Fundamental concepts

Introduction

The Overall Reaction

- Both an oxidation and a reduction must occur in a redox reaction
- The oxidizing agent accepts electrons from the reducing agent

$$Cu^{2+}(aq) + Fe(s) \leftrightarrow Cu(s) + Fe^{2+}(aq)$$

Redox reaction

Reduction
- **occur at cathode**
- **gain of electrons**
- **loss of oxygen**

Oxidation
- **Occur at anode**
- **loss of electrons**
- **gain of oxygen**

Cell

It is a device which helps to convert chemical energy into electrical energy and vice versa.

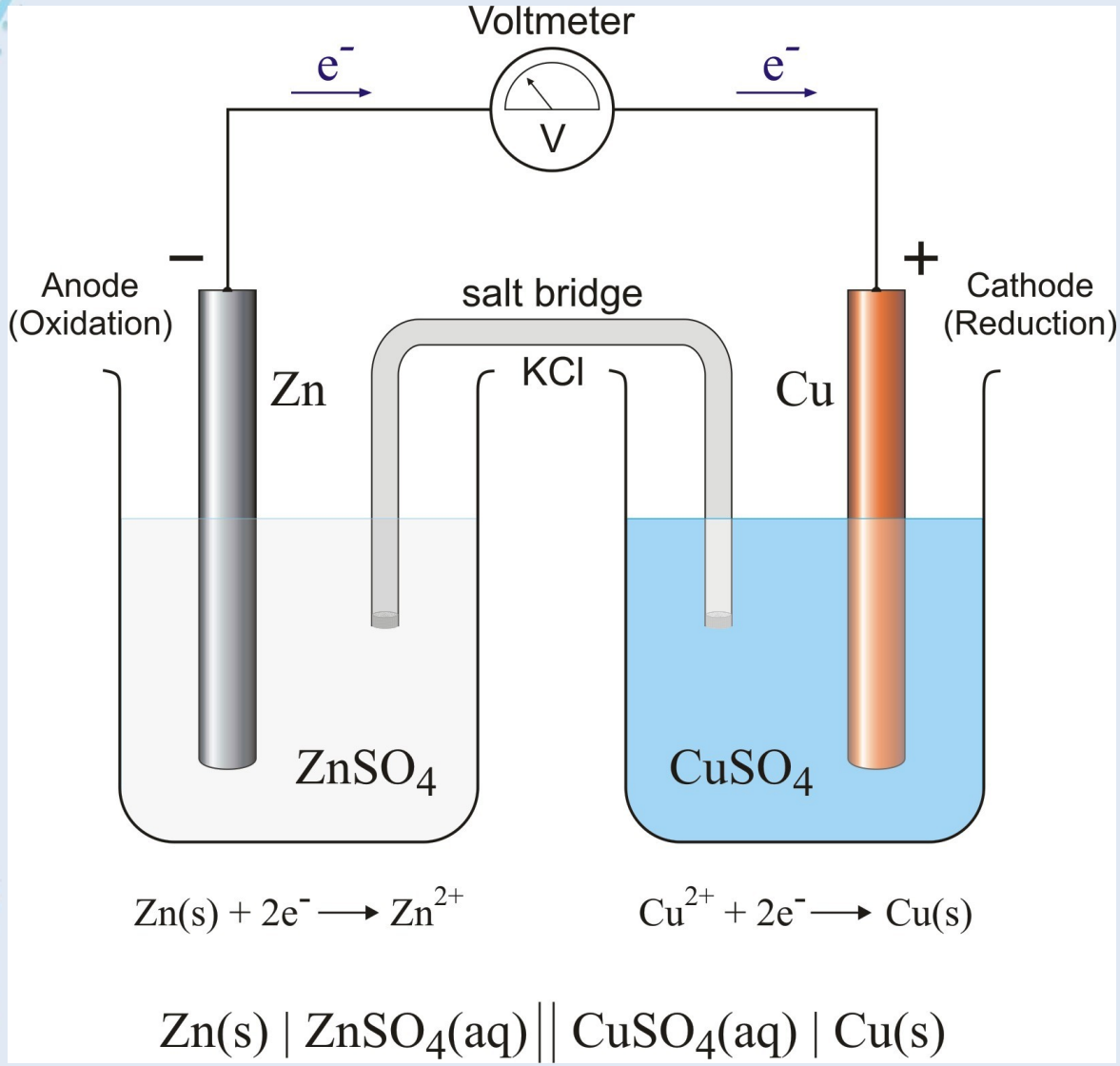
Galvanic cell

- Converts chemical energy into electrical Energy
- Spontaneous process

Electrolytic cell

- converts electrical energy into chmical Energy
- Non spontaneous process

Galvanic Cell



Electrode Potential

- The tendency of metal to get oxidised or reduced when it is placed in a solution of its own salt is known as electrode potential.

If metal is dipped in its aqeous solution and metal undergoes oxidation reaction, then positive ions may pass into the solution.

- If metal is dipped in its aqeous solution and metal undergoes reduction reaction, then negative ions may get deposited over metal surface.

- **Standard electrode potential:-**

It is a measure of tendency of a metallic electrode to lose or gain electrons, when it is in contact with a solution of its own salt of 1 molar concentration at 25^0 C.

Electrode Potential

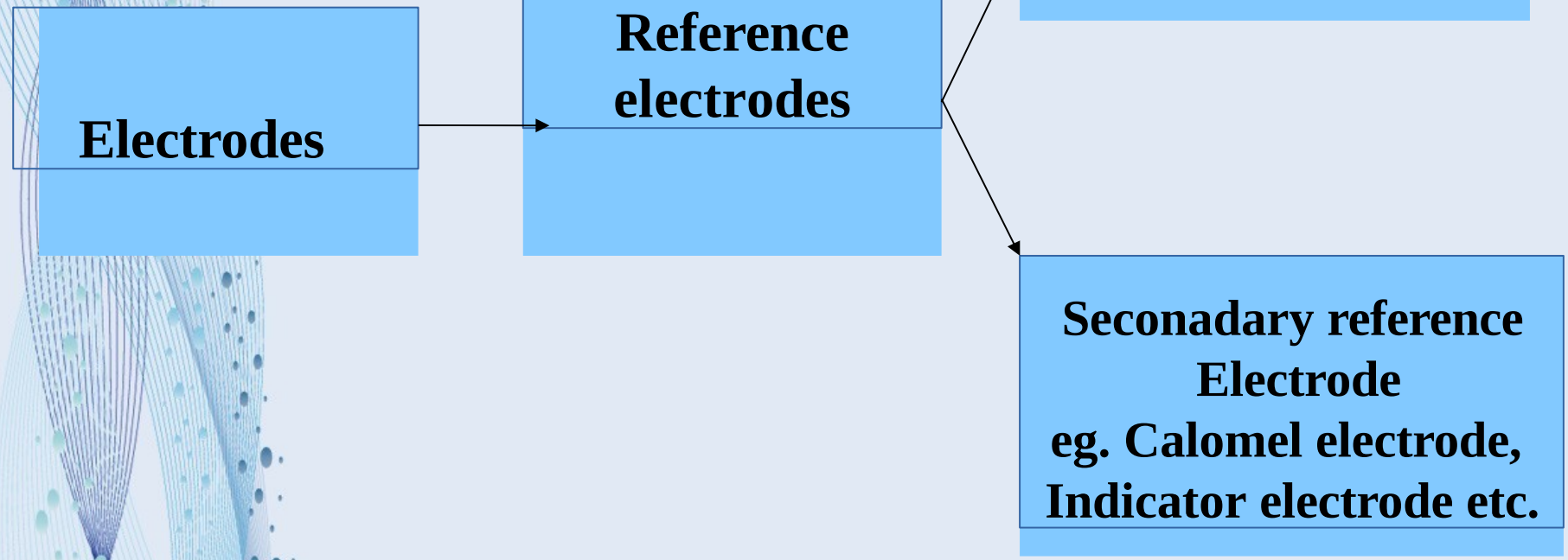
Oxidation potential:-

When electrode is negatively charged with respect to solution.

Reduction Potential:-

When electrode is positively charged with respect to solution.

Only difference in potential between two electrodes can be measured experimetally. It is therefore necessary to couple the electrode with another electrode whose potential is known.



Reference Electrode

- The electrode which has stable and reproducible eletcrode potential.

Ideal reference electrode:-

a) is reversible and obeys the Nernst's equation.

b) exhibits a potential that is constant with time.

c) returns to its original potential after being subjected to small currents.

