Chapter 8

Unit - V

Batteries

Part - B

1. Explain the construction and working of a lead storage battery. *(Coim A.U Jan 2009) (TNV. AU. May 2009) (Dec 2008, Jan 2013, Dec 2014, Dec 2015)*

(or)

What are lead accumulators? Explain the construction and functioning of a lead accumulator. *(A.U. June 2014)*

(or)

Describe the construction of lead-acid battery with reaction occuring during discharging. *(A.U June 2016)*

A Lead accumulator is a secondary battery, which can operate both as a voltaic cell and as an electrolytic cell.

Construction

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 PbO_2 or a grid made of lead, packed with PbO_2. A number of lead plates (anodes) are connected in parallel and a number of PbO_2 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. H_2SO_4 (38% by mass) having a density of 1.30 gm/ml.

The cell may be represented as;

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

Working (Discharging)

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

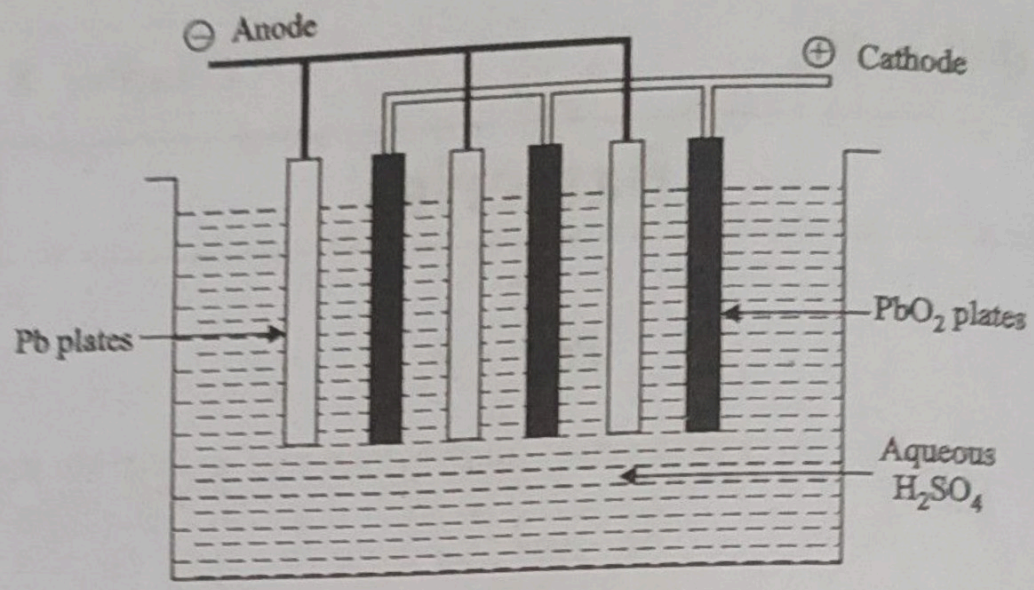

Fig. Lead storage cell

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

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

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

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

Overall cell reaction during use (discharging):

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

Recharging the Battery

The cell can be charged 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 during charging is

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

2. **Describe the construction and working of hydrogen-oxygen fuel cell.**

(Chen A.U. Jan 2010, Jan 2013, Dec 2014, May 2017)

(or)

With a neat diagram, explain the working principal of $H_2 - O_2$ fuel cell with cell reaction.

(A.U June 2016, (A.U. June 2014)

Definition

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

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 electrolytic solution such as 25% KOH or NaOH is filled. The two electrodes are connected through the volt meter.

Working

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

Various reactions

At Anode

Hydrogen gas, passed through the anode, is oxidised with the liberation of electrons which then combine with hydroxide ions to form water.

