Module – 1
Electrochemistry and Battery Technology

Course Objectives:

To provide students with knowledge of engineering chemistry for building technical competence in industries, research and development in the field of Electrochemical and Battery technology.

Course Outcome:

On completion of this module, students will have knowledge in Electrochemical and concentration cells. Classical and Modern batteries and fuel cells.

Introduction:

Electrochemistry is the branch of chemistry, which deals with the inte action of matter and electrical energy i.e., producing electrical energy from chemic l e ction (spontaneous process) or bringing out chemical reactions by applying electric l energy (non spontaneous process). A device used for producing an electrical cu ent f om chemic l reaction (redox reaction) is called an electrochemical cell. It gives the elationship between electrical, chemical phenomenon and the laws of interaction of this phenomenon. The laws of electrochemistry form the basis of electrolysis and electro synthesis.

Single electrode potential:

It is defined as the potential developed when an electrode is in contact with a solution of its own ions. It is denoted as **E.**

Standard Electrode potential:

It is defined as the potential developed when an electrode is in contact with a solution of 1M concentration, at 298 K and 1 atm pressure. It is denoted as **E^o.**

Nernst equation:

Nernst derived an equation to establish relationship between electrode potential and concentration of metal ion.
Due to the power output from an electrochemical cell, the free energy decreases i.e.

$$-\Delta G = nFE \quad \text{(or)} \quad \Delta G = -nFE$$

Under standard conditions the free energy G is given by the equation

$$\Delta G^\circ = -nFE^\circ$$

E° is a constant called standard electrode potential.
Consider a reduction reaction:

$$M^{n+} + ne^- \rightleftharpoons M$$

For spontaneous reaction, the change in the free energy depends on the concentration of reacting species.

$$\Delta G = \Delta G^\circ + RT \ln K_c$$

$$\text{Where } K_c = \frac{[\text{Products}]}{[\text{Reactants}]}$$

Substituting the value of Kc in above equation, we get

$$\Delta G = \Delta G^\circ + RT \ln \frac{[\text{Product}]}{[\text{Reactant}]}$$

$$\Delta G = \Delta G^\circ + RT \ln \frac{[M]}{[M^{n+}]}$$

Substitute for G and G° in above equation

$$-nFE = -nFE^0 + RT \ln \frac{[M]}{[M^{n+}]}$$

Under standard conditions [M] = 1

$$-nFE = -nFE^0 + RT \ln \frac{1}{[M^{n+}]}$$

Dividing eq (5) by –nF we get

$$E = E^\circ - \frac{RT\ln}{nF} [1/M^{n+}]$$

Converting ln to log we get

$$E = E^\circ - \frac{2.303RT}{nF} \log [1/M^{n+}]$$

Substituting for R = 8.314, T = 298K and F = 96500 in eqn (6) we get

$$\boxed{E = E^0 - \frac{0.0591}{n} \log \frac{1}{[M^{n+}]}} \quad \textbf{or} \quad \boxed{E = E^0 + \frac{0.0591}{n} \log [M^{n+}]}$$

In general Nernst equation is,

$$E = E^\circ \quad \frac{0.0591}{n} \log \frac{[Product]}{[Reactant]}$$

<u>Reference electrode</u>

Reference electrode is that whose potentials is known and used for determination of potential of other electrodes.

Note: Types of reference electrodes:

<u>Beyond syllabus:</u>

<u>Primary reference electrode:</u>

Whose potential is fixed as zero at all temperature and pressure. Example: Standard hydrogen electrode (SHE).

<u>Secondary reference electrode:</u>

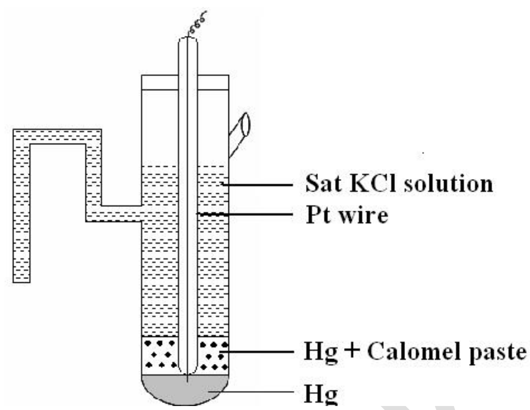
Whose potential is known in connected with SHE. Secondary reference electrodes have several advantages over SHE. These electrodes are commonly used for determining the electrode potentials of other metals. The two commonly used secondary reference electrodes are *calomel electrode and silver-silver electrode.*

<u>Calomel Electrode:</u>

Construction:

Calomel electrode consists of long glass tube with two side tubes. One at the top to fill sat KCl solution and the other side tube is connected to the salt bridge. Mercury is placed at the bottom which is covered with a layer of Hg and Hg_2Cl_2 (calomel) paste. The remaining portion is filled with saturated KCl solution. A platinum wire is dipped into the mercury and is used to provides external electrical contact. The calomel electrode is represented as,

$Cl^- / Hg_2Cl_2 / Hg$



Working:

Calomel electrode behaves as anode or cathode depending upon the nature of other electrode.