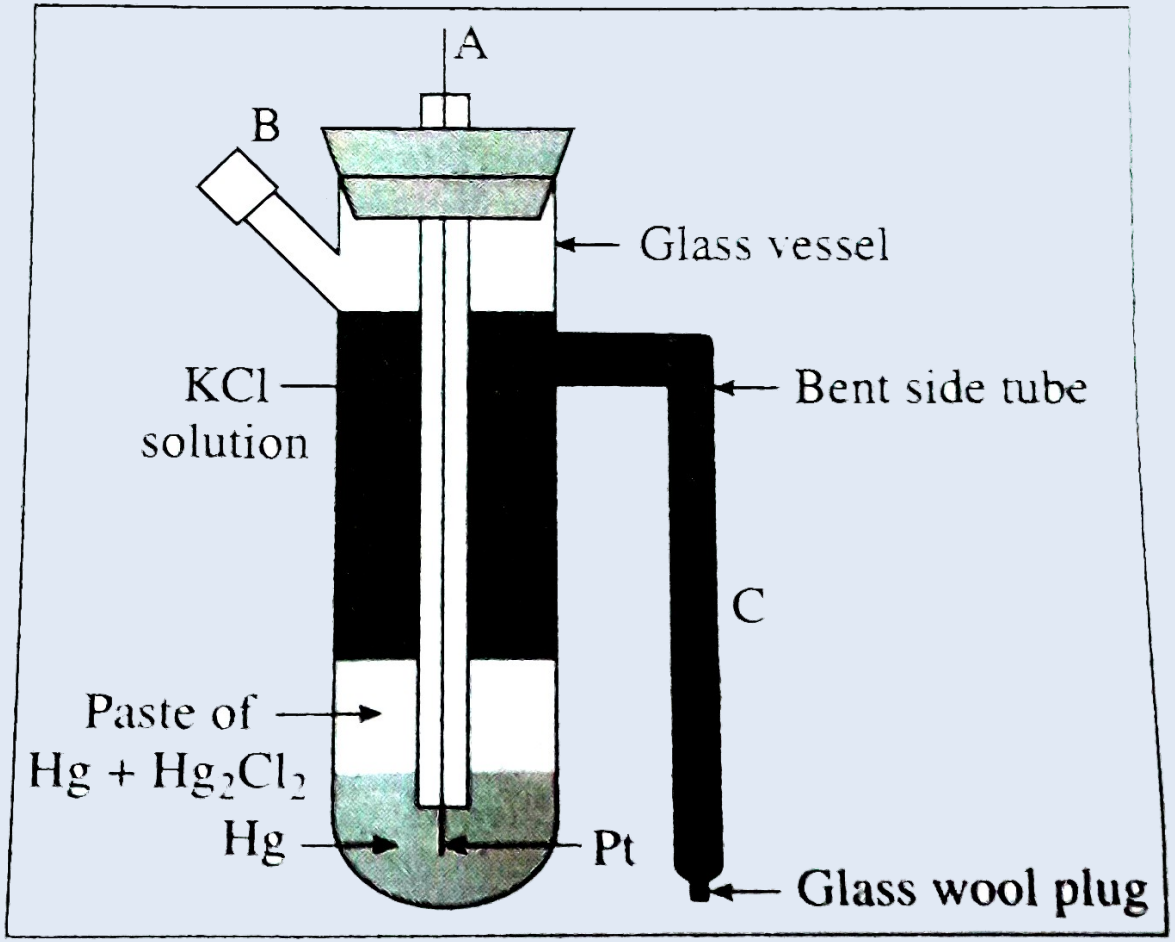
Types of refernce electrodes:-

a) Primary reference electrode- eg. Hydrogen electrode

b) Secondary reference electrode:- eg. Calomel elctrode, silver silver chloride electrode.

Secondary reference electrode

Calomel Electrode:-



Calomel electrode

Calomel Electrode

1. It consist of inner jacket and outer sleeve.
2. Inner tube has wire contact with mercury and plugged with a mixture of calomel (Hg_2Cl_2) nd Hcl.
3. This is surrounded by outer sleeve.
4. Tip is filled with crystals of KCl and porous plug of asbestos.
5. The space between inner jacket and outer sleeve is filled with saturated KCl/ 1N KCl/ 0.1 N Kcl solution.
6. Potential of electrode depends on concentrationof Kcl solution.
7. Standard potentials of electrode

KCl conc	Potential
Saturated KCl	0.24 V
Normal (1N)	0.28 V
Decinormal (0.1 N)	0.33 V

Calomel Electrode

Reactions:-The electrode reaction when electrode acts as cathode is,

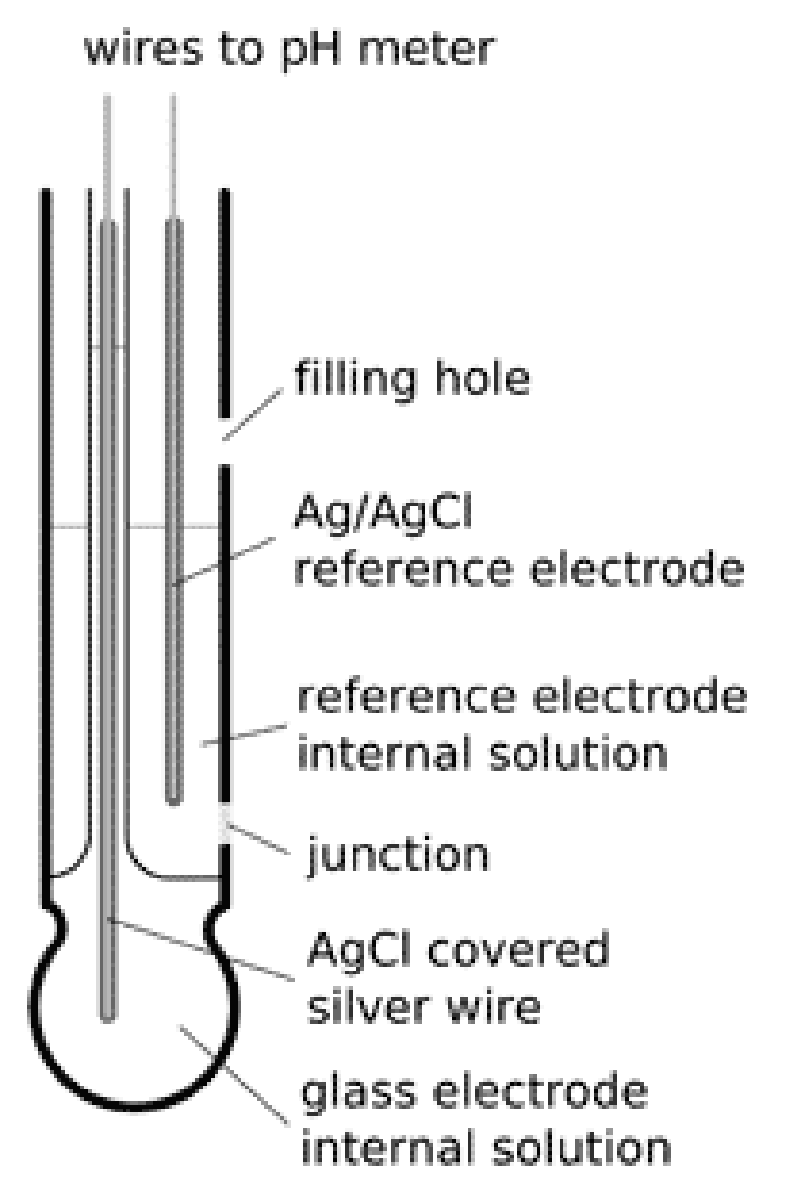
$$Hg_2Cl_2 + 2e \longleftrightarrow 2\,Hg + 2Cl^-$$

If electrode is anode reaction is reverse.

1. The calomel operating temperature is usually below 80^0 C as mercurous chloride at high temperature disproportionate into mercury and mercuric chloride.
2. Used in pH metric measurements.

Merits:-	**Demerits**:-
• Easy of construction.	Dependent on temp.
• Stability of potential.	

Glass Electrode



Glass Electrode

1. It consist of a very thin walled glass bulb, made from a low melting point glass having high electrical conductivity.
2. The bulb contains **0.1 N HCl solution,** sealed into the glass tube is a silver wire coated with silver chloride at its lower end.
3. The lower end of silver wire is dipped into the HCl forming silver silver chloride electrode.
4. When glass electrode is dipped in a solution the potential develops across the glass membrane as a result of a concentration difference of H^+ ions on the two sides of the membrane.
5. The potential of glass electrode is determined using standard calomel electrode.

Advantages of glass electrode:-

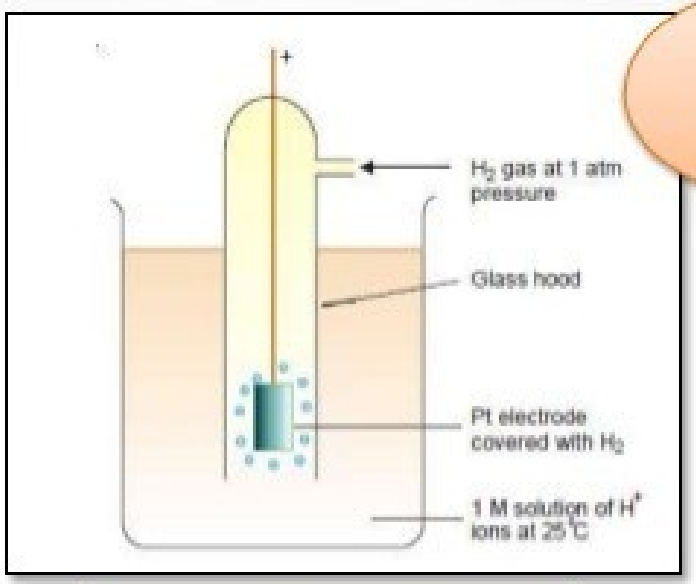
1. It is portable and compact.
2. Equillibrium is easily maintained.
3. It is stable electrode and can be used in presesnce of strong oxidising and reducing agents.
4. It can be used in presence of biological fluids.
5. It can detect H^+ ions in presence of other ions.

Disadvantages:-

1. It takes certain time to come to equillibrium due to resistance of glass to electricity.

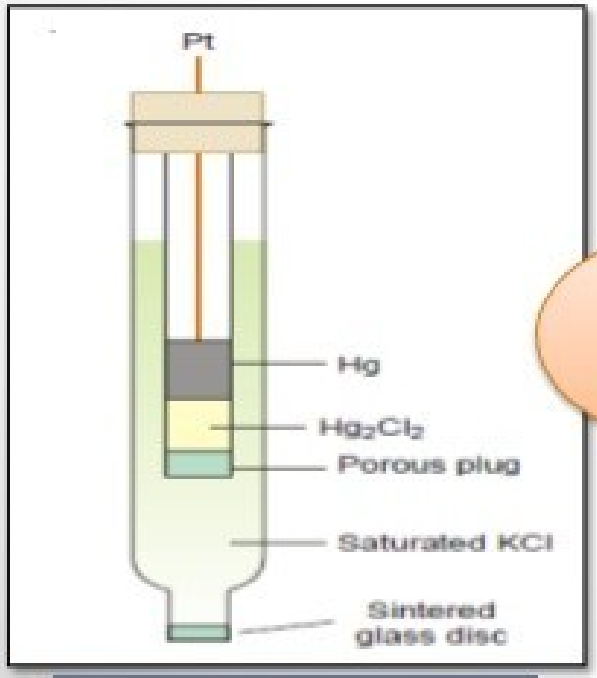
Reference Electrodes

Primary Standard Electrodes

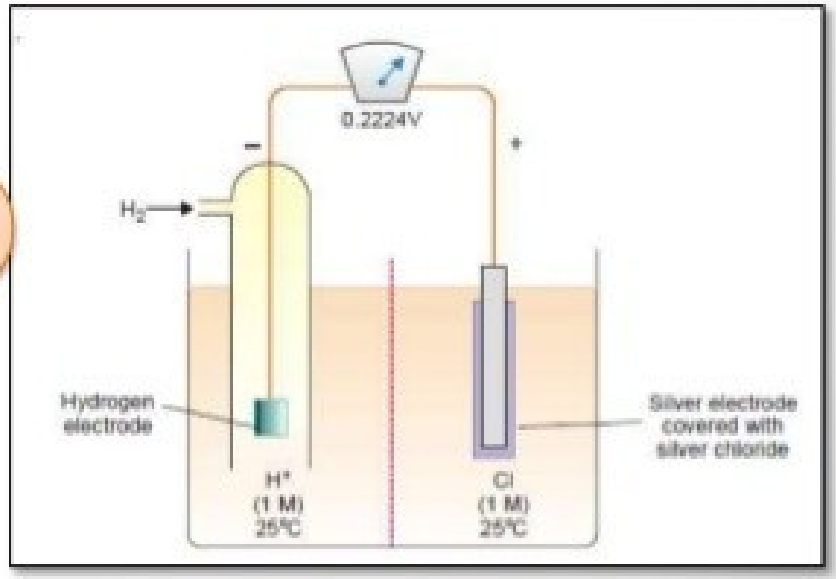


Standard Hydrogen Electrodes

Secondary Standard Electrodes



Calomel Electrode



Ag/ AgCl electrode with SHE

Conductometry

Conductometry

1. It is defined as determination or measurement of the electrical conductance of an electrolyte solution by means of a conductometer.
2. Electrical conductivity of solution depends on:-
    a) types of charged ions
    b) concentration of ions
    c) temperature
    d) mobility of ions
3. It is based on principle which depends on the conductance of electric current through electrolyte soluions.
4. According to ohm's law, the current (I) passing through a given solution is directly proportional to the potential difference between the two ends of the conductor through which the current is flowing. $R = E/I$

