ENGINEERING CHEMISTRY-CY8151

Unit-V

Energy Sources and Storage Devices

Question Bank (Part-A & Part-B)

Part-A (2-marks)

1. What are the non-conventional energy sources? Give two examples. 2.
Define nuclear fission? (2008, 2009, 2015)
3. Define nuclear fusion?
4. Give an example each for nuclear fission and nuclear fusion reaction. (2018)
5. What are the drawbacks of nuclear energy.(2014)
6. Define nuclear chain reaction? (2017)
7. What is nuclear energy? Explain using a suitable example. (2009)
8. What are the components of a nuclear reactor? (2008)
9. What are coolants? Give an example. (2011)
10. What are fissile and fertile nuclides? (2013)
11. What is breeder reactor? (2009, 2013)
12. What is photogalvanic cell (or) solar cell. (2008, 2013)
13. What is wind energy. How it is obtained? (2015)
14. What are the merits of wind energy? (2010)
15. Write any four methods adopted for harnessing wind energy? (2009)
16. What is Battery? How does it differ from a cell? (2014, 2016)
17. What is primary battery? Give an example (or) what are primary cells? (2006)
18. What are secondary cells? (2013)
19. How will the emf of battery vary with size? Give reason for your answer. (2014) 20. State the reaction when a lead storage battery is recharged. (2009) 21. What are fuel cells?
22. What are the electrodes used in the fuel cells porous?
23. What are the limitations of H_2-O_2 fuel cell?
24. What is lithium-ion battery?
25. What are the advantages of lithium cell? (2018)
26. What are the uses of lithium-ion cell?
27. What are super capacitors?

Part-B (8 Marks)

1. State any eight characteristics of nuclear fission reaction.
2. Difference between the nuclear fission and fusion
3. What are the components of a nuclear power reactor?
4. Explain the functioning of light water nuclear power reactor with a neat diagram?
5. Describe the Breeder reactor?
6. Thermal conversion (Solar heat collectors and Solar water heater)
7. State the principle and applications of solar batteries?
8. Write a note on Wind energy?
9. What is primary battery. Give an example
10. Explain the construction, charging and discharging of lead-acid accumulator.
11. Explain in detail about Lithium-ion battery (LIB) 12. Explain the working of H_2-O_2 fuel cell.
13. Write notes on super capacitors

Part-A (2-marks) *Energy sources:*

1. **What are the non-conventional energy sources? Give two examples.**

Non conventional energy sources are those energy sources which are renewable and ecologically safe.

Ex: Sunlight, wind hydropower, nuclear energy.

2. **Define nuclear fission? (2008, 2009, 2015)**

It is defined as the process of splitting of heavier nucleus into two (or) more smaller nuclei with liberation of large amount of energy.

Ex: $_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{56}Ba^{140} + {}_{36}Kr^{93} + 3{}_{0}n^{1}$

3. **Define nuclear fusion?**

It is defined as the process of combination of smaller nuclei into heavier nuclei with liberation of larger amount of energy.

Ex: $_{1}H^{2} + {}_{1}H^{2} \longrightarrow {}_{2}He^{4} + \text{Energy}$

4. **Give an example each for nuclear fission and nuclear fusion reaction. (2018)**

a. Nuclear fusion reaction

$$_{1}H^{2} + {}_{1}H \longrightarrow {}^{2}\,{}_{2}He^{4} + \text{Energy}$$

b. Nuclear fission reaction

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow Ba\ {}_{56}{}^{140} + {}_{36}Kr^{93} + 3{}_{0}n^{1}$$

5. **What are the drawbacks of nuclear energy.(2014)**

i. The nuclear radiation can damage the structure of cells in the human body ii. It causes diseases like cancer and blindness iii. It causes genetic disorder in a human body iv. It causes serious pollution problem

6. **Define nuclear chain reaction? (2017)**

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

7. **What is nuclear energy? Explain using a suitable example. (2009)**

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

Ex: when U^{235} nucleus is hit by a thermal neutron, the following reaction occurs with the release of energy.

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{56}Ba^{139} + {}_{36}Kr^{94} + 3{}_{0}n^{1} + \text{Energy}$$

8. **What are the components of a nuclear reactor? (2008)**

i. Fuel rods ii. Control rods iii. Coolents iv. Moderators v. Pressure vessel vi. Protective shield vii. Turbine

9. **What are coolants? Give an example. (2011)**

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

Ex: water (acts as moderator & coolant), heavy water

10. What are fissile and fertile nuclides? (2013)

i. The fissionable nuclides such as U^{235} & Pu^{239} are called fissile nuclides.

ii. The Non-fissionable nuclides such as U^{238} & Th^{232} fertile nuclides.

11. What is breeder reactor? (2009, 2013)

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

12. What is photogalvanic cell (or) solar cell. (2008, 2013)

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

It consists of a p-type semiconductor (such as Si doped with B) and n-type semiconductor (such as Si doped witrh P). They are close contact with beach other. The solar energy is available freely and also it is pollution free, in future its utility is very important.

13. What is wind energy. How it is obtained? (2015)

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.

14. What are the merits of wind energy? (2010)

i. It does not cause any air pollution

ii. It is very cheap and economic iii.