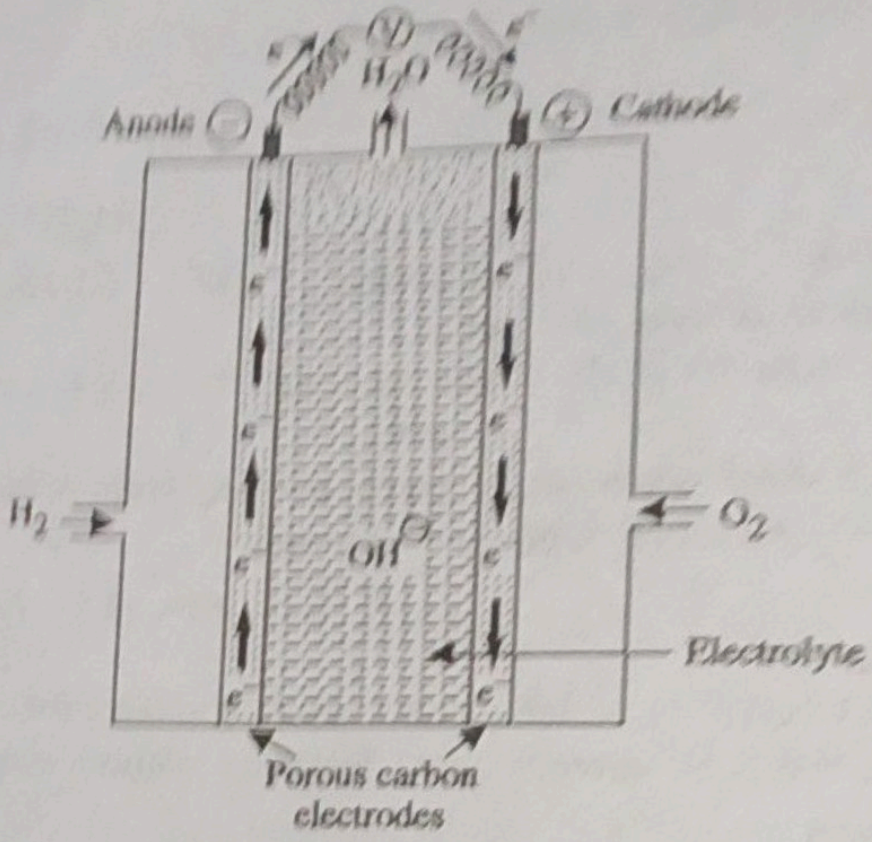

Fig. $H_2 - O_2$ Fuel cell

$$H_2 \longrightarrow 2H^+ + 2e^-$$

$$2H^+ + 2OH^- \longrightarrow 2H_2O$$

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

Multiply by 2: $2H_2 + 4OH^- \longrightarrow 4H_2O + 4e^-$

At cathode

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.

$$O_2 + 4e^- \longrightarrow 2\,O^{2-}$$

$$2O^{2-} + 2H_2O \longrightarrow 4OH^-$$

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

Overall cell 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**

3. Explain the construction, working of Leclanche's Cell

It is a primary cell, which works without fluid component.

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, $ZnCl_2$ and MnO_2 in the form of paste using starch and water. A carbon rod (graphite), acts as cathode, is immersed in the electrolyte in the centre of the cell. The zinc cylinder has an outer insulation of cardboard case. During use, the zinc cylinder gets consumed and at the end, it will develop holes which are responsible for leakages.