Conductometry

Important Definations and relations:-

1. **Conductance (G)** :- ease with which current flows per unit area of conductor per unit potential applied and is reciprocal to resistance (R). G= I/R unit :- ohm^{-1}

2. **Specific conductance (K) :-**

Conductance of a conductor of uniform length (l) and uniform area of cross section (A). K=1/R X 1/A

unit:- $mho.cm^{-1}$

3. **Specific resistance (p):-**

It is resistance offered by a conductor of unit length and having unit cross section area. P= R X a/l

unit:- ohm.cm

Conductometry

4. Cell constant (1/a) :-

It is defined as ratio of distance between the two electrodes (l) to the area of electrodes (A).

Specific conductance = Measured conductance X cell constant

Unit:- cm^{-1}

5. Equivalent Conductance (λv):-

It is defined as the conductance of a solution containing one gram equivalent of an electrolyte.

V= 1000/C (C= Normality)

λv = K X V

λv = K X 1000/C

unit:- $ohm^{-1}.cm^{2}.equiv.^{-1}$

Conductometry

6. Molar conducatnce (λm) :-

It is the conductivity of the solution containing 1 mole of the electrolyte.

$V = 1000/C$ (C=Molarity)

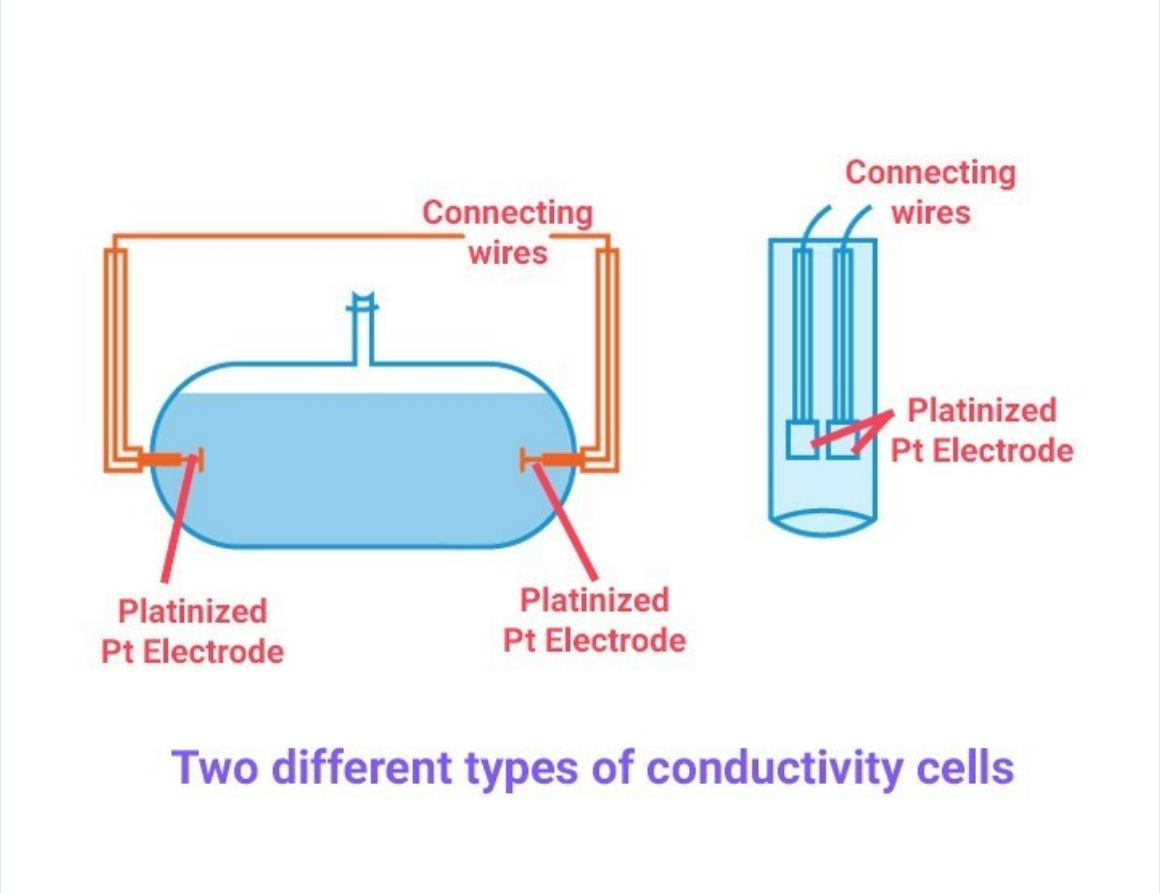
$\lambda m = K \times V$

$\lambda m = K \times 1000/C$

unit:- $ohm^{-1}.cm^{2}.mol.^{-1}$

Conductivity cell

1. It helps in measurement of conductance of a solution using alternate current.



Two different types of conductivity cells

Conductivity cell

- The common laboratory conductivity cell employ a potentiometric method and electrodes.
- Often the electrodes are cylindrical and arranged
- parallel. The electrodes are usually made of platinum
- metal.
- These electrodes are fitted in cell coated with platinum black.
- The contact with copper wires of the circuit is made by dipping them in mercury contained in the tubes.
- An alternating current is applied to the outer pair of electrodes.
- Conductivity involves principle determination using distance between the electrodes and their surface area.

Generally for accuracy a caliberation is employed using elctrolytes of well known conductivity.

Determination of cell constant

1. Cell constant can be determined by measuring the distance between the electrodesand their area of cross section.

Specific conductance (K) =1/R X l/A

2.Standard KCl solution whose specific conductance at given temperature is known is used.

3.Then a solution of KCl of same strength is prepared and conductance is determined experimentally at the same tempretaure.

Kohlrausch's law

Kohlrausch's law states that the equivalent conductivity of an electrolyte at infinite dilution is equal to the sum of the conductances of the anions and cations.

$$\lambda_{eq}^{\infty} = \lambda_{c}^{\infty} + \lambda_{a}^{\infty}$$

where,

$$\lambda_{eq}^{\infty} = Equivalence\ Conductivity\ at\ Infinite\ Dilution$$

$$\lambda_{c}^{\infty} = Conductivity\ of\ Cation$$

$$\lambda_{a}^{\infty} = Equivalence\ Conductivity\ of\ Anion$$

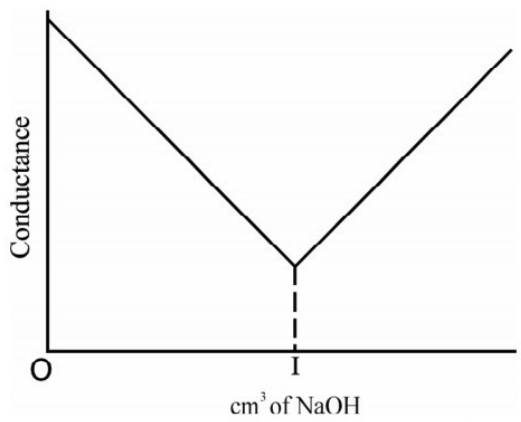
Conductometric Titrations

Four types of conductometric titrations

1.Strong acid versus strong base

eg. HCl versus NaOH

$$H^+ + Cl^- + Na^+ + OH^- \longrightarrow H_2O + NaCl$$



Conductometric titration of a strong acid (HCl) vs. a strong base (NaOH)

Nature of graph:-

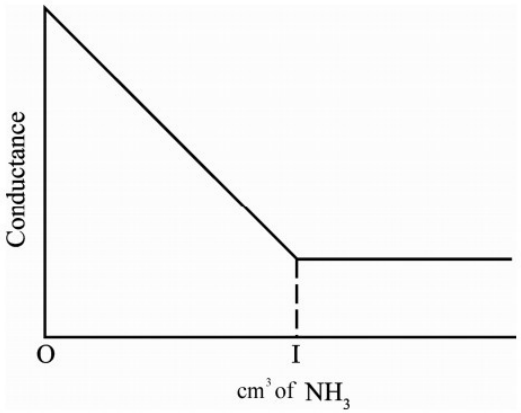
1. Initially conductance is high due to H+ ions
2. Addition of NaOH replace H+ by Na+ from solution so conductance dereases.
3. At the end excess addition of NaOH increases OH- Concentration so having high mobility so conductance increases.

