Unit 3 : Battery Technology: Introduction to Battery, Primary and Secondary batteries (reversible and irreversible). Examples: Dry Cell, Lead-acid battery, Lithium ion battery ,fuel cell and applications.

Electrochemical cell and types.

An arrangement consisting of two metallic electrodes dipped into the fused or aqueous solution of same or different electrolytes in electrical contact is called an electrochemical cell.

These are of two types.

a) Electrolytic cells:- Electrolytic cells are those in which electric energy is used which brings about a chemical change.
   Cells used in electrolysis of the solution of copper sulphate, sodium chloride etc. are examples of these cells.

b) Galvanic or Voltaic cells :- A device which is capable of producing electric current by virtue of a chemical process (spontaneous redox reactions) going on inside it is called Galvanic or Voltaic cell. (Nowadays these cells are also called electrochemical cells)
   Example – Daniel cell, Dry cells etc.

Daniel cell or Simple voltaic cell or Galvanic cell.

Daniel cells or Simple voltaic cells or Galvanic cells are cells in which chemical energy is converted into electrical energy through a redox (oxidation – reduction) reaction.

A single unit is known as cell while a combination of several cells is known as battery.(One or more electrically connected galvanic cells in series is called battery)

Charge

The operation of a cell when an external source of current reverses the electrochemical reactions of the cell to restore the battery to its original charged state is called charge.

Dis-charge.

The operation of a cell when current flows spontaneously from the battery into the external circuit is called discharge.

Closed circuit voltage.

The voltage measured across the terminals of the cell or battery when current is flowing into the external circuit is called closed circuit voltage.

Open circuit voltage.

The voltage measured across the terminals of the cell or battery when no external current is flowing is called open circuit voltage.

Electrochemical couple.

Electrochemical couple is the combination of the electrode reactions of the anode and cathode to form complete galvanic cell. The number of electrons given up by the anode to the external circuit must be identical with the number of electrons withdrawn from the external circuit by the cathode.

Internal resistance or impedance.

The internal resistance or impedance of the battery is the resistance to the flow of current which operates in addition to the resistance of the external load.

Separator.

Separator is a physical barrier between the positive and negative electrodes to prevent direct shorting of the electrodes. Separator must be permeable to ions but must not conduct electrons. They must be inert in the total environment.

Electromotive force.

The difference of potential, which causes a current to flow from the electrode of higher potential to one of lower potential is called the electromotive force (emf) of the cell, and is expressed in volts.

Electrolyte.

Any substance which produces ion in solution or in fused state and allows the electric current to pass through it is known as electrolyte.

Anode

It is the negative electrode of a primary cell. In a rechargeable cell, the anode acts as negative pole during discharging and as positive pole during charging.

Cathode.

It is the positive electrode of a primary cell. In a rechargeable cell, the cathode is the positive pole during discharge and the negative pole during charging.

Energy Density

Energy Density is a term used for the amount of energy stored in a given system or region of space per unit volume. Often only the useful or extractable energy is quantified, which is to say that chemically inaccessible energy such as rest mass energy is ignored.

Power density.

Power density (Volume power density or volume specific power)is the amount of power (time rate of energy transfer) per unit volume. In energy transformers like batteries, fuel cells, motors, etc but also power supply units or similar, power density refers to a volume. It is then also called volume power density which is expressed as W/m3

Classification of Batteries

Batteries are classified as follows.

Classification of Batteries

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Primary **Secondary**

1. Primary battery: 2. Secondary battery

1. Primary battery: - It is designed to be discharged only once and then discarded. Ex. Dry cell

Application It is used in domestic electrical devices which works on D.C such as torches, tape recorders, wall clock, toys, flash guns, transistors, electric bells etc.

2. Secondary battery :- It is rechargeable and can be used like the primary battery, then recharged and used again. The cycle is repeated until the capacity fades or is lost suddenly due to internal short circuit.

Ex.1). Lead acid storage battery

Applications:-

In automobiles Here 3 to 6 cells are connected in series to give voltage of 6 or 12 volts.

In telephones or telegraph office

In train lighting system

Ex.2) Alkaline Ni-Cd storage battery .

Ex.3)Lithium ion battery

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Primary battery.

In a primary cell, a chemical reaction proceeds spontaneously and its free energy is converted into electrical energy. The production of electrical energy at the expense of the free energy of the cell is called discharging of the cell, such cells once are run down cannot be used again i.e. The non rechargeable battery is called primary battery or cell and it is discharged only once and then discarded.

The cathode (i.e. the electrode at which reduction occurs) during discharge of primary cells is designated as positive.

The examples of primary cells include the simple voltaic cells, Daniel cell, lechlanche cell, dry cell etc.

The main categories of primary cells are

Carbon-zinc cells (including Lechlanche cell and Zinc chloride cells)

Alkaline cells and

Lithium cells

Advantages :-

Its cost is low.

It is light in weight.

Disadvantage:-1) The chemical reaction in the cell is irreversible.2) Its life is short.

Example Dry cell.

