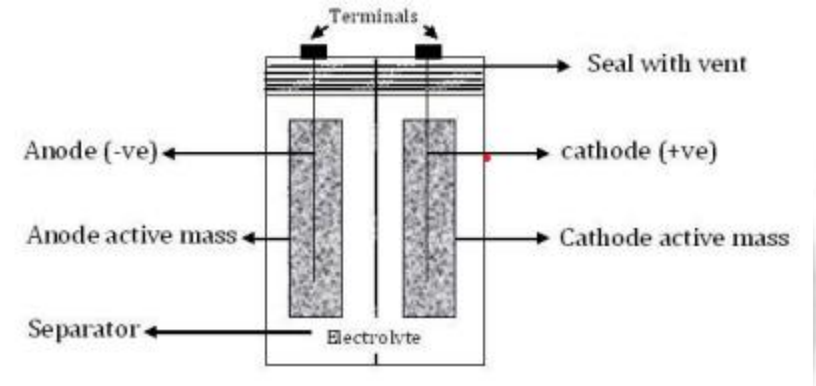
### 3.5 Battery and its types

**Battery:** It is a device consisting of two or more galvanic cells connected in series or parallel or both.

**Principle components of a battery are:**

1. An anode where oxidation occurs.
2. A cathode where reduction occurs.
3. An electrolyte, which is ionically conducting.
4. A separator to separate anode and cathode compartments.




**Classification of batteries:**

1. **Primary batteries:**
   In these batteries the cell reaction is not reversible, after discharging cannot be rechargeable. Ex. Zn-MnO2 dry cell.
2. **Secondary batteries:**
   In these battery the cell reaction is completely reversible, after discharging can easily rechargeable. Ex. Lead-acid battery, Ni-Cd battery.
3. **Reserve batteries:**
   In these batteries, one of the active components (e.g. electrolyte) of the battery is separated from the rest of the components. It is assembled just before the use.
   Ex. Mg-water activated battery
4. **Flow or Fuel battery:**
   Fuel cells are the galvanic cells in which chemical energy of fuel is directly converted into electrical energy. Reactants are continuously passing through the cell.
   Eg: $H_2$-$O_2$ fuel cell

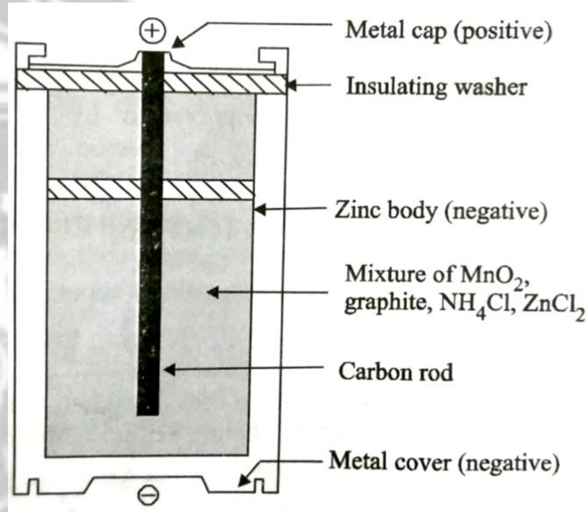
### 3.5.1 Dry cell (or) Leclanche's cell

The Leclanche cell is called dry cell because of the absence of any liquid phase.

**Description**

| | |
|---|---|
| Type of Battery | : Primary battery |
| Anode | : Zinc |
| Cathode | : Carbon rod (Graphite) |
| Electrolyte | : $NH_4Cl$ + $ZnCl_2$ + $MnO_2$ + Starch + Water |
| EMF | : 1.5 V |

**Construction**




- Dry cell consists of a cylindrical zinc container that acts as an anode.
- A carbon rod (graphite) placed in the centre acts as a cathode.
- The space between the anode and cathode is packed with a paste of $NH_4Cl$, $ZnCl_2$ and $MnO_2$ made using starch and water.
- The zinc cylinder has an outer insulation card board case.
- During use, the zinc cylinder gets consumed and at the end, it will develop holes which causes leakages.

**Working**

The cell reactions at two electrodes are as follows:

**Cell reactions:**

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

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

**Overall Reactions**: $Zn + NH_4^+{}_{(aq)} + MnO_{2(s)} \longrightarrow Zn^{2+} + MnO(OH)^- + NH_3$

**Secondary Reactions**

$2NH_4Cl + 2OH^- \rightarrow 2NH_3 + 2H_2O + 2Cl^-$

$Zn^{2+} + 2NH_3 + 2Cl^- \rightarrow [Zn(NH_3)_2]Cl_{2(s)}$

The Secondary reactions do not contribute to the emf of the cell. The voltage of Lechlanche's cell is about 1.5 V.