The half-cell reaction when it acts as an anode s

$$2Hg + 2Cl^- \longrightarrow Hg_2Cl_2 + 2e^-$$

The half cell reaction when it acts as a cathode s

$$Hg_2Cl_2 + 2e^- \longrightarrow 2Hg + 2Cl^-$$

The electrode reaction is,

$$Hg_2Cl_2 + 2e^- \longleftrightarrow 2Hg + 2Cl^-$$

Applying Nernst equation,

$$E = E^{\circ} - \frac{0.0591}{n} \log \frac{[Product]}{[Reactant]}$$

$$E = E^{o} - \frac{0.0591}{n} \log \frac{[Hg]^2[Cl^-]^2}{[Hg_2Cl_2]}$$

$$E = E^{o} - \frac{0.0591}{2} \log [Cl^-]$$

The calomel electrode potential is depends on the concentration of chloride ions in KCl. If the concentration of chloride ions increases, the potential decreases and vice versa. (The potential of calomel is inversely proportional to the concentration of chloride ions)

The potential of calomel electrode is measured with respect to SHE and it depends on concentration of KCl solution used.

Conc. KCl	0.1N	1N	Saturated KCl
Potential (V)	0.334V	0.281V	0.242V

Applications:

- Used to determine the potential of the other electrodes.

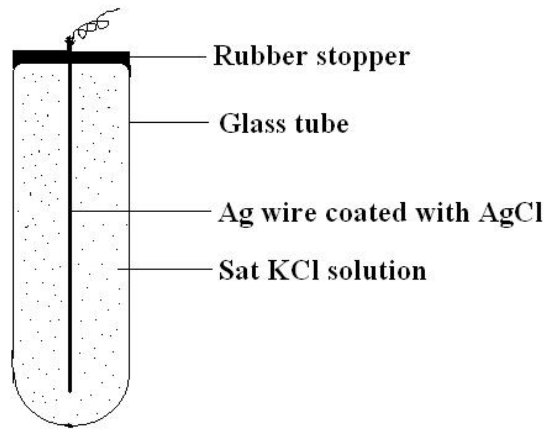
- It is commonly used as reference electrode in all potentiometric determinations.
- Electrode potential is reproducible.

Silver - Silver Chloride Electrode:

Construction:

It consists of a long glass tube in which saturated KCl solution is filled. A silver wire is coated with AgCl by electrolytic process and placed inside the tube and which provides external electrical contact. The electrode is represented as,

$Cl^-/AgCl/Ag$



Working:

The electrode behaves as anode or cathode depending upon the nature of other electrode. The half-cell reaction when it acts as an anode s

$$Ag + Cl^- \longrightarrow AgCl + e^-$$

The half-cell reaction when it acts as a cathode is

$$AgCl + e^- \longrightarrow Ag + Cl^-$$

The electrode reaction is

$$AgCl + e^- \rightleftharpoons Ag + Cl^-$$

Applying Nernst equation to the above equation,

$$E^\circ_{cell} - \frac{0.0591}{n} \log \frac{(product)}{(reactant)}$$

$$E_{cell} = E^\circ_{Cell} - \frac{0.0591}{1} log \frac{[Ag][Cl^-]}{[AgCl]}$$

$$E_{cell} = E^\circ_{Cell} - \frac{0.0591}{1} \log [Cl^-]$$

he Ag – AgCl electrode potential is depends on the concentration of chloride ions in KCl. If the concentration of chloride ions increases, the potential decreases and vice versa. (the potential of Ag – AgCl is inversely proportional to the concentration of chloride ions)

The potential of Ag - AgCl electrode is measured with respect to SHE and it depends on concentration of KCl solution used.

Conc. KCl	0.1N	1N	Saturated KCl
Potential (V)	0.29V	0.22V	0.199V

Applications:

1. As a secondary reference electrode in ion selective electrodes.
2. In determining whether the potential distribution is uniform or not in ship hulls and old pipelines protected by cathodic protection.