Dry Cell Construction:-

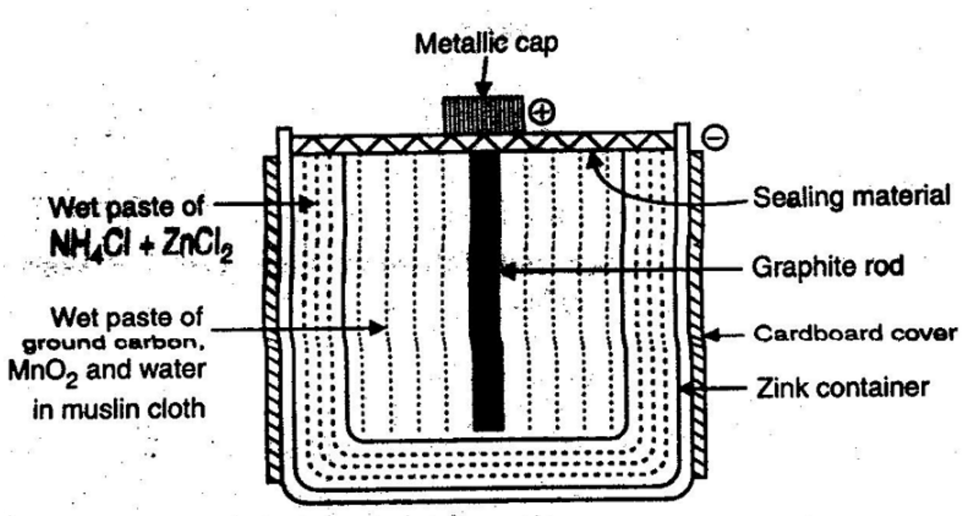


Fig-Dry Cell

(In this diagram show Anode at left side)

((LOAN-Left, Oxidation, Anode ,Negative electrode))

It consists of Zinc container which acts as an anode. It is fitted with paste of NH_4Cl, zinc chloride and water and inert filler such as asbestos or saw dust. This medium acts as salt bridge. Graphite rod is placed in centre which acts as cathode, It is surrounded by mixture of MnO_2 and carbon.

From the top, zinc vessel is sealed with wax. A copper cap is fitted on graphite rod to make the electrical contact.

Working :-

At zinc Anode (Oxidation)

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

The Zn^{2+} ions pass into the paste while electrons flow through the external circuit. They are accepted at the graphite electrode.

At this electrode, MnO_2 is reduced in presence of ammonium ions gives Mn_2O_3

At graphite cathode (Reduction)

$2MnO_2 + 2NH_4^+ + 2e^- \rightarrow Mn_2O_3 + 2NH_3 + H_2O$

Thus net cell reaction is

$Zn + 2MnO_2 + 2NH_4^+ \rightarrow Zn^{2+} + Mn_2O_3 + 2NH_3 + H_20$

The dry cell generates voltage in the range of **1.25 to 1.5 volts.**

There is a side reaction.

$Zn^{2+} + 4\ NH_3 \rightarrow [Zn(NH_3)_4]^{2+}$

Zinc ammonia complex

Application of Dry Cell-

It is used in domestic electrical devices which works on D.C. such as torches, tape recorders, wall clock, toys, flash guns, transistors, electric bells etc.

Secondary battery.

In a secondary cell electrical energy is passed into the cell when a chemical reaction is induced and the products of the reaction remain on the electrodes. These products later react in the backward direction at our choice and liberate free energy in the form of electrical energy. Such cells serve to accumulate the electrical energy in the form of some chemical reaction and later on the reaction is reversed at our will to release the electrical energy. This process is called charging the cell.

Secondary batteries are rechargeable batteries. The positive electrode at which reduction occurs during discharging of secondary cells is called cathode while during charging it is called anode. Secondary batteries are of following categories.

Acid batteries.

Ex. Lead acid accumulate

Alkaline storage batteries.

Ex. Nickel cadmium battery.

Lithium ion batteries.

Advantages:

The chemical reaction in the cell is reversible.

Its life is longer.

Disadvantage:

Its cost is high.

It is heavier.

Example Lead accumulator.

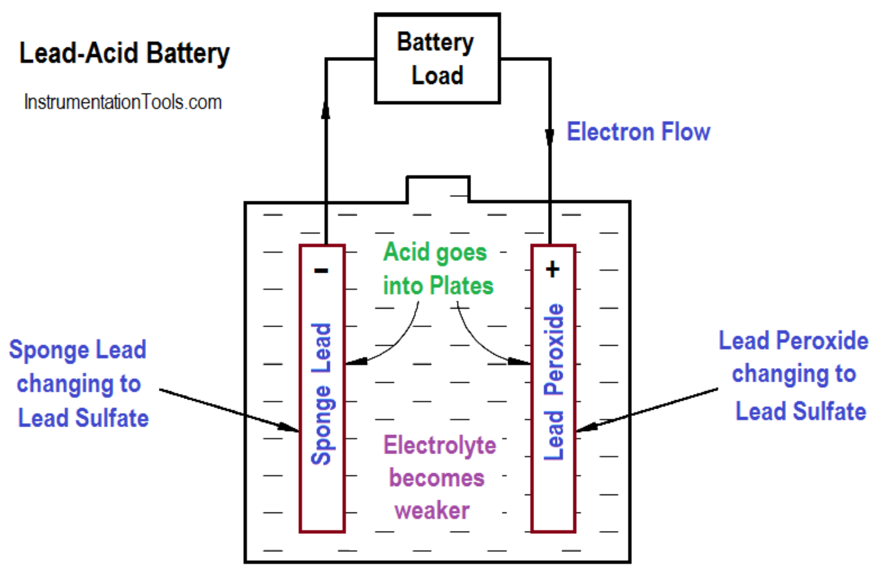
A storage cell is one that can operate both as a voltaic cell (supplied electrical energy) as well as electrolytic cell.