**Advantages**

- These cells have voltage ranging from 1.25V to 1.5V.
- The cost is low.
- The compact size of the dry cell makes it suitable for powering small electronic devices.
- The electrolyte used in dry cells is not so harmful to the environment.
- It is a portable source of electric energy.
- Even in hot weathers, it performs better than other types of batteries.

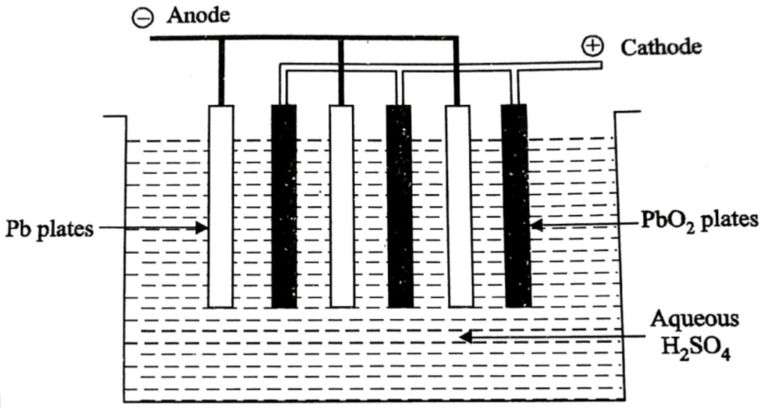
**Disadvantages**

- These cells do not have long life.
- These cells cannot be recharged.
- The life time of the cell is not definite.
- Voltage decreases with continuous usage, due to the accumulation of products at the electrode.

**Uses:** Dry cells are used in flash light, radios, tape recorders, transistors, etc.

## 3.6 Lead Acid Storage Battery or Lead Storage Cell

It is a secondary storage cell which can operate both as a voltaic and as an electrolytic cell. When it acts as a voltaic cell, it supplies electrical energy and becomes run down. While recharging the cell acts as electrolytic cell.




**Description**

| | |
|---|---|
| Type of Battery | : Secondary battery |
| Anode | : Lead |
| Cathode | : Lead dioxide |
| Electrolyte | : Aqueous sulphuric acid |
| Cell Notation | : Pb / $PbSO_4$ // $H_2SO_{4(aq)}$ / $PbO_2$ / Pb |
| EMF | : 12 V |

**Construction**

- The lead acid storage battery consists of three to six identical cells joined together in series.
- Each of its cell has a lead anode and lead dioxide cathode.
- These two electrodes are immersed in aqueous sulphuric acid electrolyte of density 1.3 gm/ml

**Working (Discharging)**

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

**At anode** :

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

$$Pb_{(s)} + SO_4^{2-}{}_{(aq)} \underset{\text{Charging}}{\overset{\text{Discharging}}{\longleftrightarrow}} PbSO_{4\,(s)} + 2e^-$$

**At cathode** :

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

$$PbO_{2(s)} + 4H^+ + SO_4^{2-} + 2e^- \underset{\text{Charging}}{\overset{\text{Discharging}}{\longleftrightarrow}} PbSO_{4\,(s)} + 2H_2O$$

**Overall cell reaction during use (discharging):**

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

✓ From the above cell reactions it is clear that, $PbSO_4$ is precipitated at both the electrodes and $H_2SO_4$ is used up.

✓ As a result, the concentration of $H_2SO_4$ decreases and hence the density of $H_2SO_4$ 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 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***

$$2PbSO_{4\,(s)} + 2H_2O + Energy \underset{Discharging}{\overset{Charging}{\longleftrightarrow}} Pb_{(s)} + PbO_{2\,(s)} + 2H_2SO_{4\,(eq)}$$

**Advantages**

- ➢ It produces very high current.
- ➢ It is highly reliable and robust.
- ➢ It acts effectively at low temperatures.
- ➢ The self-discharging rate is low when compared to other rechargeable batteries.
- ➢ It is simple and inexpensive to manufacture.
- ➢ Low cost of maintenance.
- ➢ It maintains large power in comparison to its weight.
- ➢ It can be recycled.

**Disadvantages**

- ➢ Mechanical strain reduces battery capacity.
- ➢ Recycling of this battery caused environmental hazards.
- ➢ It cannot be stored in a discharged condition.
- ➢ Danger of overheating during fact charging.