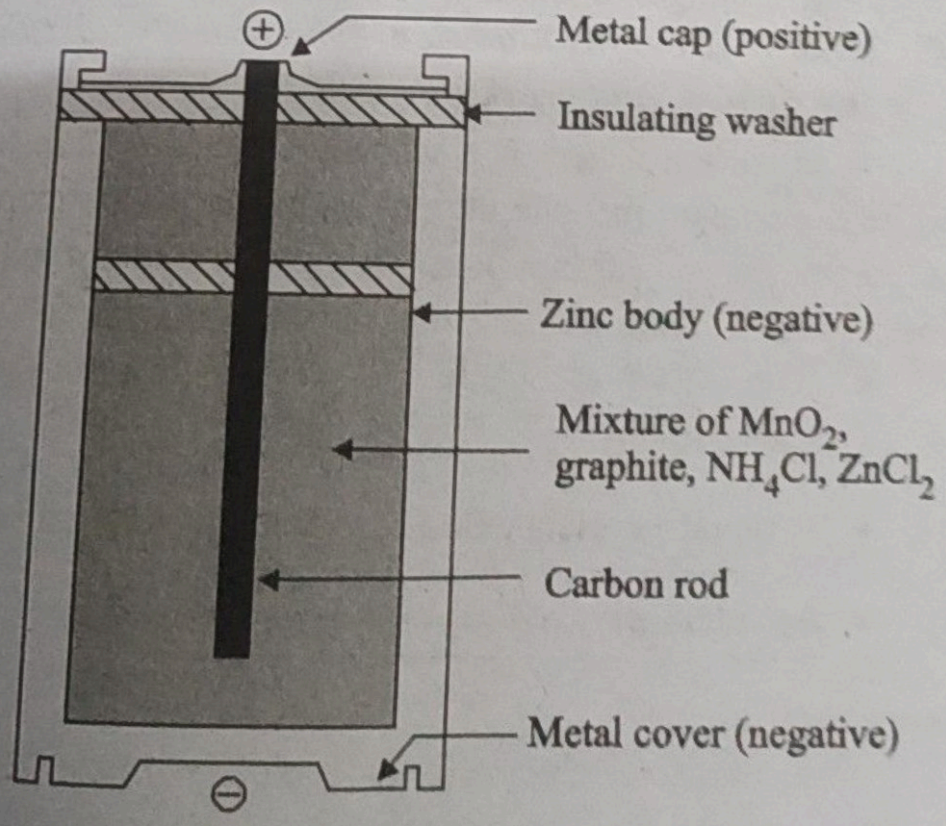

Fig. Leclanche's Cell

Working

When the cell is working, zinc loses 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:

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

At cathode:

$$NH_{4\,(aq)}^{+} + MnO_{2\,(s)} + 2e^- \longrightarrow MnO(OH)^- + NH_3$$

Overall Reaction:

$$Zn + NH_{4\,(aq)}^{+} + MnO_{2\,(s)} \longrightarrow Zn^{2+} + MnO(OH)^- + NH_3$$

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 $ZnCl_2$).

$$ZnCl_2 + 2\,NH_3 \longrightarrow [Zn(NH_3)_2]\,Cl_2(s)$$

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

4. What are Lithium-ion batteries? Explain the construction and working of 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. Lithium-ion cell has the following three components.

- A positive electrode (Layers of lithium-metal oxide) (cathode)
- A negative electrode (Layers of porous carbon) (anode)
- An electrolyte (Polymer gel) (separator)

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 (C) (graphite).

Both the electrodes are dipped in a polymer gel electrolyte (organic solvent) and separated by a separator, which is a perforated plastic and allows the Li^+ ions to pass through.

Working

Charging

During charging, Li^+ ions flow from the positive electrode ($LiCoO_2$) to the negative electrode (graphite) 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.

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

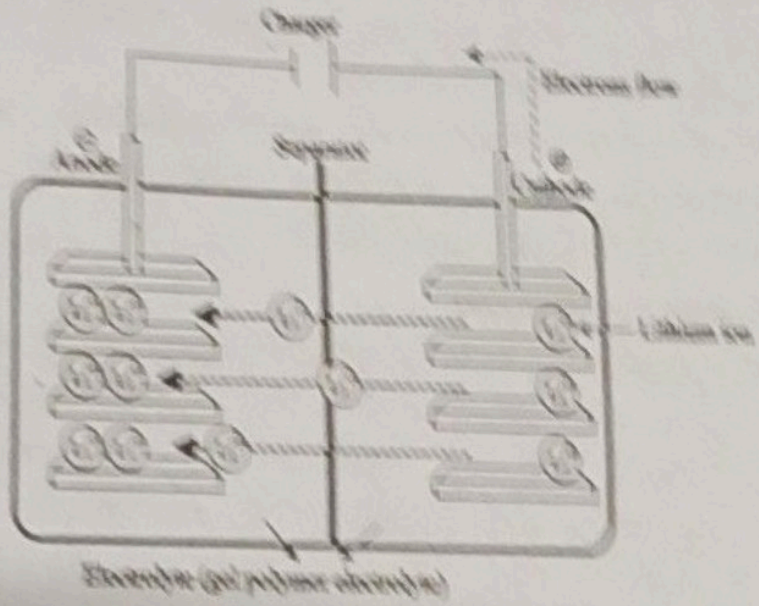

Fig. Lithium-ion cell during charging

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 at the positive electrode and deposit there as Li.