Construction:

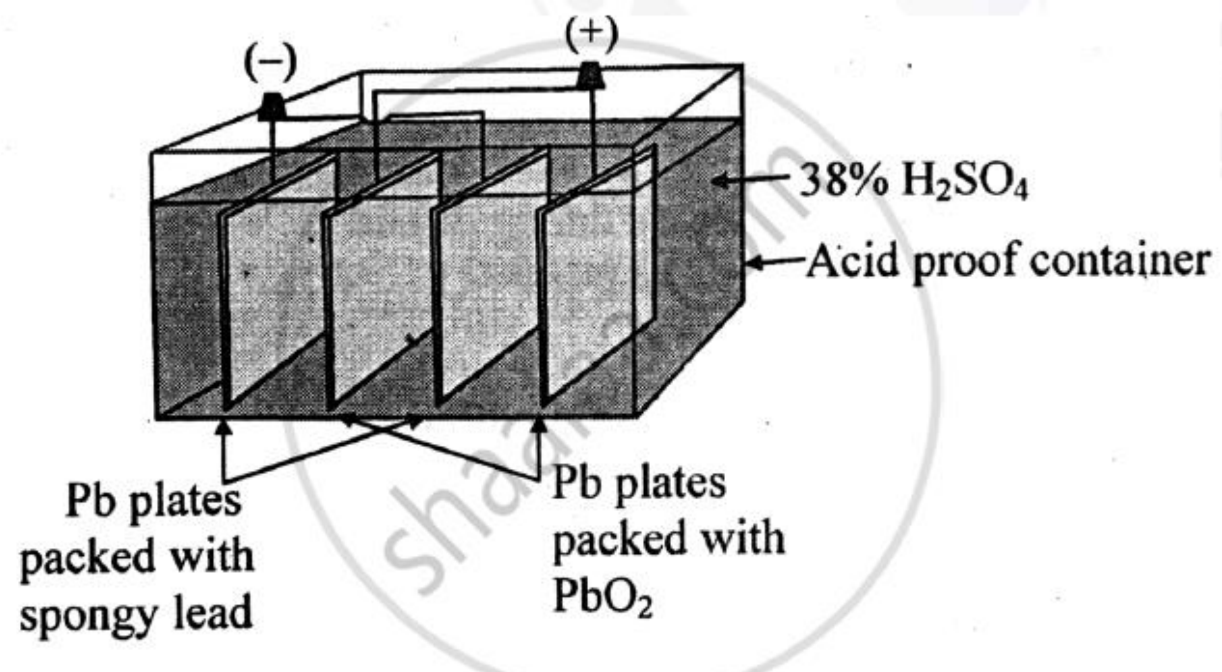
In this cell, anode or –ve electrode consist of lead plate and cathode or +ve electrode consist of lead plate impregnated with lead dioxide PbO2. The electrolyte used in 20 % H_2SO_4 with specific gravity 1.215. The emf of cell equals 2 volts.

A number of lead plates (-ve) are connected in parallel and a number of lead dioxide plates (+ve) are also connected in parallel.

Lead Acid Cell



(In the above diagram write Lead Acid Storage cell instead of battery since single unit is used)



Lead storage battery

(In the diagram instead of 38% H_2SO_4 write 20% to 38% H_2SO_4)

Working :

Dis-charging :- While discharging chemical energy gets converted into electrical energy. (voltaic cell)

At anode :- There is oxidation Lead goes in the solution in the form of Pb2+ ions depositing electrons on lead plate.

$Pb(s) + SO4^{2-} \rightarrow PbSO_4 + 2e^-$ Thus –ve plates are coated by PbSO4.

The electrons released from the anode flows to the dioxide electrode.

At Cathode :- There is reduction. PbO2 is reduced to PbSO4.

$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$

So the net reaction in the lead storage cell is

$Pb(s) + PbO_2(s) + 2H_2SO_4 \rightarrow 2PbSO_4(s) + 2H_2O$

As sulphuric acid is utilized and H2O is formed in the process, concentration of H2SO4 will decrease and specific gravity falls. When the specific gravity of H2SO4 is found to be about 1.17 them battery should be charged.

Charging :- White charging, cell is connected to external source (generator) whose emf is greater than cell (greater than 2 volts). The current flows through cell in opposite direction and cell reaction gets reversed as

At cathode (-ve terminal)

$$PbSO_4 + 2e \longrightarrow Pb + SO_4^{2-}$$

At anode (+ve terminal)

$$PbSO_4 + 2H_2O \rightarrow PbO_2 + 4H^+ + SO_4^{--} + 2e^-$$

Hence the net reaction is

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

Thus H_2SO_4 is regenerated and specific gravity will go on increasing. When it comes to 1.215 cell is said to be charged fully. In the charging process, accumulator acts as a electrolytic cell.

Thus overall cell reaction is as follows

$$Pb + PbO2 + 2H2SO4 \underset{\textbf{Charging}}{\overset{\textbf{Dis-charging}}{\rightleftarrows}} 2\ PbSO4 + 2H2O$$

Applications of Lead accumulator.

1) Used as electric supply in laboratories.