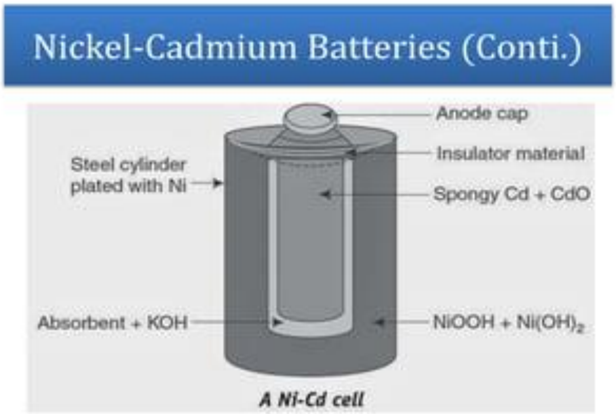
**Uses**

- ➢ It is used to supply current for electric vehicles, automobiles like cars gas ignition and telephone exchanges, railway trains, mines, hospitals, etc.
- ➢ Stand by back-up power for electrical installations, submarines.

## 3.7 Nickel – Cadmium Battery

**Description**

It consists of a cadmium anode. A metal grid containing a paste of NiO2 acting as a cathode. KOH is electrolyte.




**Cell reactions**

**At anode**: $Cd(s) + 2OH^- \rightarrow Cd(OH)_2(s) + 2e^-$

**At cathode**: $NiO_2 + 2H_2O(l) + 2e^- \rightarrow 2OH^- + Ni(OH)_2\ (s) + energy$

**Overall reaction**:

$$Cd(s) + NiO_2 + 2H_2O(l) \rightarrow Cd(OH)_2(s) + Ni(OH)_2\ (s) + energy$$

**Uses:** It is used in calculators. Electronic flash units, transistors and cordless appliances.

### 3.7.1 Lithium Battery

- It is a solid state battery. Solid electrolyte is used.

**Description**

- It consists of a lithium anode and a TiS2 cathode.
- A solid electrolyte generally a polymer is packed in between the electrodes.
- The electrolyte permits the passage of ions but not electrons.

**Cell reactions**

**At anode:** $Li\ (s) \rightarrow Li^+ + e^-$

**At cathode:** $TiS_2 + e^- \rightarrow TiS_2^-$

**Over all reaction:** $Li\ (s) + TiS_2 \rightarrow Li^+ + TiS_2^-$

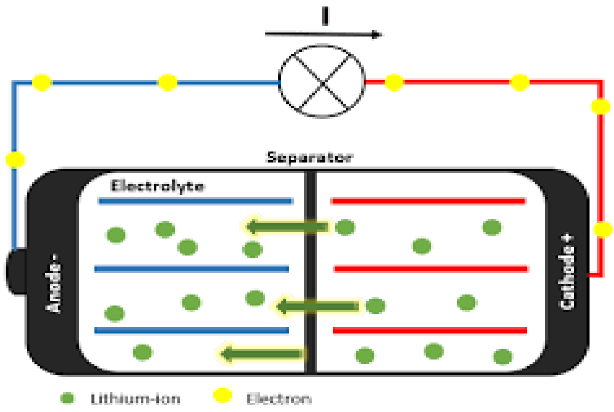
**Recharging**

The battery is recharged by passing an external current, which drives the lithium ions back to the anode.

The overall reaction is,

$$LiTiS_2 \rightarrow Li^+ + TiS_2^-$$

- The cell has a voltage of 3.0 V.




**Uses:**

- It possesses very small size and high energy density. So it is used in calculators, electronic flash units, computers, transistors head phones etc.

**Advantages (**It is the cell future. Why?)

- The cell has a voltage of 3.0V.
- Li is a light-weight metal. Just 7g (1 mole) of Li is required to produce 1 mole of electrons.
- Li has the most negative $E^o$ value. So it gives a higher voltage than other cells.
- It is a total solid state battery.
- There is no risk of current leakage from the battery.
- It is manufactured in a variety of sizes and shapes.

**Disadvantages**

It is more expensive than other batteries.

### 3.8 Battery Hazards

Batteries are becoming increasingly more important in the technology of the future; it is important to make sure that they are manufactured according to safety guidelines. If there is a structural issue or energy does not cycle properly, there are serious safety hazards vulnerable to vicious side effects.