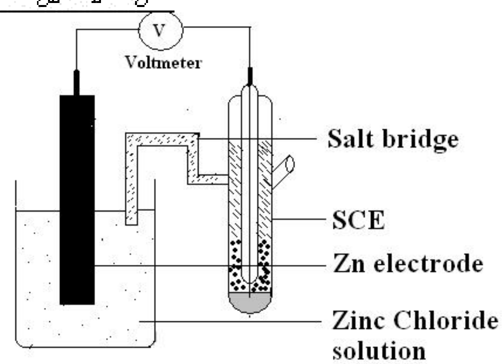
Measurement of standard electrode potential using calomel electrode:

The electrode potential of unknown electrode is measured by connecting to a saturated calomel electrode through salt bridge. (The potential of saturated calomel electrode is fixed to 0.24V for sat KCl solution).

Ex: Zinc electrode coupled with saturated calomel electrode.

To measure the standard electrode potential of Zn, Zn electrode is dipped in Zinc chloride solution and coupled with saturated calomel electrode through voltmeter. Zinc electrode acts as anode and SCE acts as cathode. The emf of the cell is measured through voltmeter. Representation of the cell is

$Zn / Zn^{2+} // Hg_2Cl_2/Hg$



The two half-cell reactions are:

At anode, oxidation occurs, $Zn \longrightarrow Zn^{2+} + 2e^-$ (oxidation)

At cathode, reduction occurs, $Hg_2Cl_2 + 2e \longrightarrow 2Hg + 2Cl^-$

The standard electrode potential is calculated by substituting the potential values in the relation

$$E_{cell} = E_{SCE} - E_{Zn/Zn^{2+}}$$

$$E_{Zn/Zn^{2+}} = E_{SCE} - E_{cell}$$

$$= 0.24 - 1.0$$

$$E_{Zn/Zn^{2+}} = -0.76V$$

Ion-selective electrodes

The electrode, which responds to a specific ion in a mixture by ignoring other ion is known as ion selective electrode. It consists of a thin membrane in contact with ion solution.

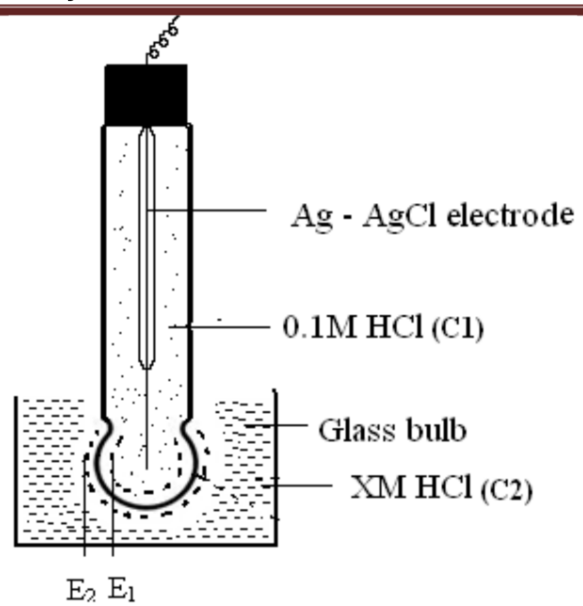
Glass Electrode:

his electrode works on the principle that when a thin, low resistivity glass membrane is in contact with a solution containing H^+ ions, a potential develops across the membrane and the solution. Potential developed depends on the concentration of hydrogen ions in the solution.

Cell representation: Ag / AgCl / HCl (0.1M) / Glass/ unknown solution

Construction:

It consist of a long glass tube with a thin walled glass bulb contains 0.1 M HCl [C_1]. Ag/AgCl electrode placed in to the solution to provide electrical contact. The glass electrode is dipped in unknown solution of concentration C_2, the potential developed across the membrane by the exchange of ions with the composition of glass is known as the boundary potential E_b (E_1 & E_2). Even when $C_1=C_2$ a small potential is developed across the membrane is called as *asymmetric potential.*



Working:

E_1 & E_2 is the potential developed at inner and outer memb ane espectively The boundary potential is,