2) Used in automobiles. Here generally 3 to 6 cells are connected in series to give voltage of 6 volts or 12 volts.

3) In telephones and telegraph office.

4) In train lighting system.

5) In the uninterrupted power supplies (UPS).

(((. Why do electrochemical cells stop working after some time?

In electrochemical cell, a chemical reaction proceeds spontaneously and its free energy is converted into electrical energy. The production of electrical energy at expense of the free energy of the cell is called discharging of the cell.

When the reactants are consumed [for ex. In lead accumulator the specific gravity of H_2SO_4 falls i.e. concentration decrease as it is consumed in the discharging process]. During discharging process, the electrochemical cells stops working as in it the reactants are not continuously fed**.)))**

Difference between primary and secondary cell.

Primary cell	**Secondary cell**
In primary cell, net cell reaction can not be reversed on applying higher external emf.	In secondary cell, When the external emf applied to the cell is greater than the cell emf, direction of current through the cell is reversed Also the net cell reaction is reversed.
The energy producing capacity of primary cells is limited	The energy producing capacity of secondary cells is large.
Its cost is low	Its cost is high
It is light in weight	It is heavier
Its life is short	Its life is longer
Such cells are non-rechargeable Example – Dry cell	Such cells are re-chargeable. Example – Lead acid storage cell.
Disposable	Regular maintenance required
Limited to specific applications	Large spectrum of applications.

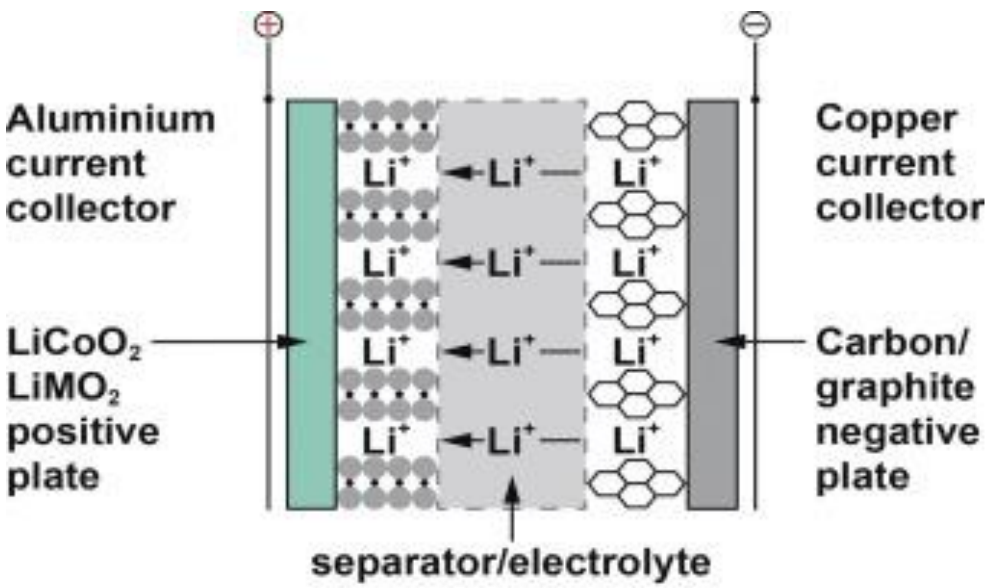
Li-ion batteries

Introduction:

A lithium-ion battery (sometimes Li-ion battery or LIB) is a family of rechargeable battery types in which lithium ions move from the negative electrode to the positive electrode during discharge, and back when charging.

Li-ion batteries use an intercalated lithium compound as the electrode material, compared to the metallic lithium used in the non-rechargeable lithium battery

Construction:



$$Li_xC + Li_{1-x}MO_2 \rightleftharpoons LiMO_2 + C$$

Fig: Li ion Battery

The three primary functional components of a lithium-ion battery are the negative electrode, positive electrode, and the electrolyte.

The negative electrode of a conventional lithium-ion cell is made from carbon (graphite) that can accommodate Li+ in solid state .

The positive electrode is a **metal oxide**, The positive electrode is generally one of three materials: a layered oxide (such as lithium cobalt oxide), a poly-anion (such as lithium iron phosphate), or a spinel (such as lithium manganese oxide).

The electrochemical roles of the electrodes change between anode and cathode, depending on the direction of current flow through the cell.

The electrolyte is a lithium salt in an organic solvent. The electrolyte is typically a mixture of organic carbonates such as ethylene carbonate or diethyl carbonate or propylene carbonate containing complexes of lithium ions.

These non-aqueous electrolytes generally use non-coordinating anion salts such as lithium hexafluorophosphate ($LiPF_6$), lithium hexafluoroarsenate monohydrate (LiAsF6), lithium perchlorate ($LiClO_4$), lithium tetrafluoroborate (LiBF4), and lithium triflate ($LiCF_3SO_3$).

Pure lithium is very reactive. It reacts vigorously with water to form lithium hydroxide and hydrogen gas. Thus, a non-aqueous electrolyte is typically used, and a sealed container rigidly excludes water from the battery pack.

The separators are micro-porous plastic films which may be coated with ceramic particles to enhance the safety of the cells.