It is renewable

15. Write any four methods adopted for harnessing wind energy? (2009) i. Sky sail ii. Ladder mill iii. Sky wind power (flying electric generator)

iv. Briza technologies (hovering wind turbine)

Storage Devices:

16. What is Battery? How does it differ from a cell? (2014, 2016)

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

A cell: contains only one anode and cathode.

A Battery: contains several anodes and cathodes.

17. What is primary battery? Give an example (or) what are primary cells? (2006)

Primary cells are cells in which the electrode and the electrode reactions cannot be reversed by passing an external electrical energy. The reactions occur only once and after use they become dead. Therefore, they are not chargeable. **Example:** Leclanche's cell

18. What are secondary cells? (2013)

Secondary cells are cells in which the electrode reactions can be reversed by passing an external electrical energy. Therefore, they can be recharged by passing electric current and used

again and again. These are also called storage cells or Accumulators. **Example:** Pb-acid cell, Ni-cd cell

19. How will the emf of battery vary with size? Give reason for your answer. (2014)

No, emf of a battery will not vary with size.

Reason: Emf of a battery depends only on concentration and nature of anode and cathode.

20. State the reaction when a lead storage battery is recharged. (2009)

The cell can be recharged by passing electric current in the opposite direction. The electrode reaction gets reversed. As a result, Pb is deposited on anode and PbO_2 on the cathode. The density of H_2SO_4 also increases.

The net reaction:

Charging

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

Discharging

21. What are fuel cells?

Fuel cell is a voltaic cell, which converts the chemical energy of the fuels directly into electricity 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

22. What are the electrodes used in the fuel cells porous?

Compressed carbon containing a small amount of catalyst like Pt, Pd, Ag are used in the fuel cells porous.

23. What are the limitations of H_2-O_2 fuel cell?

i. Hydrogen gas is explosive ii. It is very expensive to be carried out.

iii. Hydrogen is a gas, expensive to compress into liquid form

iv. Hydrogen is not present as it is, but always present in combined form with either oxygen or some other element, so it must be separated first.

24. What is lithium-ion battery?

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

25. What are the advantages of lithium cell? (2018)

i. Lithium-ion batteries are high voltage and light weight batteries.

ii. It is smaller in size

iii. It produces three time voltage of Ni-Cd batteries iv. It has none of the memory effect seen in Ni-Cd batteries

26. What are the uses of lithium-ion cell?

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

27. What are super capacitors?

Super capacitor is a high capacity 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.

Part-B (8 Marks)

1. State any eight characteristics of nuclear fission reaction. Characteristics of Nuclear Fission reaction:

i. A heavy nucleus may split into two (or) more nuclei. ii. Two (or) more neutrons are produced by fission of each nucleus

iii. It involves conversion of **small mass of nucleus** into **energy with large amount** of energy is produced.

iv. All fission reactions are radioactive, giving off **β and γ radiations**

v. The atomic weights of fission products ranges from about 70 to 160

vi. All the fission reactions are a self-propagating chain-reactions because fission products contain neutrons which further cause fission in other nuclei

vii. The nuclear chain reactions can be controlled and process is used in nuclear reactor viii. The number of neutrons produced from a fission reaction is known as multiplication factor.

2. Difference between the nuclear fission and fusion

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

2. What are the components of a nuclear power reactor?

Definition: The arrangement or equipment used to carry out **fission reaction** under **controlled conditions** is called as nuclear reactor. **Components:**

1. Fuel rods
2. Control rods
3. Moderators
4. Coolants
5. Pressure vessel
6. rotective shield
7. Turbine

S.No	Components	Functions	Examples

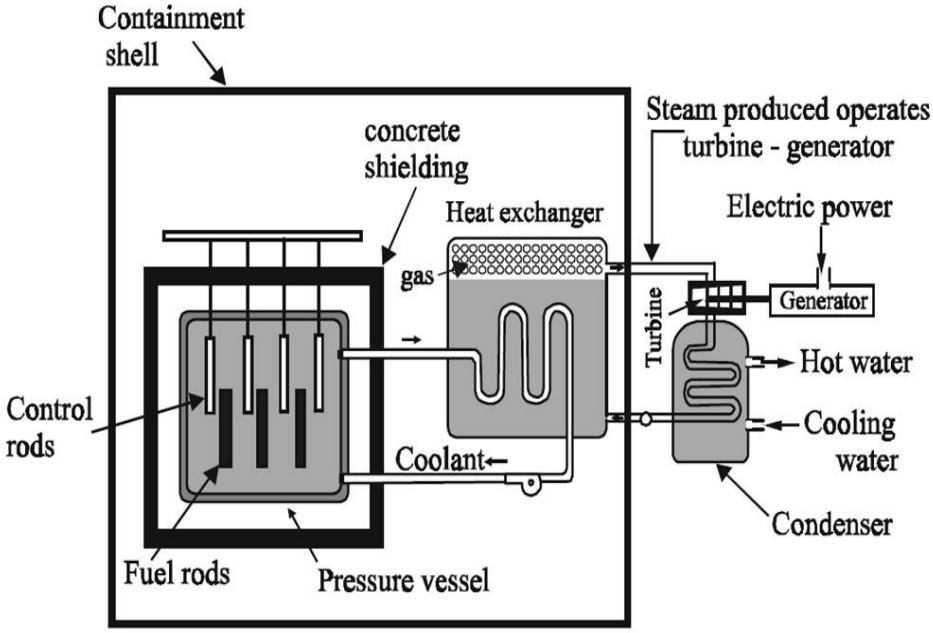
1.	**Fuel rods:** Enriched **U^{235}** can be used as fuel in the form of rods (or) strips.	It produces heat energy and neutron, that starts nuclear chain reaction	**U_{235}** and **Pu_{239}**
2.	**Control rods:** To control the fission reaction rate, movable rods, made of cadmium (or) boron, are suspended between fuel rods. These rods lowered or raised and control the fission reaction by absorbing excess neutrons.	To control the nuclear chain-reaction Avoid the damage of the reactor	**Cd_{113}** and **B_{10}**
3.	**Moderators:** The substance used to slow down the neutrons is called as moderator.	The kinetic energy of fast moving neutrons **(1meV)** is reduced to slow neutrons **(0.25eV)**	Ordinary water, heavy water
4.	**Coolants:** The substances used to absorb the heat produced during the fission, a liquid called coolant is circulated in the reactor core.	It cools the fuel core	Ordinary water, heavy water, air (CO_2)
5.	**Pressure vessel:** It encloses the core and provides the entrance and exit passages for coolant.	It withstand the pressure as high as 200 kg/cm^2	-
6.	**Protective shield:** The nuclear reactor is enclosed in a thick massive concrete shield.(more than 10 meter thickness)	Protect the environment and operating personnel's leakage of radiation	-
7.	**Turbine:** The steam produced in a heat exchanger is used to operate a steam turbine, which drives a generator to produce electricity.	-	-