Conductometric Titrations

2. Strong acid versus weak base

eg. HCl versus NH_4OH

$$H^+ + Cl^- \; NH_4OH \longrightarrow H_2O + NH_4Cl$$



Conductometric titration of a strong acid (H_2SO_4) vs. a weak base (NH_4OH)

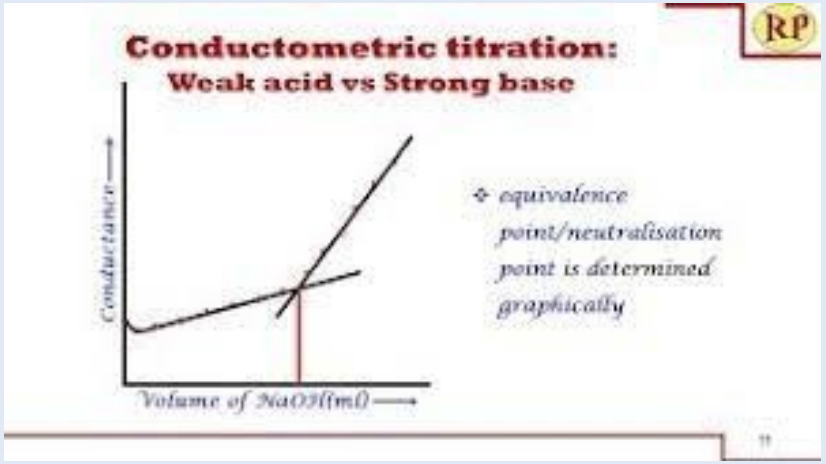
Nature of graph:-

1. Initially beaker contains strong acid from which H+ ions gives high conductance.
2. Addition of weak base from burette replaces H+ and froms salt so conductance Decreases.
3. Further more addition of weak base dissociates incompletely so conductance remains constant.

Conductometric Titrations

2. Weak acid versus Strong base

eg. CH3COOH versus NaOH



$CH_3COOH + Na + OH^- \longrightarrow CH3COONa + H2O$

Nature of graph:-

1.Initially beaker contains weak acid so conductance less due to weak dissociation.

2. Addition of strong base from burette forms salt so conductance increases.

3. Further more addition of strong base dissociates completely so conductance increases at the end.

Advantages of conductometric titrations

1. These titrations do not require indicator as conductance is measured by conductometer.

2. Titration of coloured solutions can be carried out easily.

3. Since end point is determined by graphical means so accurate results are obtained with minimum error.

4. Useful for analysis of turbid suspensions, weak acid, weak base, mixture weak and strong acids.

Disadvantages:-

1.Increased level of salt in mask conductivity changes and not gives accurate results.

2.Applications of conductometric titrations to redox system is limited, because high concentration of hydronium ions in the solution tends to mask the changes in conductance.

pH Metry

Types of pH meter

- Manual pH meter
- Digital pH meter

- A manual pH meter

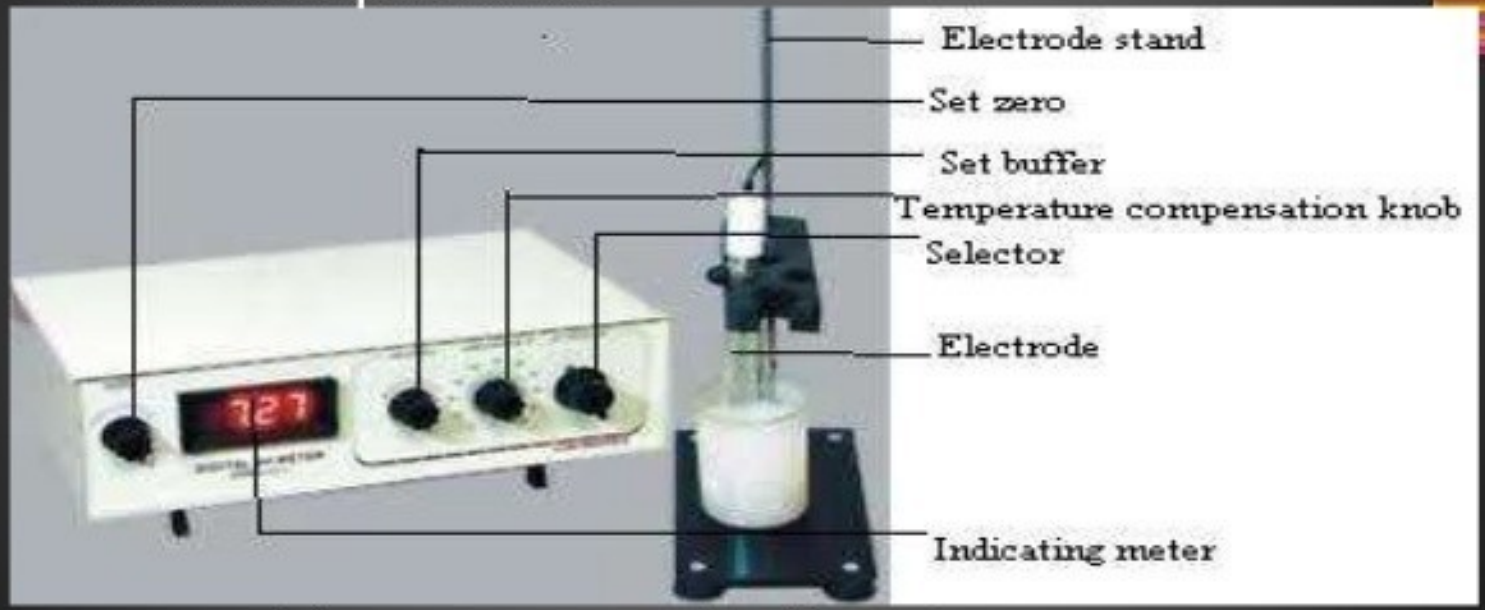


Figure : manual pH meter

Source : http://doubleroptics.tradeindia.com/deluxe-ph-meter-226808.ht

pH Metry

1. It is an electronic instrument used to measure pH of a liquid.
2. A typical pH meter consist of special measuring probes connected to an electronic meter that measures and displays the pH reading.
3. pH is negative logarithm of hydrogen ion concentration.

   $pH = -\log [H^+]$

4. pH of solution can be measured by pH meter where, the glass electrode is an half cell and the calomel electrode is another half cell.
5. The glass electrode contains Ag, AgCl and HCl. All these remain in a ionized state.

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

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

$$Hcl \longrightarrow H^+ + Cl^-$$

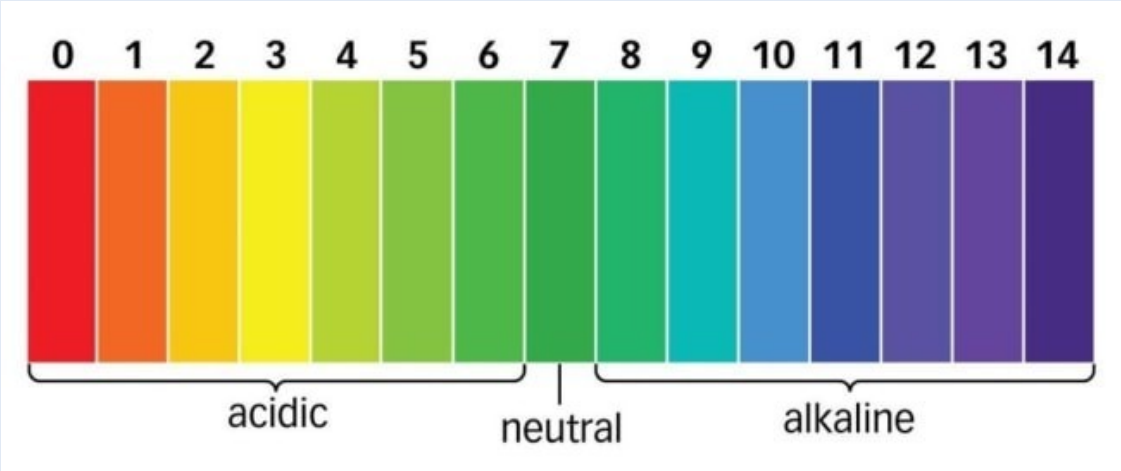
pH Metry

6. All the above three equillibrium reactions are balanced. In the glass electrode H^+ is generated.
7. The calomel electrode contains Hg, Hg_2Cl_2 and Kcl. Following ionizations takes place.

$$Hg \longrightarrow Hg^+ + e^-$$

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

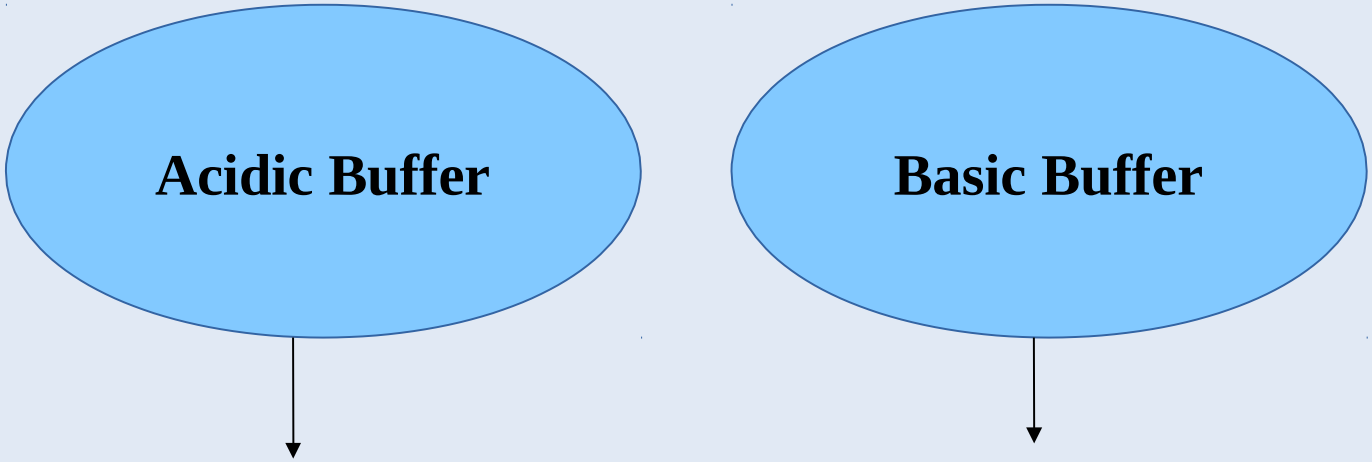
$$KCl \longrightarrow K^+ + Cl^-$$



PH scale

Buffer

1. Buffer is a solution that resist the change in pH.
2. There are two types of buffer solutions.



It is a mixture of weak acid and strong base.