Principle:

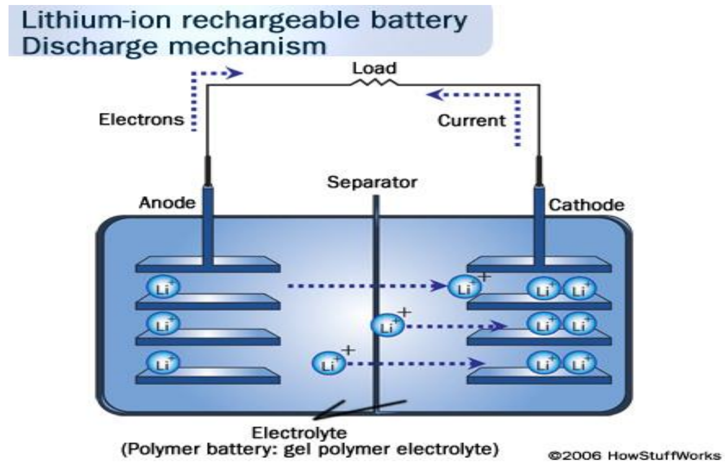
During the charge and discharge processes, lithium ions are inserted or extracted from interstitial space between atomic layers within the active material of the battery. Simply, the Li-ion is transfers between anode and cathode through lithium Electrolyte. Since neither the anode nor the cathode materials essentially change, the operation is safer than that of a Lithium metal battery.

Working

Discharging

During discharge, lithium ions Li+ carry the current from the negative to the positive electrode, through the non-aqueous electrolyte and separator diaphragm.

(i.e During discharging, Li ions are dissociated from the anode(-ve electrode carbon or graphite) and migrate across the electrolyte and are inserted into the crystal structure of the host compound of cathode.)



Anodic reaction

$Li \rightarrow Li^{+} + e^{-}$

$Li_nC \longrightarrow nLi^{+} + ne^{-} + C$

Cathodic reactions

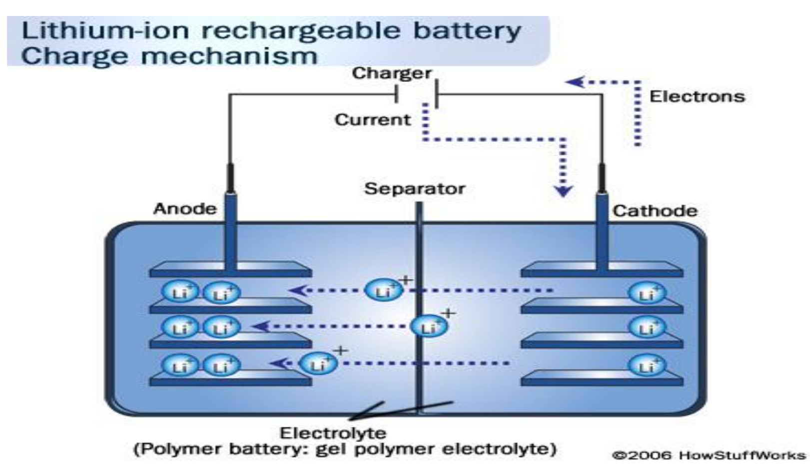
$Li_{1-n}CoO_2 + nLi^{+} + ne^{-} \longrightarrow LiCoO_2$

Net Reaction is

$Li_nC + Li_{1-n}CoO_2 \longrightarrow LiCoO_2 + C$

Li ion batteries have a nominal voltage of 3.7Volts per cell (100% full charge).In series cells can provide any voltage.

Charging

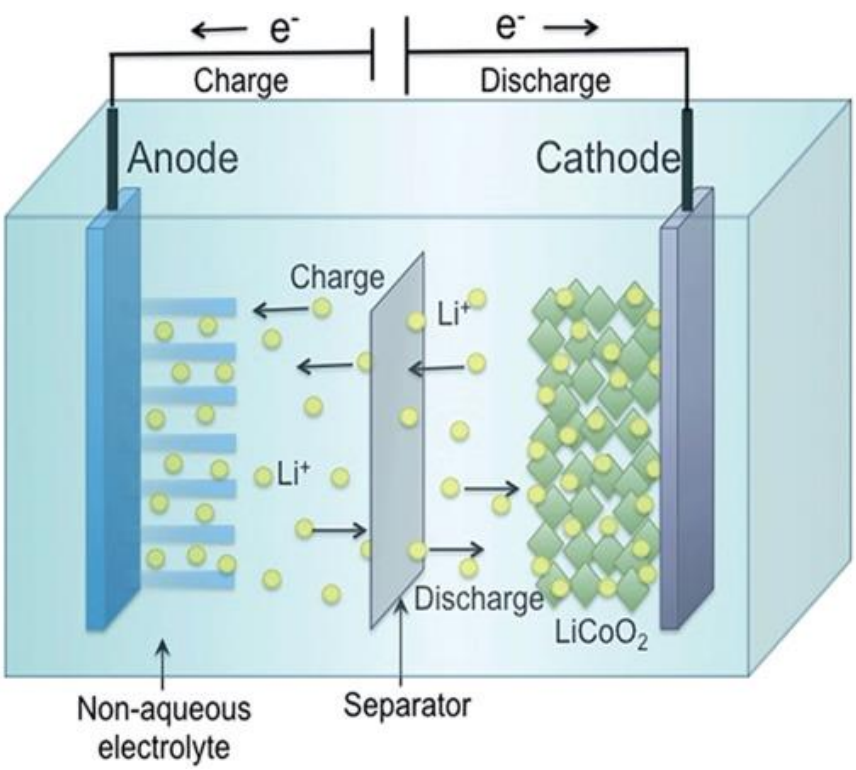


(In the above diagram instead of cathode write +ve electrode and instead of anode write –ve electrode)