4. Explain the functioning of light water nuclear power reactor with a neat diagram?

Light water Nuclear-power plant:

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

- ✓ The fission reaction is controlled by inserting (or) removing the control rods of **B^{10}** from the spaces in between 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 300° C)** then goes to the heat exchanger containing sea water.
- ✓ The coolant transfers heat to sea water, which is converted into steam.
- ✓ The stem then drives the turbines, generating electricity.



Pollution:

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

Problem on disposal of reactor waste:

- ✓ Disposal of reactor waste is another important problem because the fission products like Ba^{139} and Kr^{92}, they are radioactive.
- ✓ They emit dangerous radiations for several hundred years
- ✓ So, the waste is packed in concrete barrels, which are buried deep in the sea. Salt water will not allow the radiation to come out.

5. Describe the Breeder reactor?

It is one which converts **non-fissionable material (U^{238}, Th^{232})** into **fissionable material (U^{235}, Pu^{239}).**

Illustration:

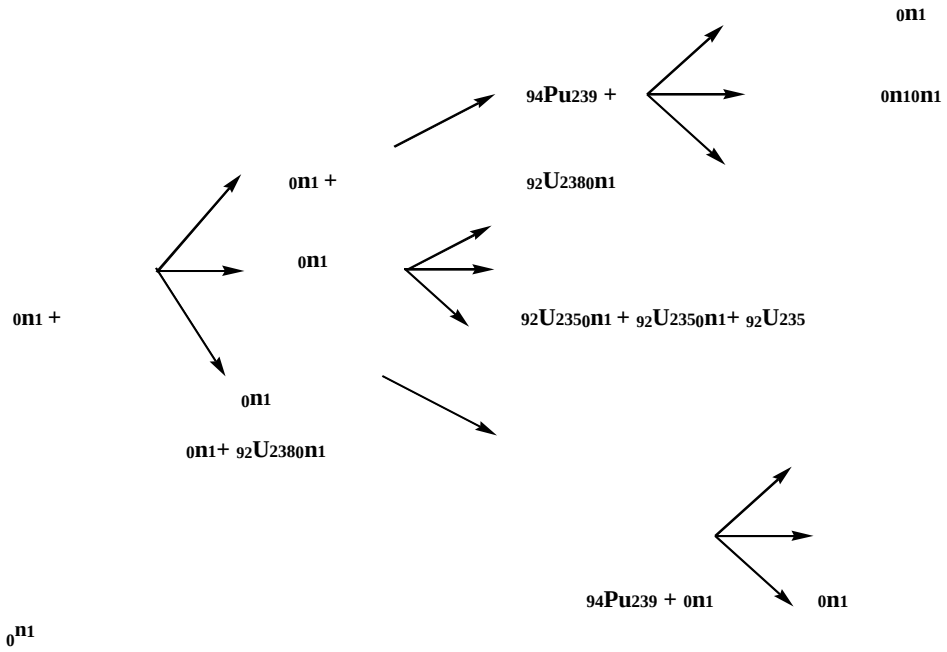
$$_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{94}Pu^{239} + 2e^{-}$$

Non-fissionable **Fissionable**

$$_{94}Pu_{239} + {}_{0}n^{1} \longrightarrow \text{Fission products} + 3n^{01}$$

- ➢ In breeder reactor, 3 neutrons are emitted in the fission of U^{235}.
- ➢ One neutron is used to propagate the fission of U^{235}.
- ➢ Other two neutrons are allowed to react with U^{238}
- ➢ Two fissionable atoms of Pu^{239} are produced for each atom of U^{235} consumed.

- Therefore breeder reactor produces more fissionable material than it uses.
- Pu^{239} is a man made nuclear fuel and is known as secondary nuclear fuel.