eg. $CH_3COOH + NaOH \rightarrow CH_3COONa + CH_3COOH$

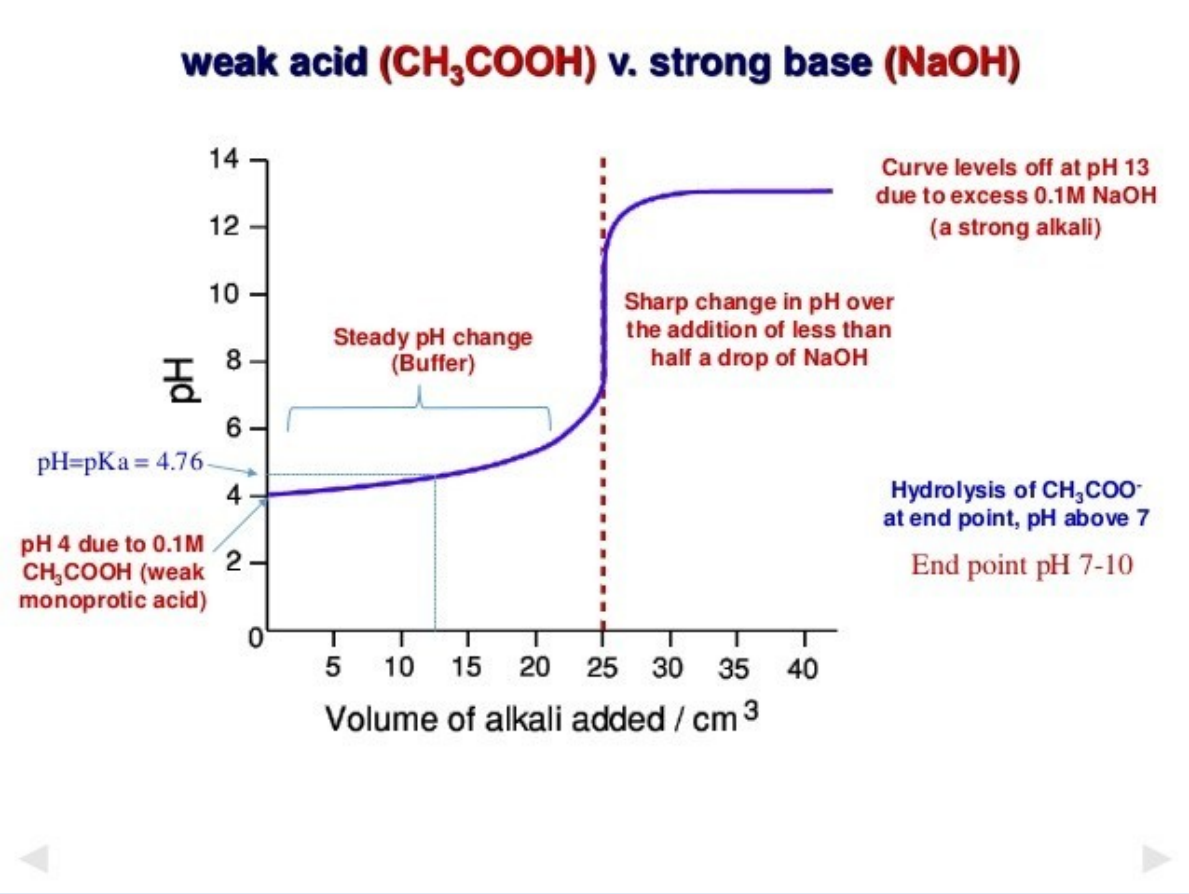
It is a mixture of weak base and strong acid.

eg. $NH_4OH + HCl \rightarrow NH_4Cl + NH_4OH$

pH Metric titrations

Titration of weak acid versus strong base :-

1. pH metric titration of CH_3COOH versus NaOH
2. Reaction:- $CH_3COOH + NaOH \longrightarrow CH_3COONa +$ N

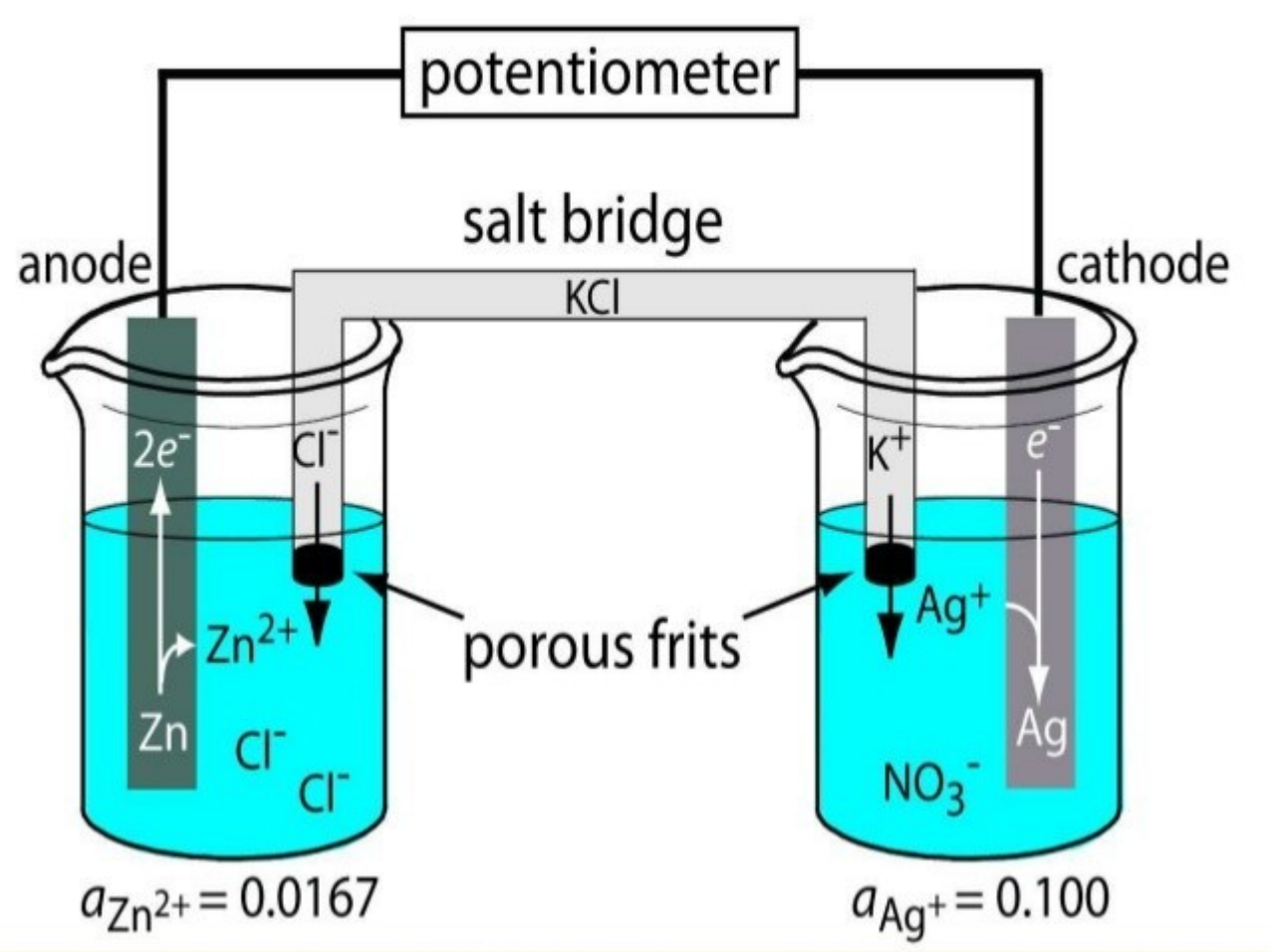


Applications of pH metry

1. It helps to determine nature of solutions.
2. It helps to determine pH of water in waste water treatments.
3. In determination of dissociation constant of weak acid by pH metric titrations method.
4. Helpful in titration of turbid and coloured solutions.
5. In dye, paper industries majorly used.
6. Highly used in qualitative and quantitative analysis.

Potentiometry

1. It is an instrument used to determine the potential differences between reference electrode and indicator electrode.



Potentiometry

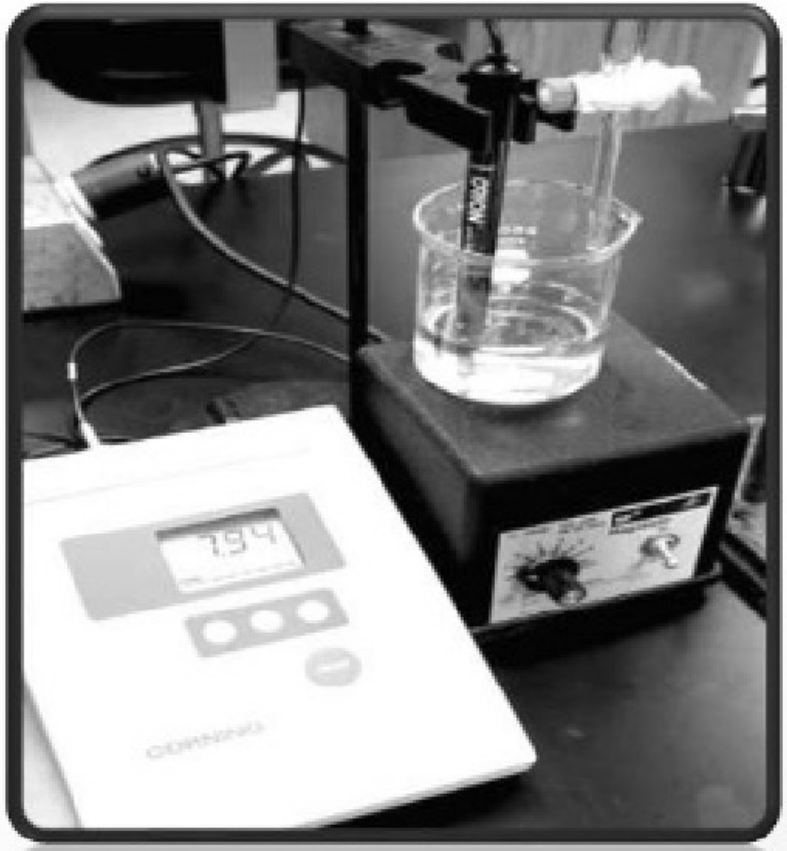
2. A potentiometer consist of two electrodes, whose reduction potential differs when inserted in a test solution.
3. The voltmeter attached to it measures potential difference between them.
4. Electrode potential can be represented as,

$$E_{cell} = E_{indicator} - E_{reference}$$

5. The main theory involved in potentiometry is, when known potential electrode immersed in sample solution then the potential is given by Nernst equation.

$$E = E^0 + (0.592/n) \log C$$

Potentiometric Titration



Redox Titration

1. The titration of ferrous ions (Fe^{2+}) with ceric ions (Ce^{+4}).
2. In beaker :- 100 ml of 0.1N ferrous solution.

   In burette :- 0.1N ceric solution.
3. It contains indicator electrode which is a shiny platinum strip dipping in the solution of Fe^{2+} ions and it is connected to standard calomel electrode.
4. Initially start adding 10 ml of 0.1N Ce^{4+} solution from burette and cell potential E, recorded after each addition..
5. As Ce^{+4} accepts electrons, it is oxidizing agent and undergoes reduction reaction whereas Fe^{2+} donates electrons or looses them, it is reducing agent and undergoes oxidation reaction.
6. Reaction:- $Ce^{+4} + Fe^{+2} \longrightarrow Ce^{3+} + Fe^{+3}$

   Oxidation:- $Fe^{+2} \longrightarrow Fe^{+3} + e^{-}$ ($E^0 = 0.75$)

   Reduction :- $Ce^{+4} + e^{-} \longrightarrow Ce^{+3}$ ($E^0 = 1.45$ V)

Redox Titration

7. EMF of cell can be calculated as follows.

I) Before equivalence point:-

When addition of Ce^{+4} is from 1ml to 99.9ml.