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

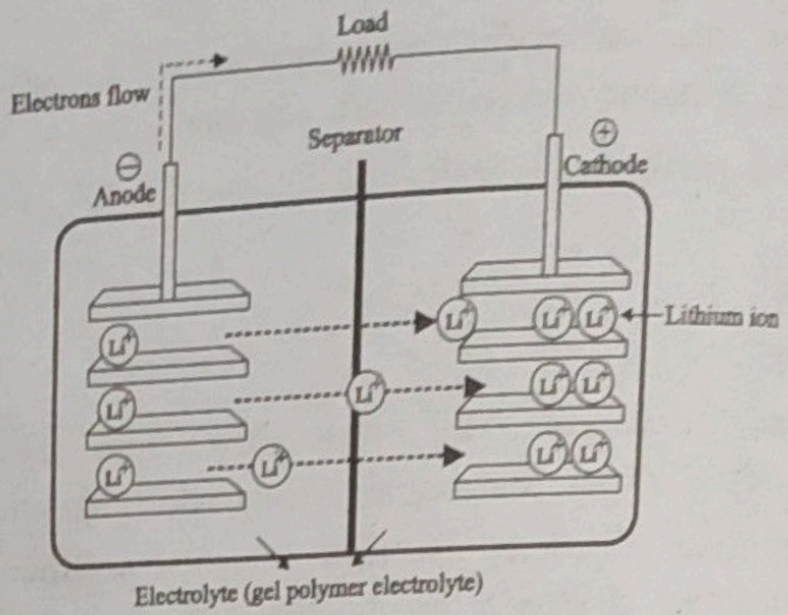

Fig. Lithium-ion cell during discharging

5. *Write notes an Super Capacitor*

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 in an electrolyte, containing positive and negative ions, connecting both the electrodes.

Working (or) Storage Principle

When the electrodes are connected to the power source, ions in the electrolyte form 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 polarised electrodes will have a layer of positive ions at the electrode/electrolyte interface.

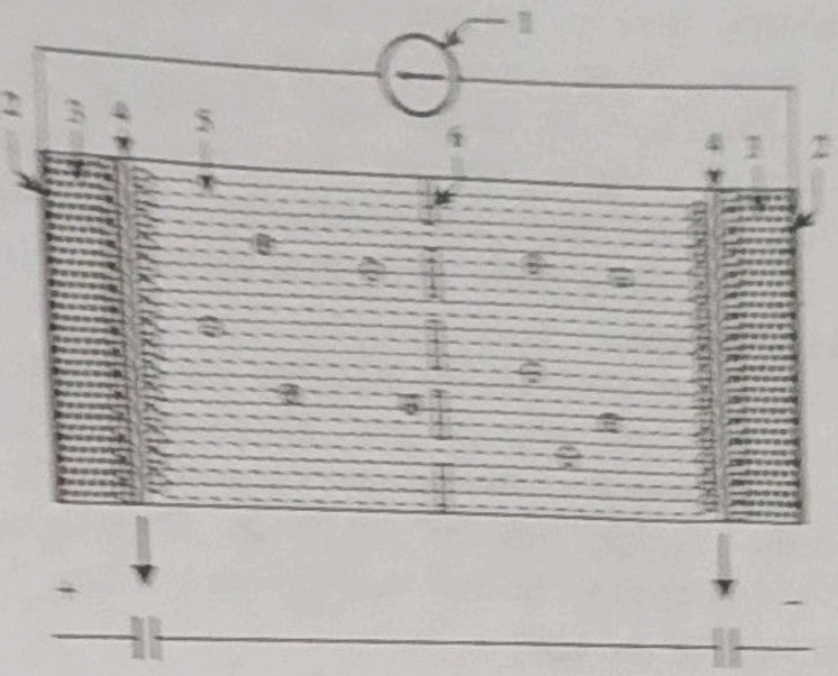

Fig. Typical construction of a super capacitor

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

This 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 at an electrode-electrolyte interface.

Advantages

1. It is highly safe 2. Its life time is very high (10 to 20 years) 3. It can be cycled millions of time

Disadvantages

1. Cost per watt is high. 2. It cannot be used as source for continuous power supply 3. If higher voltage is required, the cells must be connected in series.

Applications

Super capacitors are used in many power management applications like, 1. Voltage stabilization in start/stop system. 2. Energy harvesting, 3. Kitchen appliances

6. What are electric vehicles? Explain their working principle and advantages and disadvantages?

Electric vehicles are the vehicles that are powered on electric power. These are also referred to as battery electric vehicles. They have an electric motor instead of an internal combustion (IC) engine. Running costs are very low as they have less moving parts for maintaining. As it runs on electricity, the vehicle emits no exhaust gases.