The various battery hazards include:

1. **Short-Circuiting:**
   - If the electrical current in a battery is released in an uncontrolled manner a large amount of energy will be delivered in a short period of time.
   - This sudden surge of energy can transform into a strong electrical explosion, intense heat, or even fires that cause a hazard for everyone around it.
2. **Battery Acid:**
   - Aqueous sulphuric acid is a fundamental component of a battery, as it acts as the medium that carries electrical flow between positive and negative electrodes.
   - Sulphuric acid alone, however, is an extremely corrosive substance that can eat through surfaces & clothing, and it can burn through skin and eyes when in human contact.
3. **Flammable Gasses:**
   - Some batteries emit hydrogen gas during charge and discharge cycles due to the reaction between water and sulphuric acid.
   - Hydrogen gas ignites very easily and can cause explosions and/or fires if the levels of $H_2$ are not monitored properly or the room in question does not have proper ventilation.
4. **Battery Burst:**
   - Any combination of excessive charging, short-circuits, and build-up of gas within the battery can cause it to suddenly burst, which can lead to chemical burns and shrapnel injuries.
5. **Weight:**
   - Batteries used in large industrial applications can weigh up to 20-100+ lbs per cell, and that does not even take into account the massive battery banks that they rest on which collectively can add up to more than 1000lbs.
   - If corrosive durability or structural integrity is not properly tested, the sheer weight of the batteries in question can pose a threat for those around the system.

**Methods to minimize battery related damages:**

- The work place must be primed with optimal conditions and readily available safety equipment in case of an emergency.
- The safety equipment includes personal protective equipment such as goggles, face shields, rubber gloves, and rubber aprons as well as last resort protective equipment such as fire extinguishers, emergency showers and eyewash stations, and first-aid kits.
- There should be adequate ventilation to disperse fumes given off during charging and have built-in safety features such as sprinklers in case of a fire-related event.

### 3.8.1 Biological batteries

**Introduction**

Biological batteries, also known as bio-batteries, are devices that generate electrical energy from biochemical processes. Unlike traditional batteries that rely on chemical reactions of inorganic compounds, biological batteries harness the power of biological molecules and processes. They offer a unique approach to sustainable energy production and have potential applications in medical devices, environmental monitoring, and renewable energy.

**Principles of Biological Batteries**

**Electrochemical Cells:** Biological batteries operate on similar principles to traditional electrochemical cells, where chemical energy is converted into electrical energy. The basic components of these cells include:

- **Anode:** The electrode where oxidation occurs.
- **Cathode:** The electrode where reduction occurs.
- **Electrolyte:** A medium that allows ionic conduction between the anode and cathode.

**Biochemical Reactions:** In biological batteries, the chemical reactions involved are typically biological processes that occur within living organisms. These include enzymatic reactions, microbial metabolism, and biochemical transformations.

**Types of Biological Batteries**

**Enzymatic Fuel Cells:**

- **Enzymes as Catalysts:** Enzymatic fuel cells use enzymes to catalyze reactions that convert biochemical energy into electrical energy. Common enzymes include glucose oxidase and lactate dehydrogenase.
- **Mechanism:** For example, in a glucose-based enzymatic fuel cell, glucose is oxidized by glucose oxidase at the anode, producing electrons and protons. These electrons flow through an external circuit to the cathode, where they are used in a reduction reaction.

**Microbial Fuel Cells (MFCs):**

- **Microbes as Catalysts:** MFCs use microorganisms to catalyze the breakdown of organic matter and produce electrical energy. Microbes such as *Geobacter* and *Shewanella* can transfer electrons to an electrode.
- **Mechanism:** Microbes in the anode chamber oxidize organic substrates (e.g., glucose or waste) and release electrons. These electrons travel through an external circuit to the cathode, where they participate in a reduction reaction.

**Bio hybrid Systems:**

- **Combination of Biological and Synthetic Components:** Biohybrid systems integrate biological materials with synthetic components to enhance performance. For instance, a biohybrid battery might use synthetic electrodes combined with biological enzymes or cells.
- **Applications:** These systems are designed to improve efficiency and stability while utilizing the advantages of both biological and synthetic materials.

**Advantages and Challenges**

**Advantages:**

- **Renewable Resources:** Biological batteries can use renewable substrates such as organic waste, reducing the need for non-renewable resources.
- **Biodegradability:** Many components of biological batteries are biodegradable, which can minimize environmental impact.
- **Low Toxicity:** Compared to traditional batteries, bio-batteries often use non-toxic materials, making them safer for both users and the environment.