During charging, an external electrical power source (the charging circuit) applies an over-voltage (a higher voltage but of the same polarity) than that produced by the battery, forcing the current to pass in the reverse direction. The lithium ions then migrate from the positive to the negative electrode, where they become embedded in the porous electrode material in a process known as intercalation

$$\mathbf{Li_{1-n}\,CoO_2 + Li_nC} \underset{\textbf{Charging}}{\overset{\textbf{Dis-charging}}{\rightleftharpoons}} \mathbf{LiCoO_2 + C}$$

In a lithium-ion battery the lithium ions are transported to and from the cathode or anode, with the transition metal, cobalt (Co), in LiCoO2 being reduced from Co 4+ to Co 3+ during dis-charge and oxidized from Co 3+ to Co 4+ during charging.



(In the above diagram instead of cathode write +ve electrode and instead of anode write –ve electrode)

Advantages

Lithium ion batteries are more expensive than Ni-Cd batteries but operate over a wider temperature range with higher energy densities, while being smaller and lighter. They are fragile and so need a protective circuit to limit peak voltages.

Wide variety of shapes and sizes efficiently fitting the devices they power.

Much lighter than other energy-equivalent secondary batteries.

High open circuit voltage in comparison to aqueous batteries (such as lead acid, nickel-metal hydride and nickel-cadmium). This is beneficial because it increases the amount of power that can be transferred at a lower current.

No memory effect.

Components are environmentally safe as there is no free lithium metal

Disadvantages

Lithium-ion batteries can rupture, ignite, or explode when exposed to high temperature. Short-circuiting a battery will cause the cell to overheat and possibly to catch fire. Adjacent cells may then overheat and fail, possibly causing the entire battery to ignite or rupture. In the event of a fire, the device may emit dense irritating smoke.

Cost: A major lithium ion battery disadvantage is their cost. Typically they are around 40% more costly to manufacture than Nickel cadmium cells.

Applications:

The Li-ion batteries are used in cameras, calculators

They are used in cardiac pacemakers and other implantable device

They are used in telecommunication equipment, instruments, portable radios and TVs, pagers

They are used to operate laptop computers and mobile phones and aerospace application.

Beyond consumer electronics, LIBs are also growing in popularity for military, electric vehicle, and aerospace applications**.**

Fuel cell

These are electrochemical devices in which following reactions takes place.

Fuel + Oxidant $\rightarrow$ Reaction product + Energy

At anode :

Fuel $\rightarrow$ Fuel oxidation products + Ze –

At cathode :

Oxidant + Ze – $\rightarrow$Oxidant reduction products

Definition :-

A fuel cell is an electrochemical cell which can convert the chemical energy contained in a readily available fuel oxidant system into electrical energy by an electrochemical process in which fuel is oxidized at the anode.

The fuel cell consist of an electrolyte and two electrodes. The fuel and the oxidizing agent are continuously and separately supplied to the electrodes of the cell; at which they undergo reactions. These primary cells are capable of supplying current as long as the reactants are supplied.

Example :- Hydrogen oxygen fuel cell

Phosphoric acid fuel cells

Molten carbonate fuel cells

Classification of fuel cell

|---|---|

Acid fuel cells	**Alkaline fuel cells**	**Molten carbonate fuel cells**
(Electrolyte is concentrated Phosphoric acid)	(Electrolyte is KOH/NaOH)	(Eletrolyte is sodium or potassium carbonate)

Fuel systems are distinguished on the basis of the type of electrolyte used.

Example :- Alkaline fuel cell (H_2-O_2 fuel cell)

The alkaline fuel cell (AFC), also known as the Bacon fuel cell after its British inventor, is one of the most developed fuel cell technologies. AFCs consume hydrogen and pure oxygen producing potable water, heat, and electricity. They are among the most efficient fuel cells, having the potential to reach 70%.

Construction of H_2 – O_2 Fuel cell.

The cell consist of two electrodes made of porous graphite or porous nickel impregnated with a catalyst (platinium, silver or a metal oxide) These electrodes are placed in aqueous solution of KOH or NaOH and oxygen and hydrogen are continuously fed into the cell, under a pressure of about 50 atmospheres.

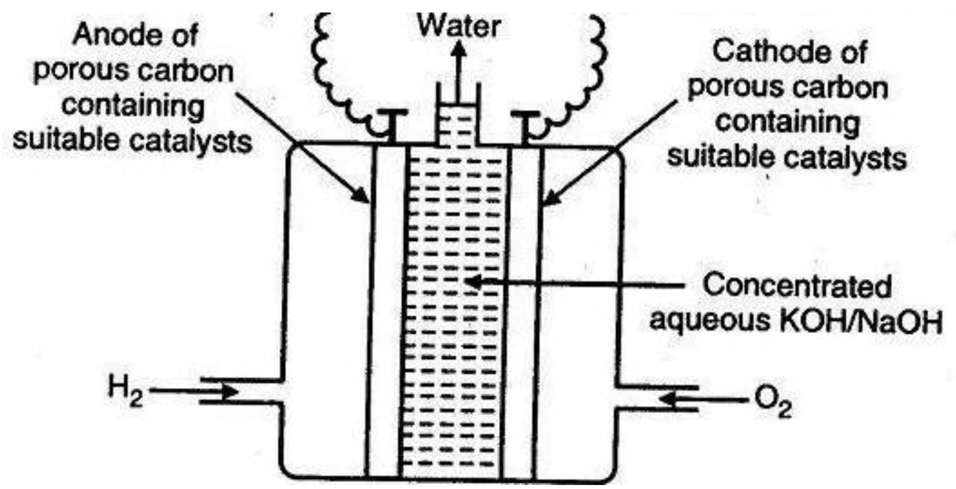


Fig H_2- O_2 Fuel Cell.