$$E_b = E_2 - E_1$$

$$E_b = \frac{0.0591}{n} \log \frac{[C2]}{[C1]}$$

$$E = \frac{0.0591}{n} \log[C2] + \frac{0.0591}{n} \log[\frac{1}{C1}]$$

$$Where \ \frac{0.0591}{n} \log[1/C_1] = L \ (constant)$$

$$E_b = L + \frac{0.0591}{n} \log[C_2]$$

Where n = 1

$$E_b = L + 0.0591 \log[C_2]$$

where $C_2 = [H^+]$ ions in outer membrane then,

$$E_b = L + 0.0591 \log [H^+]$$

$$E_b = L - 0.0591 \, pH \qquad (pH = -\log [H^+])$$

The glass electrode potential is ,

$$E_G = E_b + E_{Ag/AgCl} + E_{asy}$$

Substitute the value of E_b

$$E_G = L - 0.0591pH + E_{Ag/AgCl} + E_{asy}$$

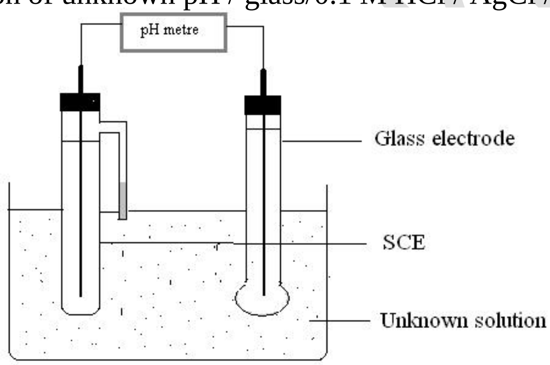
Where $L + E_{Ag/AgCl} + E_{asy} = L_1$ (constant)

$$\boxed{E_G = L_1 - 0.0591pH}$$

Determination of pH of a Solution using Glass Electrode

The potential of a glass electrode depends on the concentr tion of H^+ ions. Hence, pH of a solution can be determined by using glass electrode and c lomel electrode ssembly. The cell assembly is represented as

$Hg/Hg_2Cl_2/Cl^-$ // solution of unknown pH / glass/0.1 M HCl / AgCl / Ag



The emf of a cell is determined by using voltmeter.

E_{cell} is the difference b/w glass electrode potential E_G and the calomel electrode potential E_{SCE}

$$E_{cell} = E_G - E_{SCE}$$

$$= L_1 - 0.0591pH - E_{SCE}$$

$$pH = \frac{L_1 - E_{SCE} - E_{cell}}{0.0591} \quad [K = L_1 - E_{SCE}]$$

$$\boxed{pH = \frac{K - E_{cell}}{0.0591}}$$

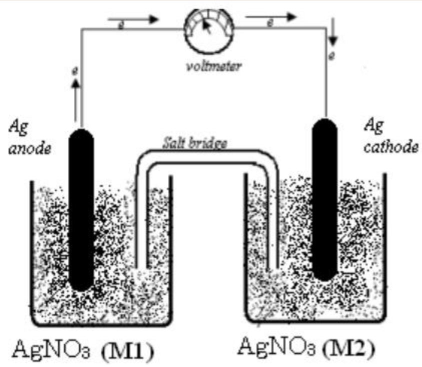
Electrolyte Concentration Cells :

It is galvanic cell, which consists of two identical electrodes which are in contact with the same solution of electrolyte at different concentrations. Example:

Consider two silver electrodes that are in contact with the $AgNO_3$ solution of different concentrations (M_1 and M_2) connected through voltmeter. The electrolytes are connected through salt bridge.

The cell representation Ag/ $AgNO_3$ (M1)// $AgNO_3$ (M2)/Ag

Where M_1 and M_2 are the molar concentration of the Ag^+ ions in the two half-cells.



Electrode reaction:

At anode: $Ag \longrightarrow Ag^{+}(M1) + e^{-}$

At cathode: $Ag^{+}(M2) + e^{-} \longrightarrow Ag$

Net cell reaction: $Ag^{+}(M2) \longleftrightarrow Ag^{+}(M1)$

The current produced in the cell due to mig ation of ions f om higher concentration to lower concentration. This takes place until the concent tion in the two H lf -cells become equal(M1=M2) hence the production of current becomes ze o. Apply Nernst equation for the cell reaction,

$$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{n}\log\frac{(product)}{(reactant)}$$

$$E_{cell} = E^{\circ}_{C} - E^{\circ}_{A} - \frac{0.0591}{n}\log\frac{(M1)}{(M2)}$$

E°_{C} & E°_{A} are of same metal so cancelled each other

$$E_{cell} = -\frac{0.0591}{n}\log\frac{(M1)}{(M2)} \quad (or) \quad E_{cell} = \frac{0.0591}{n}\log\frac{(M2)}{(M1)}$$

Battery Technology

Introduction

A battery is a portable energy source with three basic components-an anode (the negative part), an cathode (the positive part), and an electrolyte. As current is drawn from the battery, electrons start to flow from the anode through the electrolyte, to the cathode. A device enables the energy liberated in a chemical reaction to be converted directly into electricity. The term battery originally implied a group of cells in a series or parallel arrangement, but now it is either a single cell or group of cells. Examples: It ranges from small button cells used in electric watches, lead acid batteries used for starting, lighting and ignition in vehicles with internal combustion engines. The batteries are of great importance based on the ability of some electrochemical systems to store electrical energy supplied by the external source. Such batteries may be used for emergency power supplies, for driving electric vehicles, etc. For the commercial exploitation, it is important that a battery should provide a higher energy, power density along with long shelf life, low cost and compatible rechargeable units.