Significance:

- The **non-fissionable nuclides** are called as **fertile nucleides,** are converted into fissile nuclides.
- The **fissionable nucleides** are called as **fissile nucleides**
- As regeneration of fissile nucleides takes place its efficiency is more.

6. Thermal conversion (Solar heat collectors and Solar water heater)

1. Solar heat collectors

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

Uses: Generally used in cold places, where houses are kept in hot condition using solar heat collectors.

2. 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.

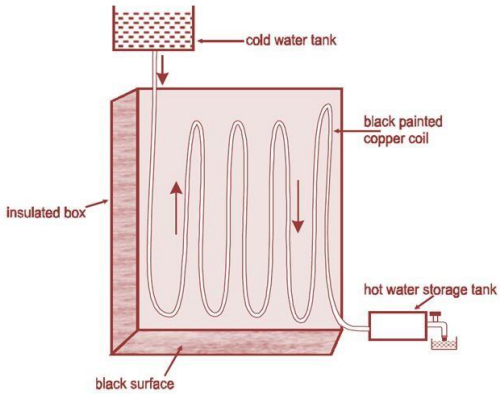


Fig Solar Water Heater

7. State the principle and applications of solar batteries?

Photogalvanic cell (or) Solar cell:

It is one, which converts the **solar energy** (obtained from the sun) directly into **electrical energy.**

Principle:

The principle of **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 two layers is produced. This potential difference causes flow of electrons and produces electricity.

Construction:

- Solar cells consist of a **p-type semi conductor** (Si doped with B) and **n-type semiconductor** (Si doped with P)
- They are in close contact with each other.

Diagram:

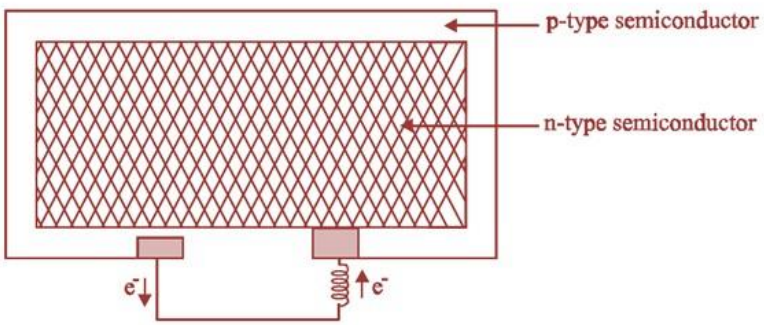


Fig. Solar cell

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 are created, which causes flow of electrons(an electric current)
- The **potential difference** and **current increases** as more solar rays falls on the surface of the top layer

- When this p and n layers are connected to an external circuit, electrons flow from n-layer to p-layer and current is produced. **Applications:**

1. **Lighting purpose:**
   Solar cells can be used for lighting purpose. Now a day's electrical street lights are replaced by solar street lights.
2. **Solar pumps run by solar battery:**
   When a large number of solar cells are connected in series, it forms a solar battery. Solar battery produces more electricity which is enough to run water pump, street light. They are used in remote areas where conventional electricity supply is a problem.
3. Solar cells are used in calculators, electronic watches, radios and TVs
4. Solar cells are superior to other types of cells, because these are non-polluting and ecofriendly.
5. Solar energy can be stored in Ni-Cd batteries and Lead-acid batteries.
6. Solar cells can be used to drive vehicles.
7. Solar cells, made of Si are used as a source of electricity in space craft and satellites.

8. **Write a note on Wind energy?**

Wind energy:

Moving air is called as wind. Energy recovered from the force of the wind is called wind energy.

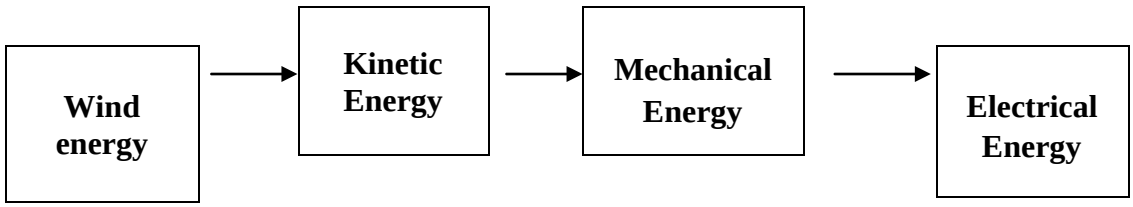
Kinetic energy of wind is converted into **mechanical energy.**

Methods of harnessing wind energy

1. Wind Mill:

It is a device used to convert **wind energy** into **mechanical energy.**

Sequence of energy conversion:



Working of wind mill:

- It consists of a wheel containing number of blades.
- The wheels rotate about an axle mounted on a pole. The **wind energy** is used to **rotate the wheel.**