Working Principle

Electric vehicles work by plugging into a charge point and taking electricity from the grid. They store electricity in rechargeable battery that power on electric motor, which rotates the wheels. Electric vehicles accelerate faster than the traditional fuel engines. So they feel lighter to drive.

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.

Advantages

(i) Electric cars are energy efficient

(ii) It reduces emission.

(iii) Its performance is high and has low maintenance.

(iv) It can be fuelled for very low price.

(v) It is more convenient and easy to recharge.

Disadvantages

(i) Electric cars can travel less distance.

(ii) It takes longer time to refuel (recharge)

(iii) These are more expensive and battery packs may need to be replaced.

(iv) Electric fuelling stations are still in the developing stages.

(v) Initial investment is very high.

7. *What is microbial fuel cell? Explain its principle and working with neat diagram.*

Microbial fuel cell is a device that converts chemical energy to electrical energy by the action of micro-organisms under anaerobic conditions.

Bioelectricity is generated by the oxidation of organic waste and renewable biomass using bacteria.

Construction (or) Principle

MFCs are type of electrochemical cells, constructed using either bioanode and (or) a biocathode. A membrane separates the compartments of the anode (where oxidation occurs) and the cathode (where reduction occurs). The electrons produced during oxidation are transferred directly to the cathode. The charge balance of the system is maintained by the ionic movement inside the cell.

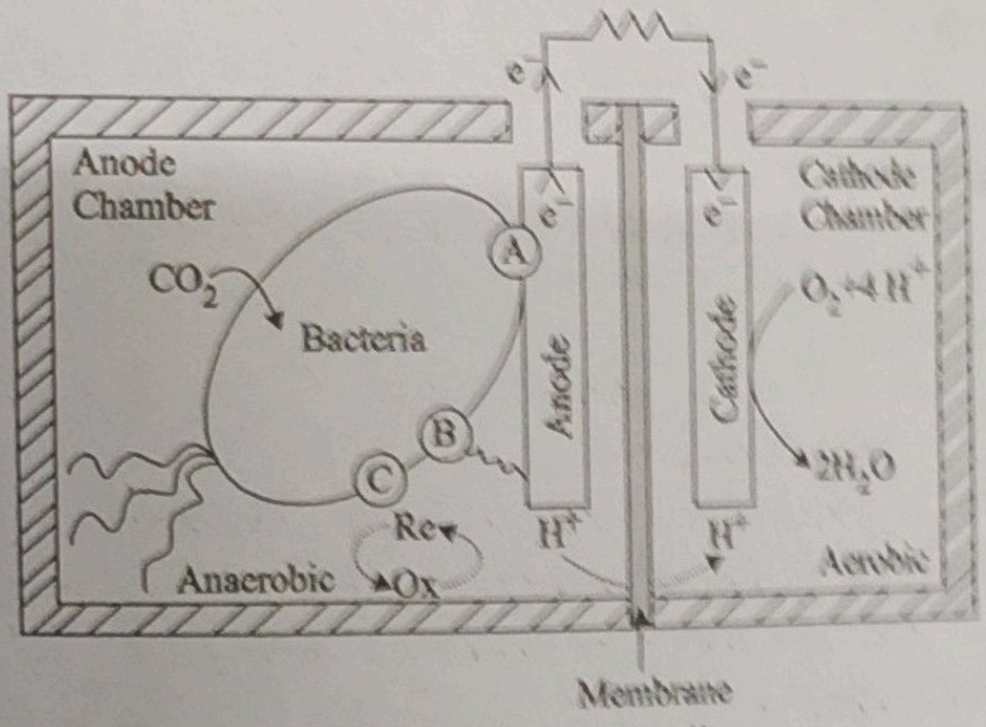

Fig. Microbial Fuel cell

Organic electron donors, that is oxidized to produce CO_2, protons and electrons, are used in most MFCs. The cathode reaction uses a variety of electron acceptors, mostly oxygen (O_2).

Working

When both the electrodes are connected, anode oxidation occurs on organic waste (biomass) and electrons released from the process are transferred to the anode. The electrons, transfered to the anode, can be accomplished by the electron mediators.

From the anode these electrons are directed to the cathode across an external circuit. For every electron, conducted, a proton is transported across the membrane to the cathode. Finally oxygen present at the cathode recombines with hydrogen and electron to produce water.