$E_1 = E^0_{cell} + 0.0591/n \log Fe^{+3} / Fe^{+2}$ $(E^0 = 0.75\ V)$

II) At equivalence point :-

Addition of Ce^{+4} ions is exact 100 ml.

$$E_{cell} = E^0_{Ce+4} + E^0_{Fe+3} / 2$$

$E_{cell} = 0.75 + 1.45 /2$

$E_{cell} = 1.1\ V$

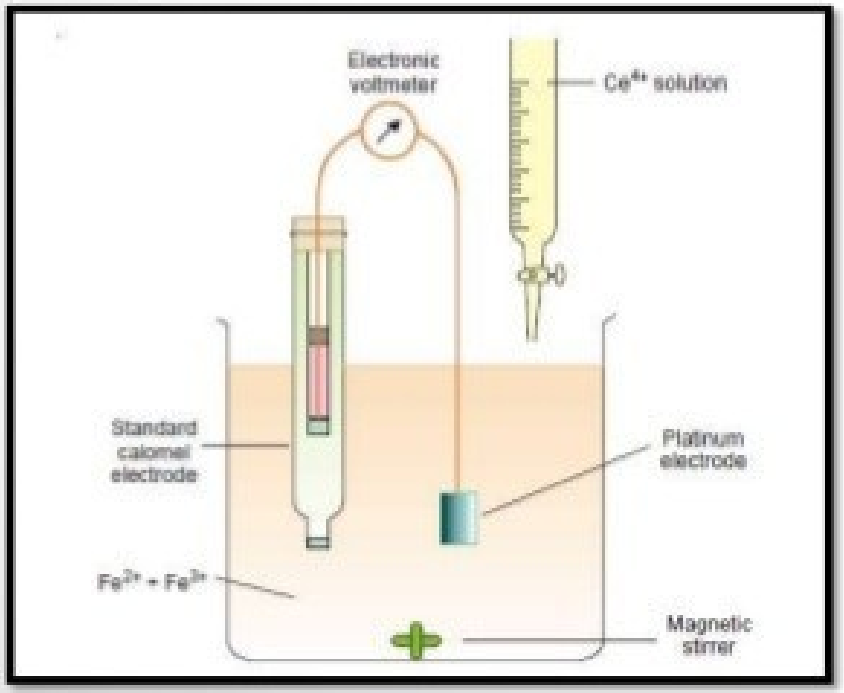
III) After equivalence point :-

Addition of Ce^{+4} more than 100 ml i.e. 101ml,102ml and so on.

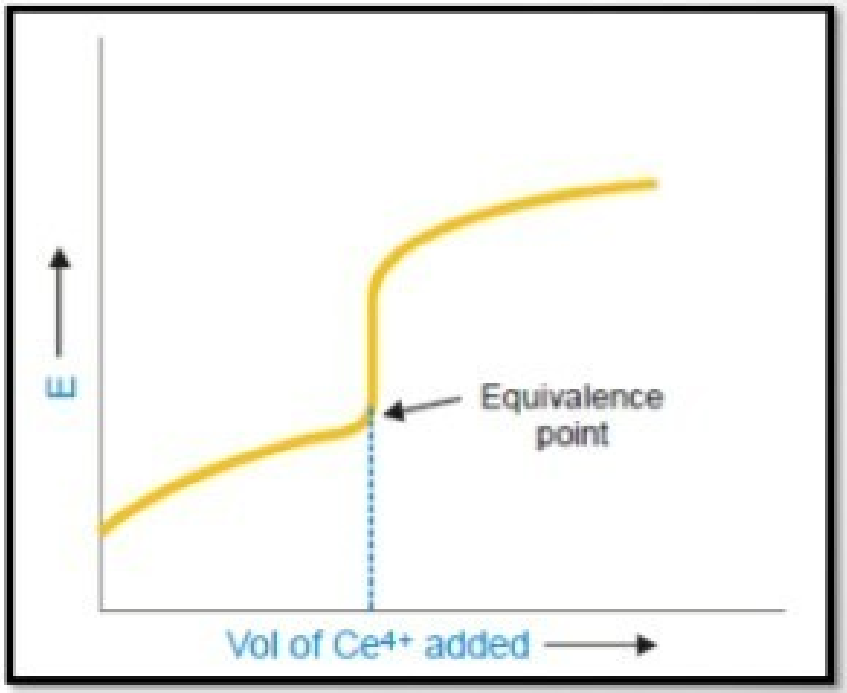
$E_2 = E^0_{cell} + 0.0591/n \log Ce^{+4} / Ce^{+3}$ $(E^0 = 1.45\ V)$

Oxidation- Reduction Titrations

Apparatus



Graphical Representation



Example: Titration of Fe^{2+} and Ce^{4+} ions

Advantages of potentiometry

1. Method is inexpensive and more accurate.
2. Coloured and turbid solution can be titrated easily.
3. ISEs are also regularly used in environmental analysis, such as in a water treatment plant to monitor nitrate levels. The instrumentation used to perform potentiometry.
4. Potentiometric titration is a laboratory method to determine the concentration of a given analyte. It is used in the characterization of acids.
5. These titrations are more sharp and accurate as the equivalence point is not determined by using colored indicators.
6. Speedy analysis.

Battery Technology

1. A **battery** is a man-made power cell used to generate electrical energy. A device containing an electric cell or a series of electric cells storing chemical energy that can be converted into electrical power, usually in the form of direct current.
2. **Batteries** are made up of three basic components: an anode, a cathode, and an electrolyte. A separator is often used to prevent the anode and cathode from touching.
3. A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars.
4. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode.

Advantages of batteries :

1. No need of electrical energy inputs.
2. Portable source of energy.
3. Can be easily replaced.
4. Available in different shapes and sizes for specific applications.

Disadvantages :

1. Can be used for only a limited time.
2. Some batteries are denderous and can lead to fire,explosion,chemical pollution.
3. Periodical maintence is required for some batteries.

Types of batteries

Primary Batteries

- Cant be reused.
- eg. Alkaline batteries

Secondary Batteries

- Can be reused.
- eg. Lead acetate battery

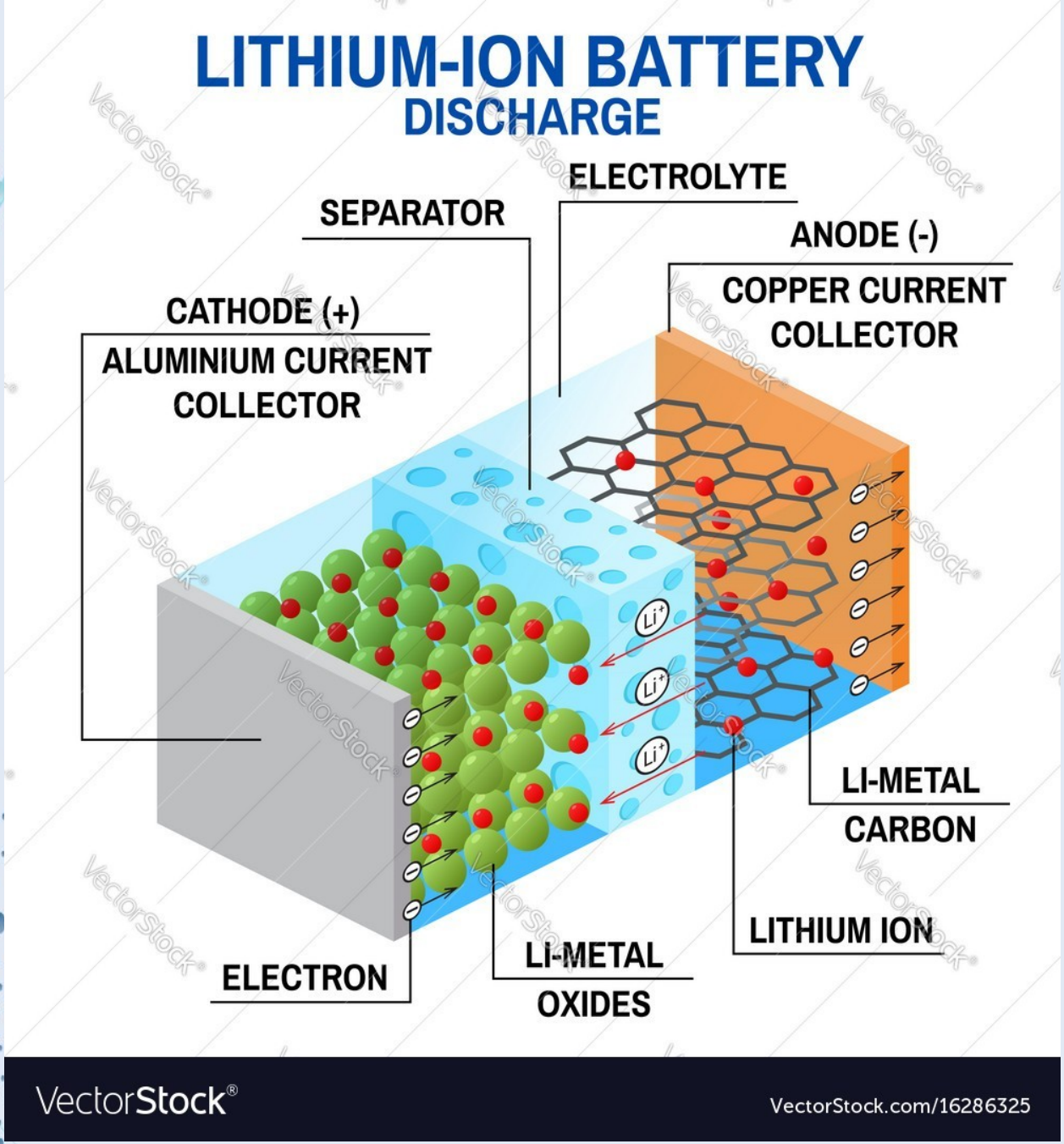
Lithium ion battery

1. Li is lightest of metal and can float on water.

2.The electrochemical properties of lithium are excellant and is also a highly reactive metal.