Classification of Batteries:

Batteries are classified as primary (non-rechargeable), secondary (rechargeable) and reserve (inactive until activated):

Primary battery:

The batteries, which produce electrical energy at the expense of free energy of active materials and produce energy only as long as active materials are present. These are not rechargeable batteries and are to be discarded after the use. These batteries are called as primary battery.

Example: Dry cell. Zn-MnO_2

Secondary battery:

The rechargeable batteries that produce electrical energy at the expense of free energy of active materials. These active materials are capable of restoring at respective electrodes on recharge and prepare for discharge once again. Such batteries are called seconda batte .

Example: Lead acid battery, NiMH battery, Ni-Cd battery

Reserve battery:

The high current batteries in which active materials re isol ted f om elect olyte due to their reactivity and are brought into contact whenever high potenti l is required for application are called reserve battery.

Example: Magnesium-water activated batteries, zinc-silver oxide b tte ies, etc.

Characteristics of a battery:

Cell potential / Voltage:

The cell potential or voltage of the attery is determined theoretically,

$E_{cell} = (E_C - E_A) - \eta_A - \eta_C - iR_{cell}$

Where E_C & E_A are reduction potent al of cathode and anode, η_A & η_C are over potential at the anode and cathode and iR_{cell} is the nternal res stance.

To attain the maximum cell potent al or voltage from the battery, difference in the standard electrode potential must be high, the electrode reaction must be fast to minimize the over potential and internal resistance must be low.

Current:

"Is measure of the rate of flow of charges in a battery".

To attain the maximum current from the battery, difference in the standard electrode potential must be high, the electrode reaction must be fast to minimize the over potential and internal resistance must be low.

Capacity:

"*The total amount of charge stored in a battery in Ampere hours.*"

he theoretical capacity may be calculated using faradays relation, C = WnF/M, where W and M is weight and mass of the active material respectively and n is the number of moles of the electro active material.

Electricity storage density:

"Amount of electrical energy stored per unit weight of the battery."

Energy efficiency:

The ratio of output energy to the input energy. Higher the efficiency, very good is the battery.

% Energy efficiency=<u>Energy released during discharge</u> x
100 Energy required during recharge

Cycle life:

"The total number of discharge and recharge cycles that are possible before the failure of the battery". It is applicable only to secondary battery, higher the cycle life, better is the battery.

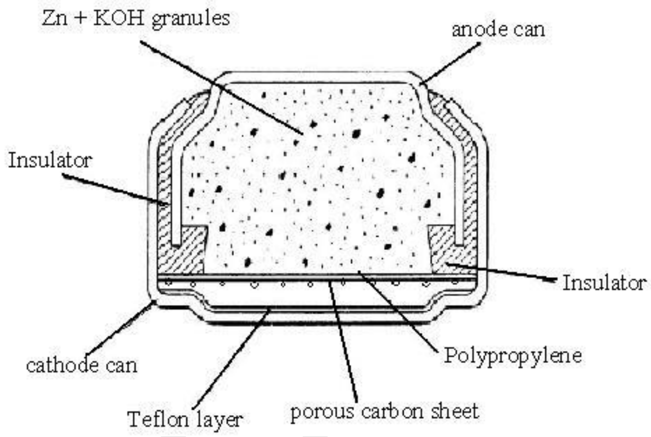
Shelf-life:

"The duration of storage of a battery without self discharge is known as shelf life of a battery". It referred to storage duration of battery. If shelf life is high, better is the battery.

Zinc-air battery

Reactive species at anode: Granulated Zn
Reactive species at cathode: pure oxygen from air
Electrolyte: KOH
Separator: polypropylene
Voltage: 1.45V

The **zinc-air,** electrochemical system can form lly defined s **zinc/potassium hydroxide/oxygen** battery but commonly known as "zinc-ai " cell.



Construction:

It consists of nickel-plated steel cans acting as anode and cathode..

1. The anodic can contain the zinc powder and electrolyte in the form of granules with a gelling agent.
2. The cathode active material is carbon sheet impregnated with MnO_2 (to increase the conductivity of cathode) with multiple air holes punched at the bottom to provide air access to the cathode. The sheet is laminated with Teflon layer (to diffuse the oxygen faster to cathode side) on one side.
3. he anodic and cathodic compartments are separated by polypropylene
4. he alkaline electrolyte is potassium hydroxide.
5. he output voltage is 1.45 Volts.