Working

Reactions at Anode- Oxidation half cell reaction

Hydrogen is oxidized to H+ ions which are neutralized by the OH- ions of the electrolyte

$2H_2 \longrightarrow 4H^+ + 4e^-$

$4H^+ + 4OH^- \rightarrow 4H_2O$

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

Reactions at Cathode-Reduction half cell reaction

Reduction of oxygen takes place to OH- ions

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

So, net reaction is

$2H_2 + O_2 \dashrightarrow 2H_2O$

The emf of this cell is 1 volt.

.Advantages of H_2-O_2 Fuel cell-

1. Their efficiency is very high.(70-75% which is much higher than the conventional cells.)

2. Can be connected in series to generate higher voltage.

3. Modular and hence parts are exchangeable.

4. No emission of gases and hence pollutants are within permissible limits.

5. Hydrogen oxygen systems produce drinking water of potable quality.

AFCs are the cheapest source of fuel cells to manufacture. The catalyst required for the electrodes can be any of a number of different chemicals that are inexpensive compared to those required for other types of fuel cells

Continuous source of energy-Unlike conventional batteries,energy can be obtained from the fuel cell continuously so long as the supply of fuel is maintained.

Disadvantages / Limitation

1) High initial cost.

2) Large weight and volume of gas fuel storage systems.

3) High cost of pure hydrogen.

4) Lack of infrastructure for distributing hydrogen.

5) Liquification of hydrogen requires 30% of the stored energy.

6) Life times of the cells are not accurately known.

Difference between Fuel cell And battery.

Battery	**Fuel cell**
One or more electrically connected galvanic cells in series is called battery.	A fuel cell is an electrochemical cell which can convert the chemical energy contained in a readily available fuel oxidant system into electrical energy by an electrochemical process in which fuel is oxidized at the anode.
Advantages	Disadvantage
Batteries store the chemical energy for later release of electricity	Fuel cell do not store chemical energy.
Disadvantage	Advantages
More pollution	Less pollution
High maintenance cost	Low maintenance cost
Can not be operated on air	Can be operated on air
Have fixed life span.	Does not have fixed life span

Fuel cells differ from ordinary electrochemical energy producers (batteries) in that the reactant (Fuel + Oxidant) are continuously fed into the electrodes during operation and not before hand. This is the reason why fuel cells can operate continuously for an indefinite period of time while the reactants are supplied and the reaction products removed. Thus the distinctive feature of fuel cell is continuous operation.

But in batteries, a chemical reaction proceeds spontaneously and its free energy is converted into electrical energy. The production of electrical energy at the expense of the free energy of the cell takes place. This is called discharging of cell. (Primary batteries are designed to be discharged only once and then discarded while secondary batteries, can be used like the primary battery, then recharged and used again) In batteries reactants are not continuously fed.

Applications of fuel cell

Backup power: - They are used as a backup power source when the primary power supply is interrupted. Some backup applications include computer systems, manufacturing facilities and homes.

Aircraft, Buses, Vehicles, Rail can run on fuel cell technology.

Example

In September 2015, Aditya Birla Group bought more than 200 fuel cells from Ballard industries to power its telecom towers.

In September 2015, Intelligent Energy announced a deal of € 1.2 billion for the supply of fuel cells to power 27,400 towers in India.

French rail vehicle manufacturer Alstom with the collaboration with Germany and Canada demonstrated a fuel cell based zero carbon emission train named as Coradia iLint.

In march 2018 TATA announced India's first fuel cell powered bus.

The number of fuel cell vehicles like Toyota myriad, Honda FCX clarity, Mercedes Benz F-Cell, Hyundai ix35 FCEV.

A world's first megawatt scale carbonate fuel-cell power plant, built by Toyota and Fuel cell energy to be in operation by 2020 which could generate 2.36 Megawatt of electricity and 1.2 tonnes of hydrogen daily at the port of long beach, California.

As 2020 Olympics is going to held in Tokyo, Japan. The Japan govt. aims to install 35 hydrogen gas stations in the city with aim to have 6000 fuel cells based cars on the roads and increased the quantities of fuel cell based buses in Tokyo.

A number of aircrafts like HY4, Lockheed CL-400 sultan are based on fuel cell technology which emits zero carbon emission.

Lead-Acid vs Lithium-Ion Batteries

1. The Materials Used

Both Lithium-ion and Lead-acid batteries work on the same principle. The primary difference lies in the material used as cathode, anode, and electrolyte. In a lead-acid battery, lead is used as the anode, and lead oxide is used as a cathode. In a lithium-ion battery, carbon is used as the anode, and lithium oxide is used as the cathode. Lead-acid batteries use sulphuric acid as an electrolyte, and li-ion batteries use lithium salt as an electrolyte. While discharging, ions flow from anode to cathode through the electrolyte, and the opposite reaction occurs while charging.

