizer-oxygen and the liquid electrolyte are continuously passed through the cell.

Description

It consists of two porous electrodes anode and cathode. These porous electrodes are made of compressed carbon containing a small amount of catalyst (Pt, Pd, Ag). In between the two electrodes an electrolyte solution such as 25 percentage KOH or NaOH is filled. The two electrodes are connected through the voltmeter.

Working

Hydrogen (the fuel) is bubbled through the anode compartment, the cathode compartment, where it is oxidized. The oxygen (oxidizer) is bubbled through the cathode compartment, where it is reduced.

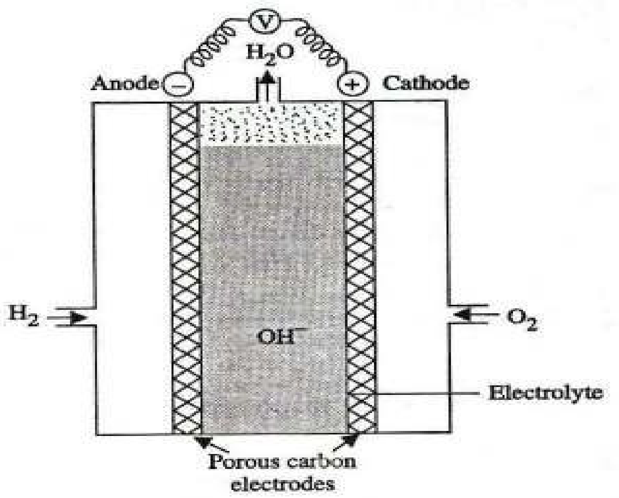


Fig. 6.6 Hydrogen-oxygen fuel cell

At anode

Hydrogen molecules are oxidized at the anode with the liberation of electrons which then combine with hydroxide ions to form water.

$$O_2 + 2H_2 + 4e^- \rightarrow 4OH^-$$

At cathode

$$2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$$

$$2H_2 + O_2 \rightarrow 2H_2O$$

The electrons produced at the anode pass through the external wire to the cathode, where it is absorbed by oxygen and water to produce hydroxide ions.

The emf of the cell = 0.8 to 1.0 V

Fuel Battery

When a large number of fuel cells are connected in series, it forms fuel battery.

6.7.2 Advantages of fuel cells

- Fuel cells are efficient and take less time for operation.
- It is pollution free technique.
- It produces electric current directly from the reaction of a fuel and an oxidiser.
- It produces drinking water.

Disadvantages

- Fuel cell cannot store electric energy as other cells do.
- Electrode is expensive and short lived.
- Storage and handling of hydrogen gas is dangerous.

Applications

- Hydrogen-Oxygen fuel cells are used as auxiliary energy source in space vehicles, submarines or other military-vehicles.
- In case of Hydrogen-Oxygen fuel cells, the product of water is proved to be a valuable source of fresh water by the astronauts.

6.8 SUPER CAPACITOR

Super capacitor is a high capacitor with capacitance value much higher than other capacitor. They store 10 to 100 times more energy per unit volume and deliver charge much faster than batteries.

Unlike ordinary capacitors, super capacitors, do not use the conventional solid electric, but rather they use electrostatic double- layer capacitance.

DESIGN OF SUPER CAPACITOR

Super capacitor consists of two electrodes separated by an ion-permeable membrane and dipped in an electrolyte, containing positive and negative ions, connecting both the electrodes.

WORKING

When the electrodes are connected to the power source, ions in the electrolyte from electric double layers of opposite polarity to the electrodes polarity, creating an electric field between them.

For example, positively polarized electrodes will have a layer of negative ions at the electrode/ electrode interface. Similarly negatively polarized electrodes will have a layer of positive ions at the electrode/electrode interface.

This electric field polarizes the dielectric so its molecules lineup in the opposite direction to the field and reduce its strength. Its mean that its stores more electrical energy at an electrode/electrode interface.

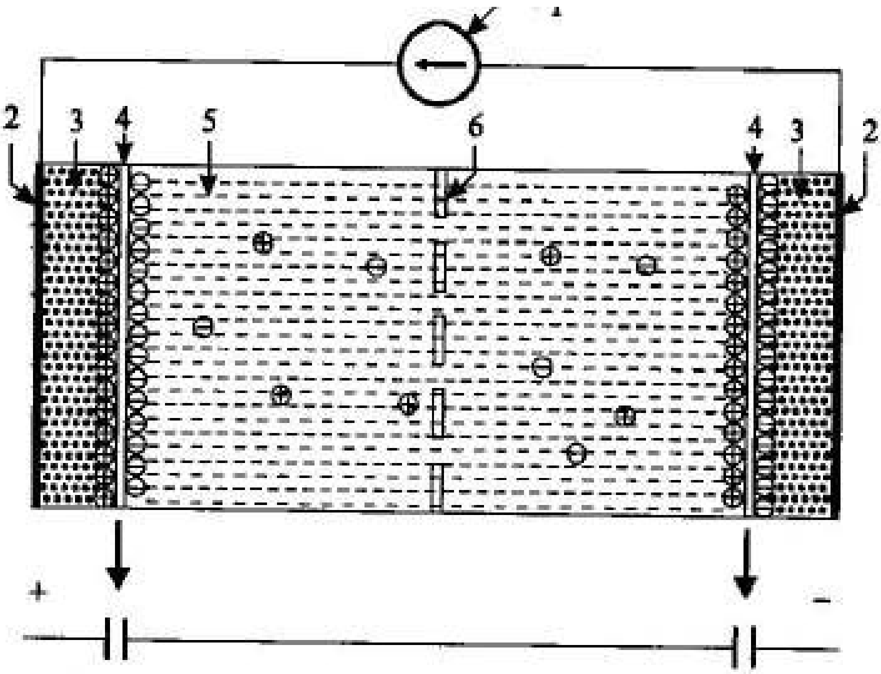


Fig. 9.6 Typical construction of a super capacitor

1. Power source 2. Collector
3. Polarized electrode 4. Helmholtz double layer
5. Electrolyte having positive and negative ions
6. Separator

Advantages

- ✓ It is highly safe
- ✓ Its life time is very high
- ✓ It can be cycled millions of time
- ✓ It can be charged in seconds

Disadvantages

- ✓ Cost per Watt is high
- ✓ It cannot be used as source for continuous power supply
- ✓ If higher voltage is require the cells must be connected in series
- ✓ High self- discharge.