Working:

When the battery discharge, the following reactions takes place at respective electrodes.

Reactions:

At anode: $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

At cathode: $\frac{1}{2} O_2 + H_2O + 2e^- \rightarrow 2OH^-$

Net cell reaction $Zn + \frac{1}{2} O_2 \rightarrow ZnO$

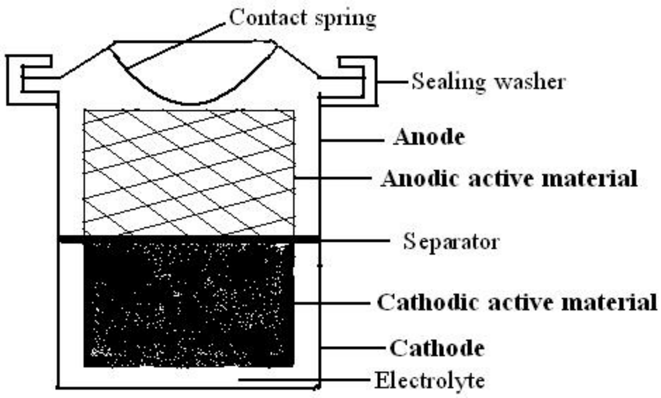
Application:

- Used in hearing aids,

- In telecommunication devices such as pagers and wireless headsets
- In medical devices such as patient monitors, recorders, nerve & muscle stimulators and drug infusion pumps.

Nickel-metal hydride battery (Ni-MH)

Anodic active material: MH
Cathodic active material: NiO (OH)
Electrolyte: 6M KOH
Separator: polypropylene
Voltage: 1.35V



Construction:

1. In a Ni-MH cell, a hydrogen in the form of metal hydride (VH_2) acts as anodic active material and nickel oxy hydroxide as cathod c act ve mater al.
2. Both the anodic and cathodic compartments are made of Nickel grids and filled with its respective active materials.
3. The electrolyte used is potassium hydroxide solution.
4. Polypropylene used as a separator that separates the two electrodes and behaves as a medium for absorbing the electrolyte.
5. The output voltage is 1.35V.

Working:

When battery is discharging/charging, the following reactions takes place at respective electrodes.

Reactions:

At anode: $MH + OH^- \underset{C}{\overset{D}{\rightleftharpoons}} M + H_2O + e^-$

At cathode: $NiO(OH) + H_2O + e^- \underset{C}{\overset{D}{\rightleftharpoons}} Ni(OH)_2 + OH^-$

Cell reaction: $NiO(OH) + MH \underset{C}{\overset{D}{\rightleftharpoons}} Ni(OH)_2 + M$

Applications:

- Used in Cellular phones and laptops
- In Emergency lights and Power tools
- In electric vehicles

Lithium battery*:*

Lithium is the lightest of metals and it can float on water. The electrochemical properties of lithium are excellent and it is a highly reactive material. These properties give Lithium the potential to achieve very high energy and power densities in high-density battery applications such as automotive and standby power. Lithium batteries are primary batteries in which lithium metal (or) lithium compound acts as a Anode. A lithium cell can produce voltage from 1.5 V to about 3 V based on the types of materials used.

There are two types of lithium-based batteries available.

1. Lithium batteries
2. Lithium-ion batteries

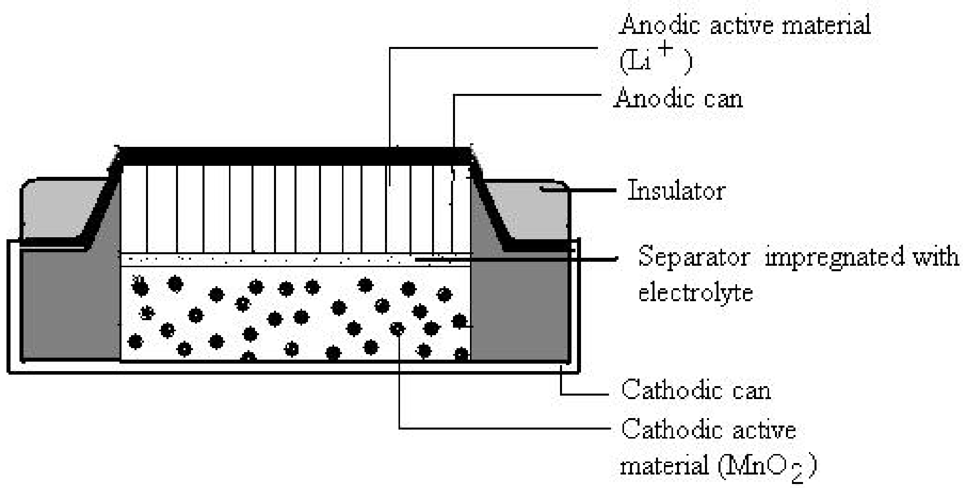
In lithium batteries, a pure lithium metallic element is used as anode. These t pes of batteries are not rechargeable.