3.These properties give lithium a very high potential to achieve very high energy and power densities in high density battery applications such as automotive and standby power.

4.A lithium cell can produce voltage from 1.5 V to 3V based on the types of materials used.



Lithium ion battery

1. It is a type of **rechargeable battery.**

2. Lithium-ion batteries are commonly used for **portable electronics** and **electric vehicles** and are growing in popularity for military and **aerospace** applications.

3.They consist of cathode (positive electrode) of lithium and anode (negative electrode) of graphite or carbon.

4. Anode : Hard carbon (LiC_6) ,Graphite (LiC_6)

Cathode: $LiCoO_2$, $LiMn_2O_4$,$LiNiO_2$.

5.Eletcrolytes : Liquid (non aqueous) electolyte which consist of lithium salts such as $LiPF_6$,$LiBF_4$ in an organic solvent such as ethylene carbonate.

6. Cathode half reaction :

$$LiCoO_2 \quad <\text{-----}> \quad Li_{(1-x)}CoO_2 + x\,Li + xe^-$$

Anode half reaction :

$$x\,Li + xe^- + 6C \quad <\text{----}> \quad Li_xC_6$$

Advantages of Li ion battery

- **High Energy Density:** One of the biggest advantages of a lithium-ion battery is its high energy density. To put it straight, lithium-ion batteries can last way longer between charges all the while maintaining a high current output.
- **Low Self Discharge:** Not only whilst being used, but lithium-ion batteries have a clear advantage when not being used as well. When kept idle, the rate of self-discharge, a common phenomenon in batteries, is extremely low. In fact, in most cases, it is as good as being negligent.
- **Low to Minimum Maintenance:** Lithium-ion batteries are popular for their low maintenance batteries too. Most other cells like Nickel Cadmium batteries have a huge cost of ownership and maintenance.
- **Options:** One of the biggest advantages of lithium ion batteries is the fact that they come in all shapes and sizes- presenting users with a large number of options to choose from according to their needs.

Applications of Li ion battery

- Li-ion batteries are available in all shapes and sizes.
- Lithium-ion batteries offer power solutions across the spectrum- from energy storage solutions to portable energy solutions.
- Power backups/UPS
- Mobile, Laptops, and other commonly used consumer electronic goods.
- Electric mobility
- Energy Storage Systems

Disadvantages of lithium ion battery

- **Inflammable:** Li-ion batteries have a reputation for catching fire easily. As a result, they need a significant amount of protection to ensure that they don’t burst into flames at the smallest inconvenience.

- **Cost:** While lithium-ion batteries are a technological marvel, they come at a cost. Li-ion batteries are often considerably more expensive to buy than their counterparts.

- **Developing Technology:** Sure, there is a lot of promise in the technology of lithium ion batteries. However, we should always remember that it is a relatively new type of power source and its story is still a developing one. With time, there might be considerable changes to the technology. So, you never know.

BATTERY TECHNOLOGY

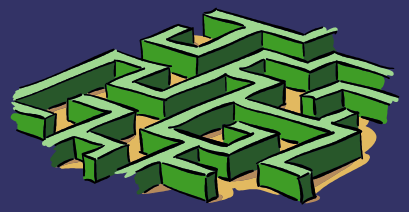
Prof. R. T. JAGTAP

PIMPRI CHINCHWAD COLLEGE OF ENGINEERING

Battery Technology

The **definition** of a **battery** is a man-made power cell used to generate electrical energy.

A device containing an electric cell or a series of electric cells storing chemical energy that can be converted into electrical power, usually in the form of direct current.

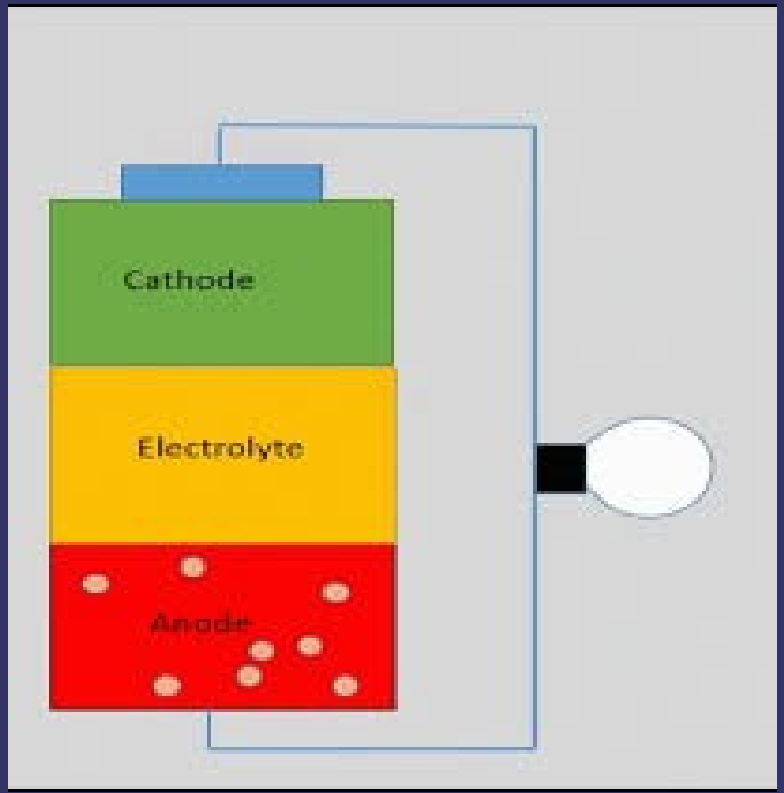


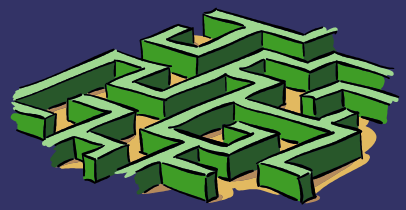
Battery Technology

Batteries are made up of three basic components:

1. an anode,
2. a cathode, and
3. an electrolyte.

A separator is often used to prevent the anode and cathode from touching

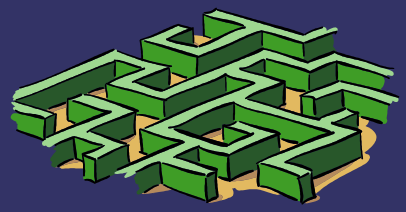




Battery Technology

A battery is a device consisting of one or more electro-chemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars.

When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode



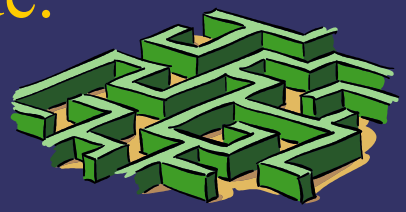
Battery Technology

Battery produces electrons through electrochemical reactions, and contains positive (+) and negative (-) terminals.

The chemical reactions in a battery involve the flow of electrons from one negative electrode to positive electrode, through an external circuit.

The flow of electrons provides an electric current that can be used to do work.

When a battery is supplying electric power , its positive terminal is the cathode and its negative terminal is the anode.



Advantages of batteries :

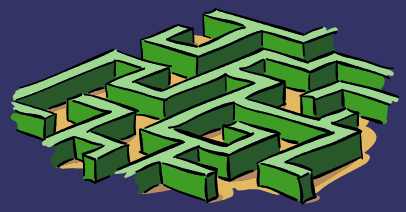
1. No need of electrical energy inputs.
2. Portable source of energy.
3. Can be easily replaced.
4. Available in different shapes and sizes for specific applications

Disadvantages :

1.Can be used for only a limited time.

2.Some batteries are dangerous and can lead to fire,explosion ,chemical pollution.

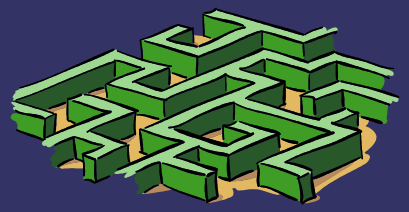
3.Periodical maintenance is required for some batteries



Requirements of batteries

Batteries should have -

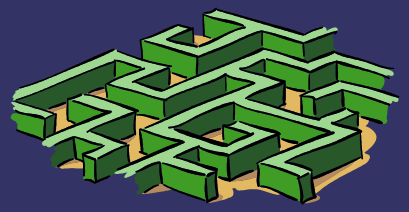
1. Compactness and lightness.
2. long life cycle.
3. Operating voltage is required i.e.voltage should not drop much during use.
4. Stable with time,temperature,vibration shocks.
5. High depth of discharge (how much of stored energy can be used) eg. Pb-acid battery = 50 % DD
   Li ion battery =80-90 % DD