**Challenges:**

- **Power Output:** Currently, biological batteries tend to have lower power outputs compared to traditional batteries. Research is ongoing to improve their efficiency and energy density.
- **Stability and Longevity:** Biological components can be sensitive to environmental conditions, which may affect the stability and longevity of bio-batteries.
- **Cost:** Production and maintenance of biological batteries can be costly, especially when dealing with complex biological systems.

**Applications**

**Medical Devices:** Biological batteries can power medical implants and devices by using body fluids or metabolic byproducts as fuel sources. They offer the advantage of being biocompatible and potentially self-sustaining.

**Environmental Monitoring:** MFCs can be used in environmental monitoring to detect pollutants and measure organic waste levels. They provide a way to monitor ecosystems while generating energy.

**Renewable Energy:** Biological batteries have the potential to be integrated into renewable energy systems, especially in niche applications where traditional batteries may not be suitable.

**Future Directions**

**Advances in Enzyme Engineering:** Developing more efficient and stable enzymes could enhance the performance of enzymatic fuel cells.

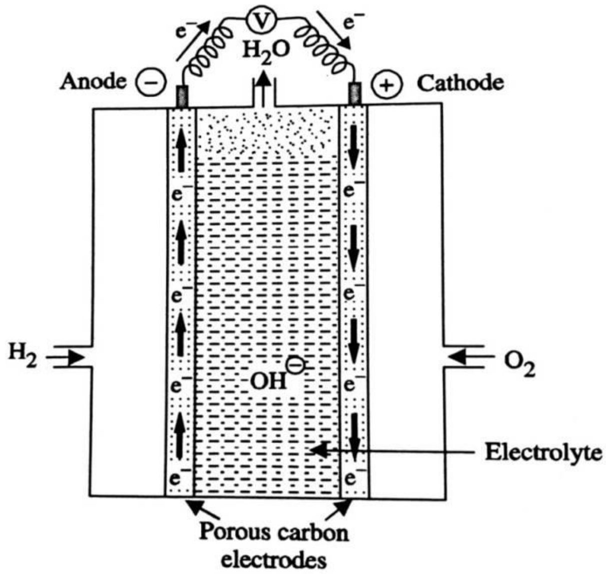
**Genetic Engineering of Microbes:** Genetic modifications of microbes can improve their efficiency and ability to function in different environments, enhancing the performance of MFCs.

**Hybrid Systems Development:** Combining biological and synthetic components could lead to more practical and scalable solutions for various applications.

**Sustainability and Cost Reduction:** Efforts are needed to make bio-batteries more cost-effective and improve their sustainability to make them viable alternatives to traditional energy storage systems.

## 3.9 Hydrogen – Oxygen Fuel Cell

**Definition**




A fuel cell is an electrochemical cell in which chemical energy of fuels is directly converted into electrical energy. The process involved in a fuel cell is as follows:

Fuel cells convert about 75% of the available chemical energy into electrical energy.

**Examples:** $H_2$ – $O_2$ fuel.

1. Methanol oxygen fuel cell.
2. Solid oxide fuel cell

**Hydrogen-Oxygen fuel cell**

It is the simplest and most successful fuel cell. It consists of,

`

| | |
|---|---|
| Fuel | : Hydrogen ($H_2$) |
| Oxidiser | : Oxygen ($O_2$) |
| Electrolyte | : 25% KOH solution |

**Description**

- It consists of two inert porous electrodes namely anode and cathode. These electrodes are made up of porous graphite. Platinum is coated on the surface of the electrodes.
- In between the two electrodes, an electrolytic solution such as 25% KOH or NaOH is filled. The two electrodes are connected through the voltmeters.

**Working**

Hydrogen (fuel) and Oxygen (Oxidiser) gases are bubbled through the anode and cathode compartment respectively.

**Various reactions**

**At anode**

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

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

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

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

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.

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

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

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

**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

**Applications**

- $H_2$-$O_2$ fuel cells are used as auxiliary energy sources in space vehicles, submarines and other military vehicles.
- The product water is proved to be a valuable source of fresh water for the astronauts.

**Fuel Battery**

When large number of fuel cells are connected in series, then it is called fuel battery.

**Advantages**

- Fuel cells are highly efficient (75%) and take less time for operation.
- Noise and thermal pollution are low.
- It produces drinking water.
- It’s maintenance is simple.
- It produces electric current directly from the reaction of a fuel and an oxidiser.

**Disadvantages**

- Maintenance of electrode is difficult.
- It is highly flammable and expensive.
- Large scale production is difficult.