In lithium-ion batteries, lithium compounds are used as anode. These batte ies a e known as re-chargeable batteries. Therefore, Lithium ion batteries are conside ed as best than pure Lithium based batteries.

By comparison, lithium-ion batteries are rechargeable b tteries in which lithium ions move between the anode and the cathode, using an inte calated lithium compound s the electrode material instead of the metallic lithium used in lithium batte ies.

$LiMnO_2$ battery

Anodic active material: Lithium
Cathodic active material: MnO_2
Electrolyte: Lithium halide (LiCl, L Br, L ClO_4 and $LiAlCl_4$)
Separator: polypropylene
Voltage: 3.0



Construction:

1. Lithium Manganese Dioxide cell, is a primary battery. Anodic active material is Lithium metal (in the form of disc) and cathode is manganese dioxide (in the form of a pellet).
2. The electrolyte is lithium halide dissolved in organic solvent.
3. Separator is polypropylene impregnated with the electrolyte. It provides an electrical contact between the two electrodes.
4. The output voltage is 3.0V.

Working:

When battery is discharging, the following reactions take place at respective electrodes.

Reactions:

At anode: $Li \rightarrow Li^+ + e^-$

At cathode: $MnO_2 + Li^+ + e^- \rightarrow LiMnO_2$

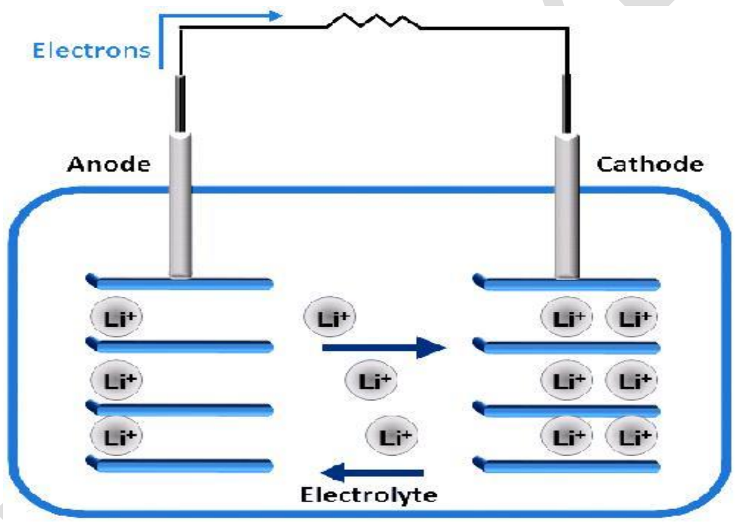
Net cell reaction: $Li + MnO_2 \rightarrow LiMnO_2$

Application:

- Outdoor use (requiring a low temperature range)
- In high-discharge devices, which include digital cameras, electric watches, hearing aids, walkie-talkies, portable televisions, handheld video games, etc

Lithium-ion battery:

Anodic active material: Li^+ / graphite
Cathodic active material: $LiCoO_2$
Electrolyte: Lithium salt
Separator: polypropylene
Voltage: 3.6V



Construction:

1. In lithium-ion battery (Li-ion battery or LIB), the lithium ions (electrons) move from the negative electrode (anode) to the positive electrode (cathode) during discharge and back when charging.

2. Anode is made of carbon material with a high energy density and large doping capacity of lithium ion. Cathodes are metal oxide material containing lithium with capable of dedoping lithium ion during charging and undergo lithium doping during discharging.

3. Electrolyte is made of lithium salts in an organic solvent ($LiPF_6$, $LiBF_4$ or $LiClO_4$ in an organic solvent, such as ether,). Lithium ion migrates between the two electrolytes via an organic solvent.

4. Separator used is polypropylene.

5. The output voltage of this battery is 3.6V.

Working:

During charging lithium ion in cathodic side (positive electrode) is migrated and move towards anodic side (negative electrode) and during charging lithium ions move from anode to cathode.