2. Cost

Lead-acid batteries are cheaper and are easier to install when compared to Lithium-ion batteries. The price of a lithium-ion battery is two times higher than a lead-acid battery with the same capacity. However, if you compare the life of the batteries, lithium-ion lasts longer than a lead-acid battery. Hence, lead-acid batteries are cheaper only for short-term applications than lithium-ion batteries.

3. Battery Capacity

Battery capacity is the amount of energy stored in a battery per unit volume. It is a direct indicator of the active material stored inside the battery. Lithium batteries have higher battery capacity when compared to lead-acid batteries.

4. Energy Density or Specific Energy

Energy density is a significant factor in determining the type of battery needed for a specific application. It indicates the relation between battery capacity and the weight of the battery.

Energy Density = (Nominal Battery Voltage (V) x Rated Battery Capacity (Ah)) ÷ Weight of Battery.

Lithium batteries have high specific energy when compared to lead-acid batteries. Hence, Li-ion batteries are used in EV applications.

5. Weight and Size

The energy density and battery capacity value of lithium batteries are high when compared to lead-acid batteries. Therefore, the weight and size of lithium batteries are much lower in comparison to lead-acid batteries with the same capacity.

6. Depth of Discharge (DOD)

Depth of Discharge indicates the maximum energy of a fully charged battery that can be used without recharging. If a battery's Depth of Discharge is 50%, you can use up to 50% of the battery capacity and recharge it. If you have used it more than 50%, the battery's life cycle will get affected. The depth of discharge is 50% for lead-acid batteries, and 80% for lithium batteries, respectively. This means you can use the lithium-ion battery for a longer period without recharging. The modern li-ion battery that is manufactured today is even more efficient, with a DOD of 100%.

7. Durability

The durability of the battery is determined by the time duration it can last. Lead-acid batteries can last up to 2 years if well maintained, i.e. recharging it after 50% of the battery is utilized. If it is fully drained or above 80%, it can sustain only for 350 cycles or one year. Instead, a lithium-ion battery has a warranty period of 10 years and can sustain for 10,000 cycles.

8. Cycle Life

Cycle life is the number of charging and discharging cycles a battery can undergo without compromising its performance. Usually, lithium-ion batteries possess a cycle life of 5000, and complete discharge does not affect the life cycle. Whereas a lead-acid battery lasts for 300 to 500 cycles. The complete discharge of the battery significantly affects its life cycle.

9. Charging Time

Lithium-ion batteries charge much faster than lead-acid batteries. If a lead-acid battery takes eight hours to charge, a lithium-ion battery would probably take less than two hours to charge, provided they both have the same capacity. Li-ion batteries are eight times faster than lead-acid batteries while charging. This is one of the reasons why Lithium-ion batteries are deployed in most EVs.

10. Safety

There are many reasons for failures that can occur in batteries. It is your responsibility to be cautious while using batteries of high voltage. In both lead-acid and lithium-ion batteries, overcharging may lead to an explosion.

The sulfuric acid in the lead-acid battery is highly corrosive, and there is a chance of leakage. If overcharged, hydrogen and oxygen gases may evolve, leading to an explosion. In lithium-ion batteries, there are high chances for thermal runaway. Thermal runaway is the condition that occurs when the heat generated within the battery exceeds the heat dissipated to the surroundings. The thermal runaway also has the potential to trigger a battery explosion. It is the responsibility of the BMS engineer to build robust battery pack systems to reduce the risk of failures. CATL, Panasonic Corporation, Clarios and Bharat Power Solutions are some of the key players in manufacturing batteries. Based on the usage their market is classified into automotive, aerospace, energy storage, solar, military, defence and others. Each sector has a set of guidelines to be followed for the manufacturing of batteries to ensure safety.

To compare the advantages of lead-acid vs a lithium-ion battery, you must first decide on the application. For EV applications and areas that require a long-lasting power supply, a lithium-ion battery would be the ideal option. For power backup applications like UPS for computers and inverters, a lead-acid battery may be the cost-effective option. A BMS engineer with knowledge in battery technology has to perform a lead acid vs lithium-ion battery comparison for each application to choose the right option.

The dependency on batteries is increasing, and the market for batteries is expected to surge up to USD 90 billion by 2025. A course in battery technology will equip you with the necessary skillsets to build a robust battery pack design for EV applications. Skill-Lync can offer you hands-on training in MATLAB and Simulink to kickstart your career as a BMS engineer.

Electrochemical cell	Electrolytic cell
It is a device which converts chemical energy into electrical energy.	It is a device which converts electrical energy into chemical energy.
The redox reaction is spontaneous and is responsible for the production of electrical energy.	The redox reaction is non-spontaneous and electrical energy is supplied to make the reaction to occur.
The two half cells are set up in different containers and are connected through salt bridge or porous partition.	Both the electrodes are placed in the solution or molten electrolyte in the same container.
In electrochemical cell, anode is negative and cathode is positive electrode.	In electrolytic cell, anode is positive and cathode is negative electrode.

The electrons move from anode to cathode in external circuit.	The electrons are supplied by the external battery and enter through cathode and come out through anode.