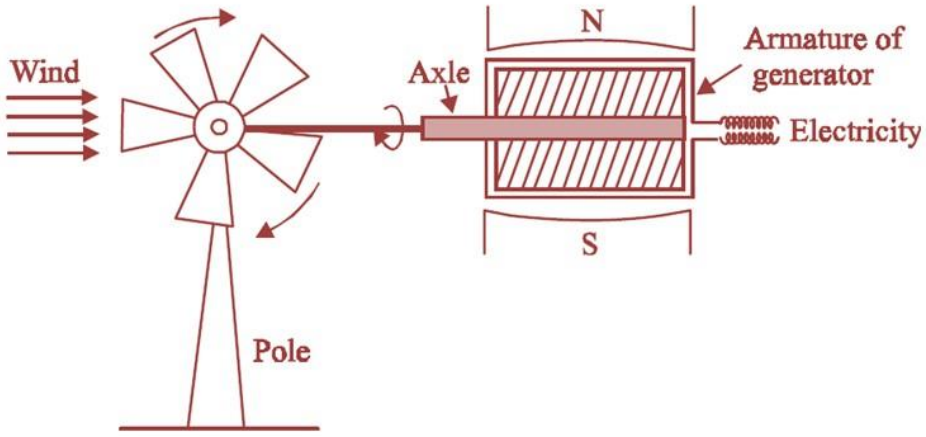


Fig. Wind Energy

- The **one end of axle** is connected to the **armature of a generator,** which rotates between two poles of a strong magnet.
- **Another end of the axle** is connected to the **shaft of the wind mill.** When wind falls on the wheel of the wind mill, it rotates and electric current is produced. The kinetic energy of the wind is converted into electric energy.

2. Wind Farm:

- The electricity produced by a **single wind mill is very small,** which cannot be used for commercial purpose. To produce electricity on a **large scale, a large number of wind mills are connected.**
- The small amount of electricity produces by each generator connected to each wind mill is combined to get electricity on a large scale.

3. Other methods

i. Sky sail ii. Ladder mill

iii. Kite ship (large free flying sails) iv. Sky wind power (Flying electric generator) **Advantages:**

- It does not cause any pollution
- It is very cheap and economic
- It is renewable **Disadvantages:**
- Wind farms produce unwanted sound
- Wind turbines interfere with electromagnetic signals (TV, Radio signal) Wind energy is not sufficient to operate very heavy machine.
- Due to noise generated by the machines and loss of aesthetic appearance public resists for locating the wind farms in populated areas.

Batteries and Fuel Cells

9. What is primary battery. Give an example

Dry cell (or) Leclanche's cell

Primary cell, which works without fluid component.

Description:

Anode: Zinc body

Cathode: Carbon rod (Graphite)

Electrolyte: Mixture of MnO_2 + graphite + NH_4Cl + $ZnCl_2$ + starch

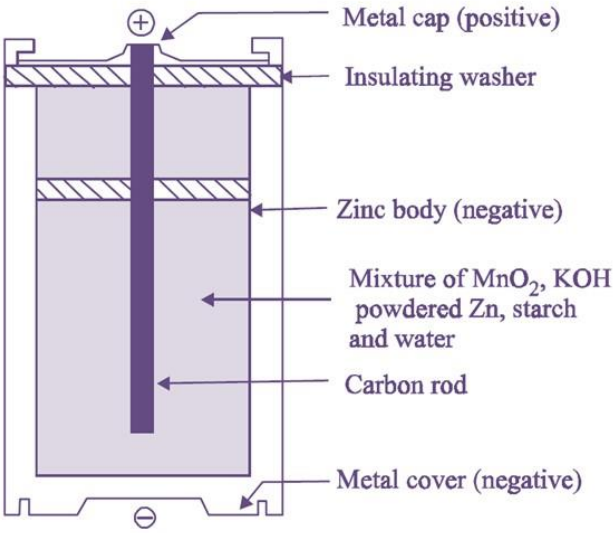


Fig. Alkaline battery

Working:

At anode: $\longrightarrow$ $Zn \quad Zn^{2+} + 2e^-$

At cathode: $NH_4^+{}_{(aq)} + MnO_{2\,(s)} + \longrightarrow 2e^- \quad MnO(OH)^- + NH_3$

Overall Reaction: $Zn + NH_{4+(aq)} + \longrightarrow +$

$MnO_{2(s)} Zn^{2+} MnO(OH)^- + NH_3$

In cathode reaction, **Mn** is reduced from **+4** oxidation state to **+3** oxidation state. The liberation of NH_3 gas, which disrupts the current flow, is prevented by a reaction of $NH_{3\,(g)}$ with Zn^{2+} **(from** $ZnCl_2$**)**

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

The voltage of Leclanche's cell is about **1.5 V.**

Disadvantages:

i. Dry cell does not have an indefinite life, because of NH4Cl being acidic corrodes the zinc container, even if it is not used.

ii. When current is drawn rapidly from it, products build up electrodes, so voltage drop occurs.

Uses: Used in transistor radios, calculators, flash lights, torches etc.,

10. Explain the construction, charging and discharging of lead-acid accumulator. Storage cell:

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

A lead acid battery consists of a number of (3 to 6) voltaic cells connected in series to get 6 to 12 V battery.