Reactions:

At cathode: $LiCoO_2 \underset{D}{\overset{C}{\rightleftharpoons}} Li_{(1-x)}CoO2 + xLi^+ + xe^-$

At anode: $xLi^+ + xe^- + xC \underset{D}{\overset{C}{\rightleftharpoons}} xLiC$

Net cell reaction $LiCoO_2 + xC \underset{D}{\overset{C}{\rightleftharpoons}} Li_{(1-x)}CoO2 + xLiC$

Application:

- The Li-ion batteries are used in mobile phones, cameras, calculato s, LCD TVs, pagers, to operate laptop computers and aerospace application

FUEL CELLS

Fuel cell is a device, which converts chemical ene gy of the fuel, and oxidant into electrical energy.Electrical energy is obtained by the combustion of fuels in these galvanic cells. Here, the fuels are supplied from outside and do not form integral part of the cell. These do not store energy. Electrical energy can be obtained continuously as long as the fuels are supplied and the products are removed simultaneously. In these aspects, fuel cells differ from conventional electrochemical cells.

"Fuel cells are galvanic cells which converts chemical energy of the fuels into electrical energy through catalyzed redox reactions w th el m nat on of minimum harmful biproducts". Fuel is represented as

Fuel / electrode / electrolyte / electrode / oxidant

At anode, fuel undergoes oxidation, when battery discharge potential, the following reactions takes place at respective electrodes.

Fuel $\longrightarrow$ oxidized product + ne

At cathode, oxidant is reduced, oxidant + ne $\longrightarrow$ reduced product

Limitation of Fuel cell

1. Power output is moderate.
2. Fuels are to be stored in tanks under very high pressure in tanks.
3. he refueling and the starting time of fuel cell vehicles are longer and the driving range is shorter than in a "normal" car.
4. It generates only DC and should be converted to AC.

Advantages of fuel cells:

1. Do not pollute the atmosphere
2. Electrical energy can be obtained continuously.
3. Fuel cell provides high quality of DC power.
4. Fuel cells have a higher efficiency than diesel or gas engines.

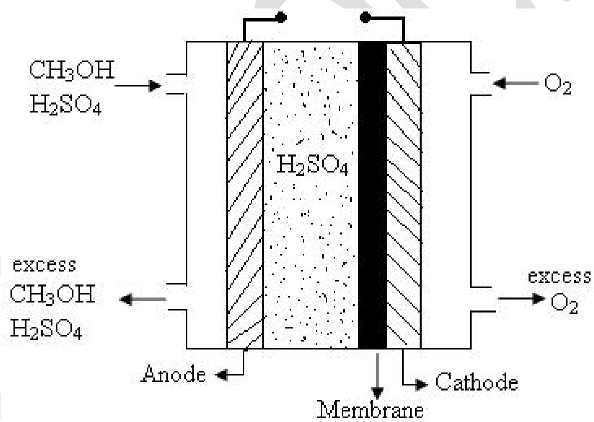
Difference between conventional cell and fuel cell

S. No	Conventional battery	Fuel cells

1	Battery makes electricity from the energy it has stored inside the battery	Fuel cell makes its electricity from fuel in an external fuel tank
2	Battery may run dead	Fuel cell will make electricity as long as fuel is supplied
3	Store chemical energy	Do not store chemical energy
4	Reactants are not supplied and the products are not removed	Reactants are supplied continuously and the products are removed simultaneously
5	Construction cost is high	Construction cost is low
6	Life time is less	Life time is higher than batter
7	Battery produce electricity depends on concentration of the electrolyte	fuel cell will produce elect icity as long as it has a fuel supply
8	Recharge of the cell is required.	Recharge of the fuel cell is not required.

Methanol – oxygen fuel cell

Fuel: CH_3OH
Oxidant: Oxygen
Electrolyte: H_2SO_4
Voltage: 1.2V



Construction:

1. It consists of anodic and cathodic compartments. Both the compartments contain platinum electrode.
2. Methanol containing H_2SO_4 is passed through anodic compartment. Oxygen is passed through cathodic compartment.
3. Electrolyte used is of sulphuric acid.
4. A membrane made of cellulose is provided which prevents the diffusion of methanol into the cathode.
5. The output voltage is 1.2V.

Working:

Reactions:

At anode: $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$

At cathode: $3/2O_2 + 6H^+ + 6e \rightarrow 3H_2O$

Net cell reaction $CH_3OH + 3/2O_2 \rightarrow CO_2 + 2H_2O$

Application:

- Used in military applications
- Large-scale power productions.

Note:

1. *KOH is not used as electrolyte as it reacts with CO_2 and gets conve ted into ca bonate. Thus, conductivity of the electrolyte decreases as well as the efficiency.*
2. *The advantage of acid electrolyte is that the CO_2, a product of the e ction can be easily removed.*

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