Anode: lead

Cathode: PbO_2 (lead dioxide)

Electrolyte: dil.H_2SO_4 (38% by mass)

The cell represented as

$Pb / PbSO_4 // H_2SO_{4(aq)} / PbSO_4 / Pb$

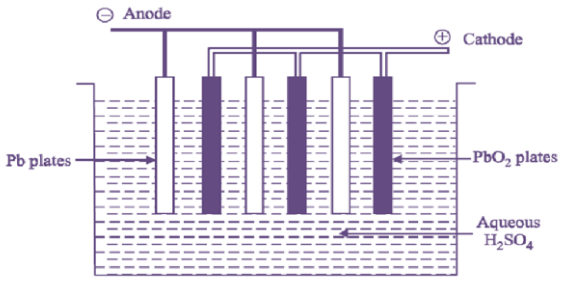


Fig. Lead storage cell

Working (discharging):

Anode:

$$\text{discharging } Pb_{(s)} + SO_4^{2-}{}_{(aq)} \rightleftharpoons PbSO_{4\,(s)} + 2e \quad \text{Charging}$$

Cathode:

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

$$\text{Charging}$$

Overall reaction:

$$Pb_{(s)} + PbO_{2\,(s)} + 2H_2SO_{4\,(aq)} \underset{\text{Charging}}{\overset{\text{discharging}}{\rightleftharpoons}} 2PbSO_{4\,(s)} + 2H_2O + \text{Energy}$$

From the above cell reaction clear that, $PbSO_4$ is precipitated both electrodes and H_2SO_4 is used up. As a result, the concentration of $H2SO_4$ decreases and hence the density falls below 1.2 gm/ml. so the battery needs recharging.

Recharging the battery:

Charging

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

Advantages:

i. It is made easily ii. It produces very high current iii. The self-discharging rate is low when compared to other rechargeable batteries.

iv. It also acts effectively at loe temperature.

Disadvantages:

i. Recycling of this battery causes environmental hazards.

ii. Mechanical strain and normal bumping reduces battery capacity. **Uses:**

i. Lead storage cell is used to cars, buses, trucks, etc.,

ii. Also used as gas engine ignition, telephone exchanges, hospitals, power stations, etc.,

11. Explain in detail about Lithium-ion battery (LIB)

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

Anode: Negative electrode (layers of porous carbon)

Cathode: Positive electrode (layers of lithium-metal oxide)

Elecrtrolyte: Polymer gel (separator)

Construction:

- The positive electrode is typically made from a layers of chemical compound lithium-cobalt oxide ($LiCoO_2$)
- The negative electrodes is made from layers of porous carbon (C) graphite
- Both electrodes are dipped in a polymer gel electrolyte (organic solvent) and separated by a separator, which is perforated plastic and allows the Li^+ ions to pass through.

Working:

Charging

$LiCoO_2 + C$ $^+$ ions flow from the positive electrode **$Li_{1-x}CoO_2 + CLix$** ($LiCoO_2$) to the During charging, Li negative electrode (graphite) through the electrolyte. Electrons also flow from the positive electrode to negative electrode through the wire. The electrons and Li^+ ions combine at the negative electrode and deposit there as Li.

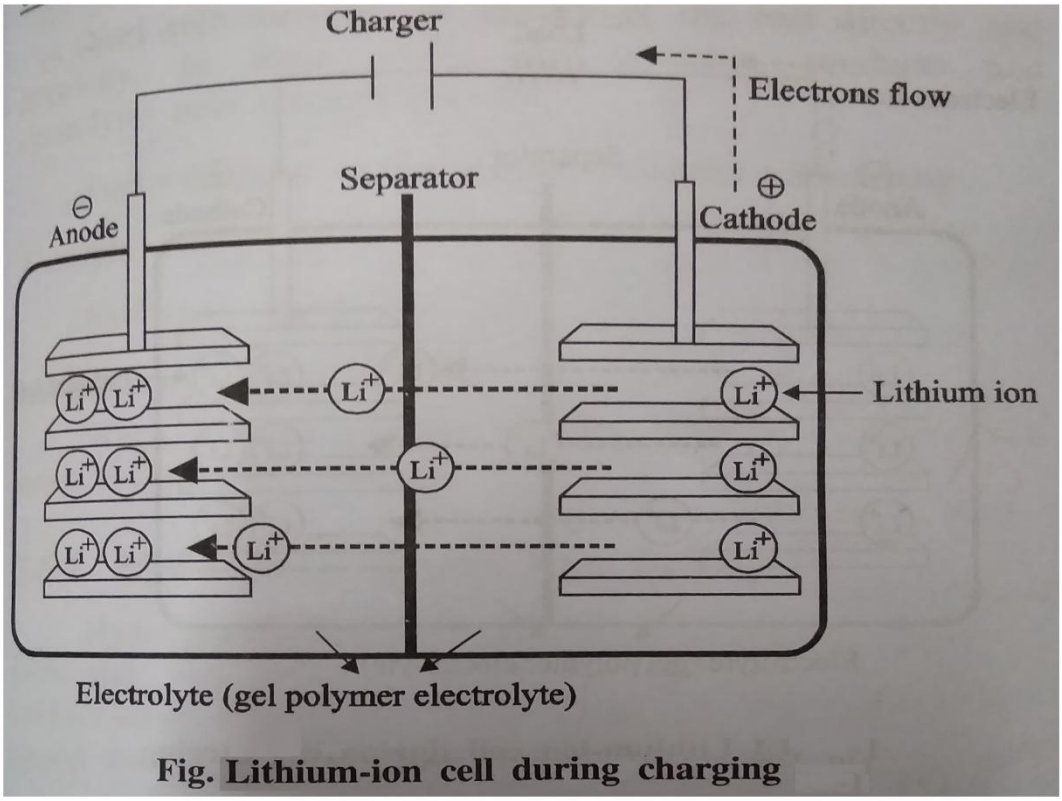


Fig. Lithium-ion cell during charging

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 the positive electrode and deposit there as Li.

$$Li_{1-x}CoO_2 + CLix \longrightarrow LiCoO_2 + C$$

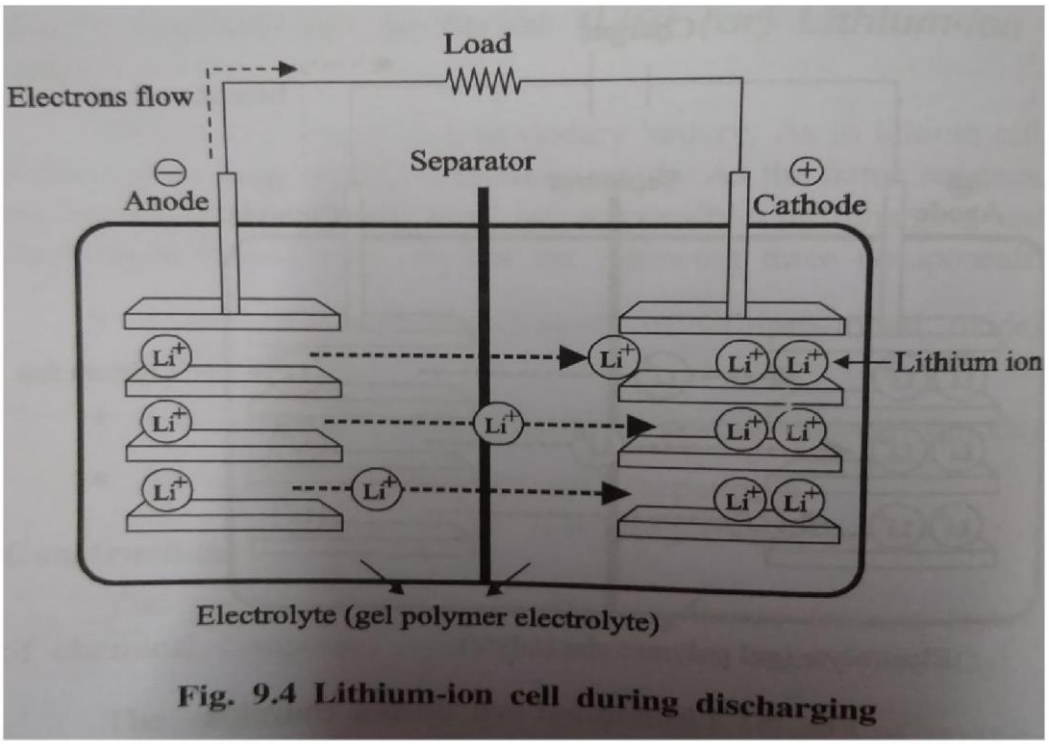


Fig. 9.4 Lithium-ion cell during discharging

Advantages:

i. Lithium-ion batteries are high voltage and light weight batteries. ii. It is smaller in size iii. It produces three time voltage of Ni-Cd batteries iv. It has none of the memory effect seen in Ni-Cd batteries

Uses of Lithium cell:

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

12. Explain the working of H_2-O_2 fuel cell.

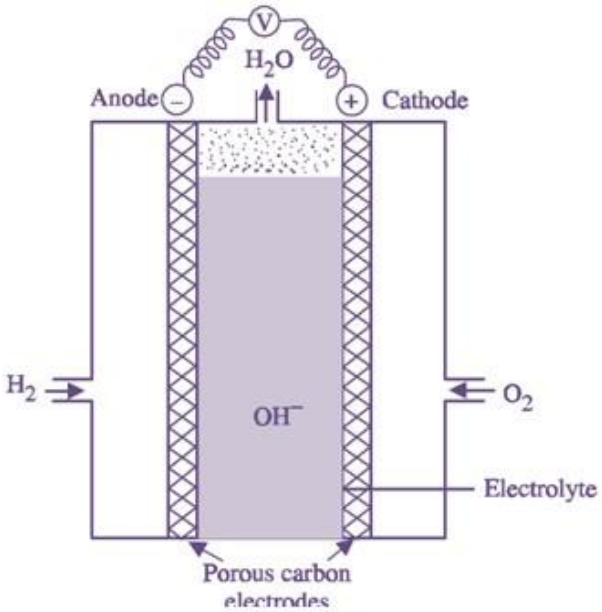
Definition: It is the simplest and most successful cell, in which the **fuel-hydrogen** and **oxidizer-oxygen** and liquid **electrolyte** are passed through the cell.

Description:

- Consists of two porous electrode **anode** and **cathode**
- Two porous electrodes are made of compressed carbon containing a small amount of catalyst (Pt, Pd, Ag).
- In between two electrodes an **electrolyte 25%KOH (or) NaOH** is added.
- The two electrodes are connected through **voltammeter.**

Working:

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



H_2-O_2 Fuel cell

Reaction: **At Anode (Oxidation):**

$$H_2 \longrightarrow 2H^+ + 2e^-$$
$$2H^+ + 2OH^- \longrightarrow 2H_2O$$
$$\mathbf{H_2 + 2OH^- \longrightarrow 2H_2O + 2e^-}$$

$_2$ $\longrightarrow$ $_2$ **Multiply by 2:** **2H + 4OH$^-$** **4H O + 4e$^-$**

At Cathode (Reduction):

$$O_2 + 4e \quad 2O$$
$$2O^{2-} + 2H_2O \quad 4OH^-$$

$^-$ $\longrightarrow$ $^{2-}$ $\longrightarrow$

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

Overall reaction:

At anode : $2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$

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

$2H_2 + O_2 \longrightarrow 2H_2O$

The emf of the cell = **0.8 to 1.0 V Applications:**

i. Auxiliary energy source in space vehicle, submarines (or) other military-vehicles.

ii. The product of H_2O is proved to be a valuable source of fresh water by the astronauts.

Advantages:

i. Emits only water vapour and no other harmful chemicals to the environment.

ii. Efficiency is more than 75% iii. It causes less noise pollution **Disadvantages (or) limitations:**

i. Hydrogen gas is explosive ii. Very expensive to be carried out.

iii. Hydrogen gas, difficult to compress into liquid form.

13. Write notes on super capacitors

Super capacitor is a high capacity 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 dielectric, but rather they use electrostatic double-layer capacitance.

Design of super capacitor:

Super capacitor (Electro-chemical capacitor) consists of two electrodes (made from metal coated with a porous substance like powdery activated carbon) separated by an ion-permeable membrane (separator) and dipped an electrolyte, containing positive and negative ions, connecting both the electrodes.

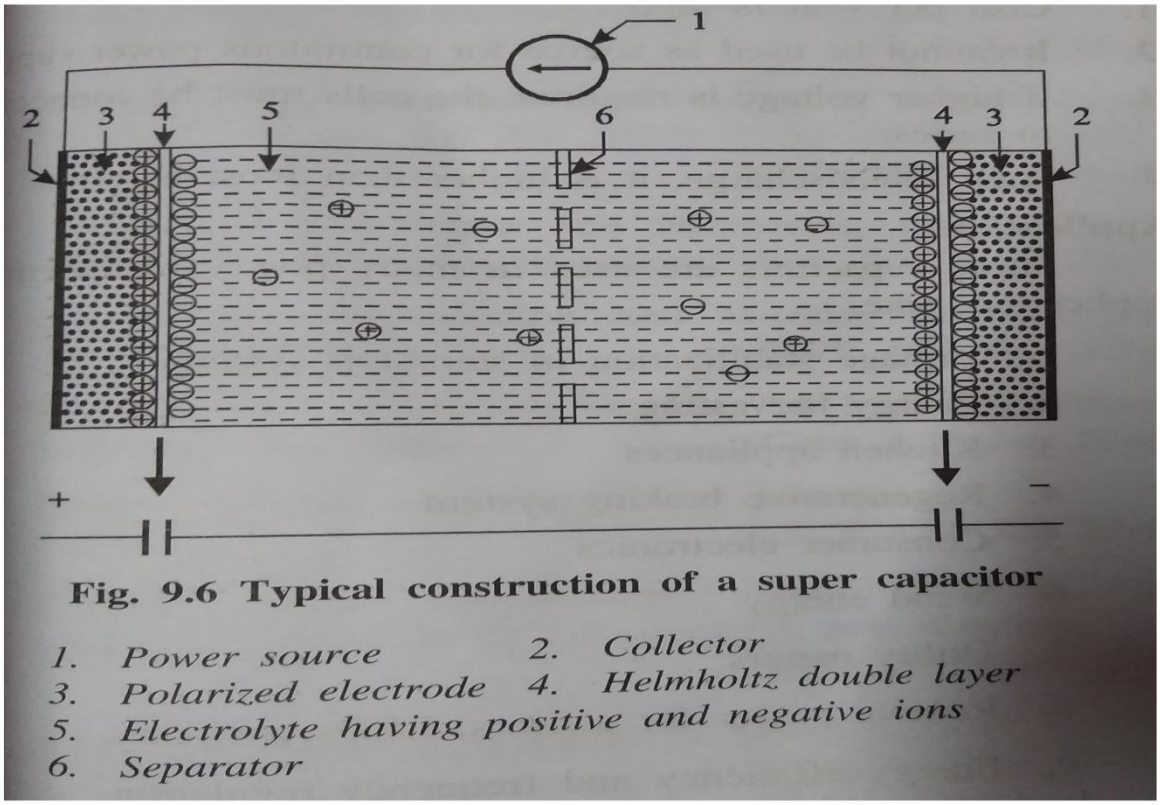


Fig. 9.6 Typical construction of a super capacitor

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

Working:

- The electrodes are connected to the power source, ions in the electrolyte from electric double layers (Helmholtz electrical double layer) 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/ electrolyte interface.

- Similarly negatively polarized electrodes will have a layer of positive ions at the electrode/ electrolyte interface.
- The electric field polarizes the dielectric, so its molecules lineup in the opposite direction to the field and reduce its strength.
- It means that it stores more electrical energy an electrode-electrolyte interface. **Advantages:**

i. It is highly safe

ii. Lifetime is very high (10 to 20 years) iii. It can be cycled millions of time iv. It can be charged in seconds

Disadvantages:

i. Cost per watt is high ii. It cannot be used as source for continuous power supply iii. If higher voltage is required, the cells must be connected in series.

Applications:

i. Voltage stabilization in start/stop system ii. Energy harvesting iii. Kitchen appliances iv. Regenerative braking system

v. Consumer electronics