Types of batteries

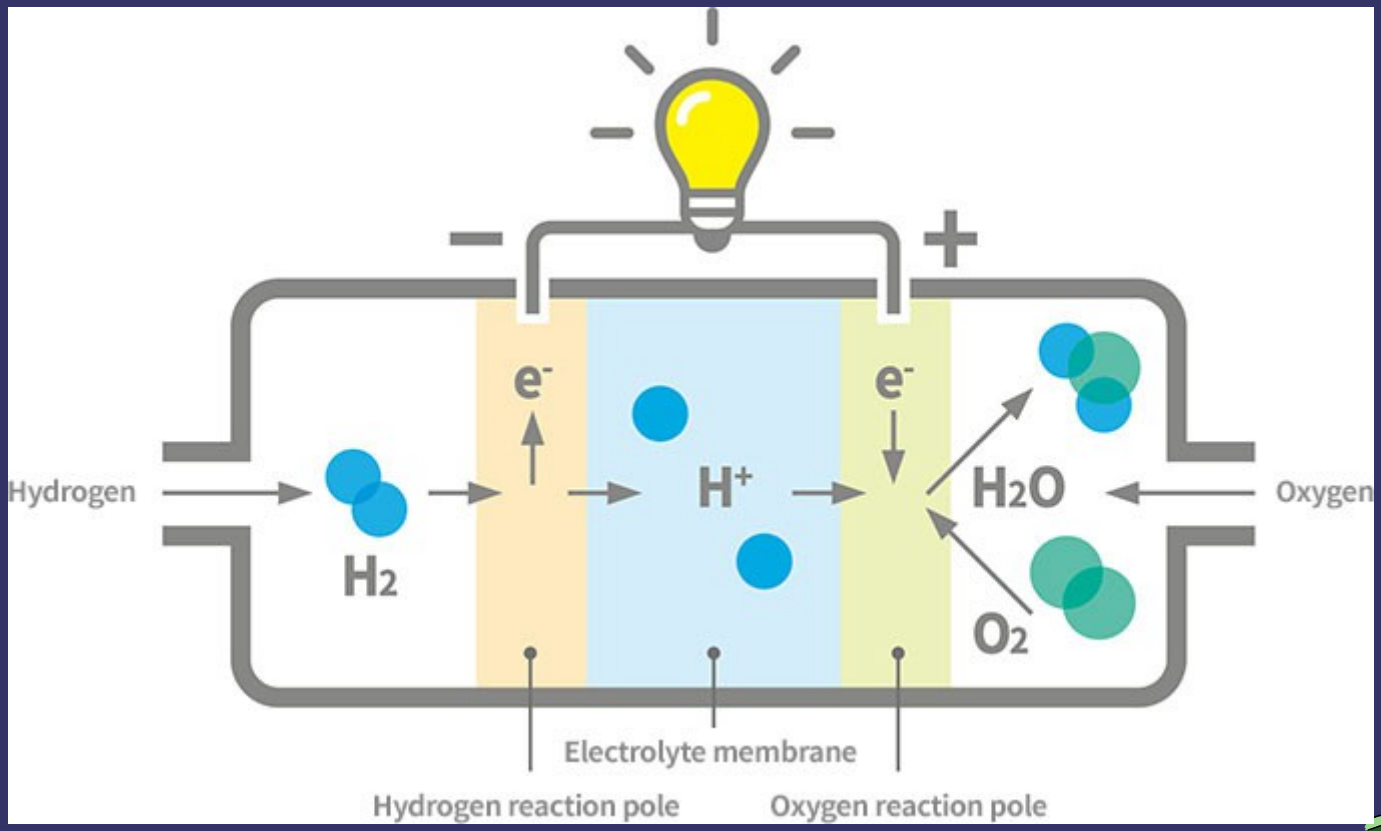
1.Primary batteries :
Primary (single-use or "disposable") batteries are used once and discarded, as the electrode materials are irreversibly changed during discharge.
eg. alkaline battery used for flashlights and a multitude of portable electronic devices.

2. Secondary (rechargeable) batteries : These batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. This regenerates the original chemical reactants, so they can be used, recharged,and used again multiple times.
eg. lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and mobile phones.



Fuel cells

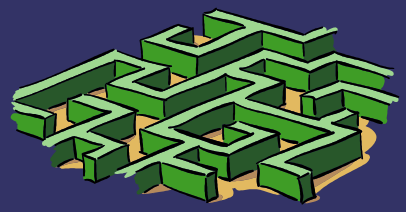
In fuel cells , energy is produced from oxidation of fuel gases such as H2,CH4 etc.



Battery Technology

Batteries are of many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones , to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centres.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat offset by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines



Fuel cells

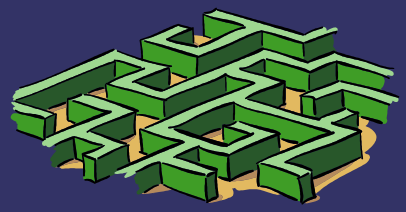
In fuel cells , energy is produced from oxidation of fuel gases such as H2,CH4 etc.

Batteries are of many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smart-phones , to large lead acid batteries or lithium-ion batteries in vehicles, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centres.

Batteries have much lower specific energy (energy per unit mass) than common fuels such as gasoline. In automobiles, this is somewhat off-set by the higher efficiency of electric motors in converting chemical energy to mechanical work, compared to combustion engines

Lithium Cells :

They are primary (disposable) batteries.
Lithium cells have lithium metal as anode and different types of cathodes and electrolytes.
Lithium cells are safer,less expensive and non toxic and meet the needs of present as well as future generations.
It produces voltage from 1.5 V to 3.7 V due to its high electrode potential. This output is twice the voltage of an ordinary battery.
Lithium cells are of three types.
1.Lithium cell with solid cathodes.
2.Lithium cell with liquid cathodes.
3.Lithium cell with solid electrolytes.

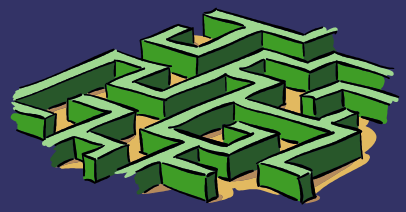


Lithium-ion battery (Li-ion battery) :

It is a type of rechargeable battery.

Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aero-space applications.

In 2019, The Nobel Prize in Chemistry was given to Yoshino, Goode-nough, and Whittingham "for the development of lithium ion batteries".

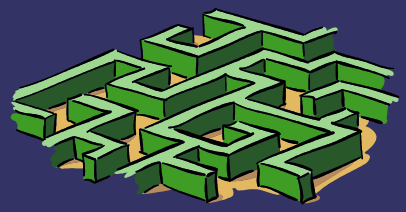


Li - ion battery

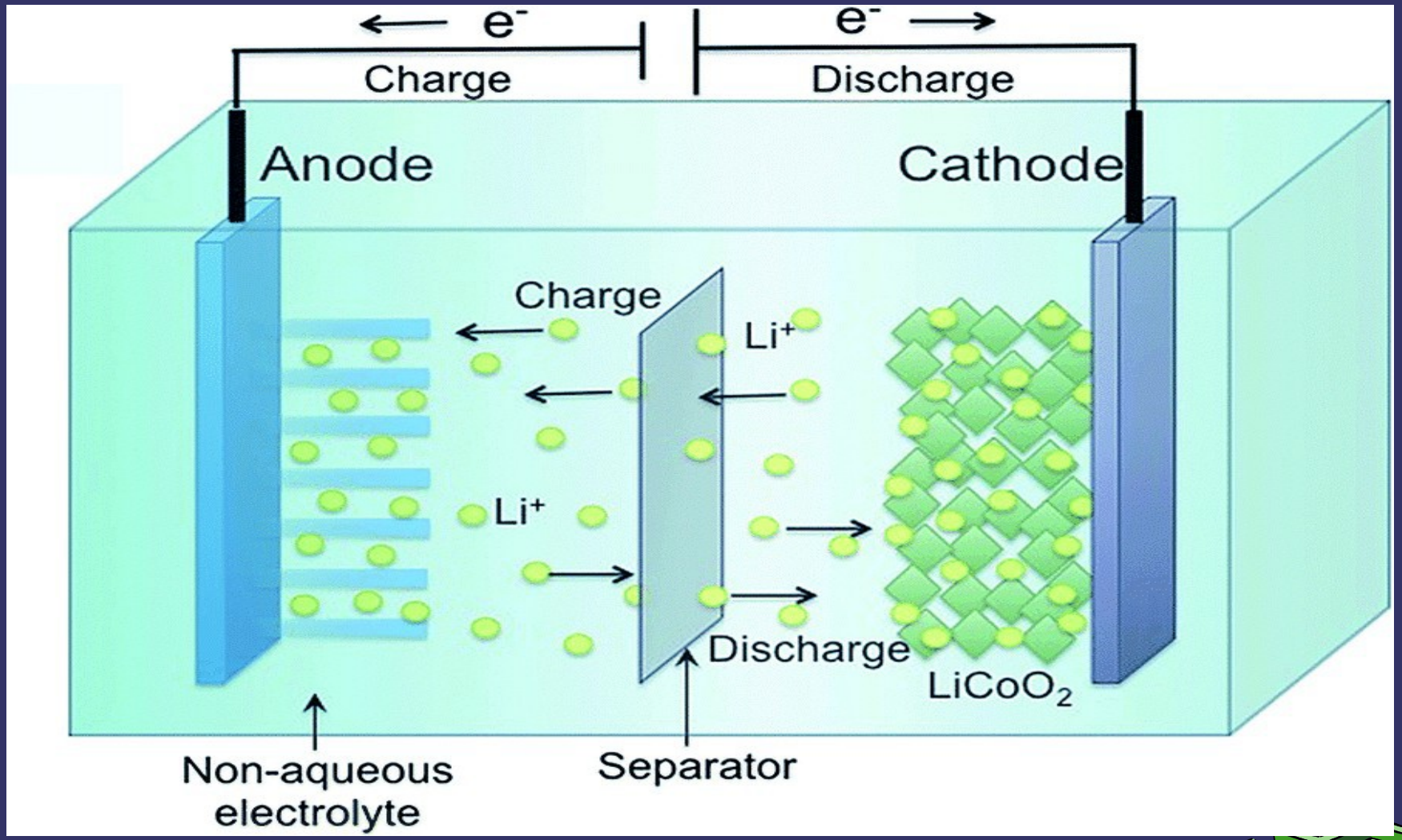
It consist of :
1. Cathode (positive electrode) of lithium and
2. Anode (negative electrode) of graphite or carbon.

In these batteries, during discharge ,lithium ions move from the negative electode through an electrolyte to the positive electrode.

During charging ,external power source.the current pass in the reverse direction.The positive terminal of the charging circuit is connected to the cathode of battery and negative terminal is connected to the anode.



Li - ion battery



Li - ion battery

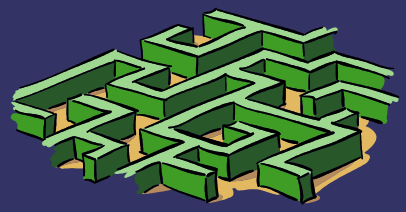
Anode : Hard carbon (LiC6) ,Graphite (LiC6)
Cathode: LiCoO2 , LiMn2O4 ,LiNiO2.
Eletcrolytes : Liquid (non aqueous) electolyte which consist of lithium salts such as LiPF6,LiBF4 in an organic solvent such as ethylene carbonate.

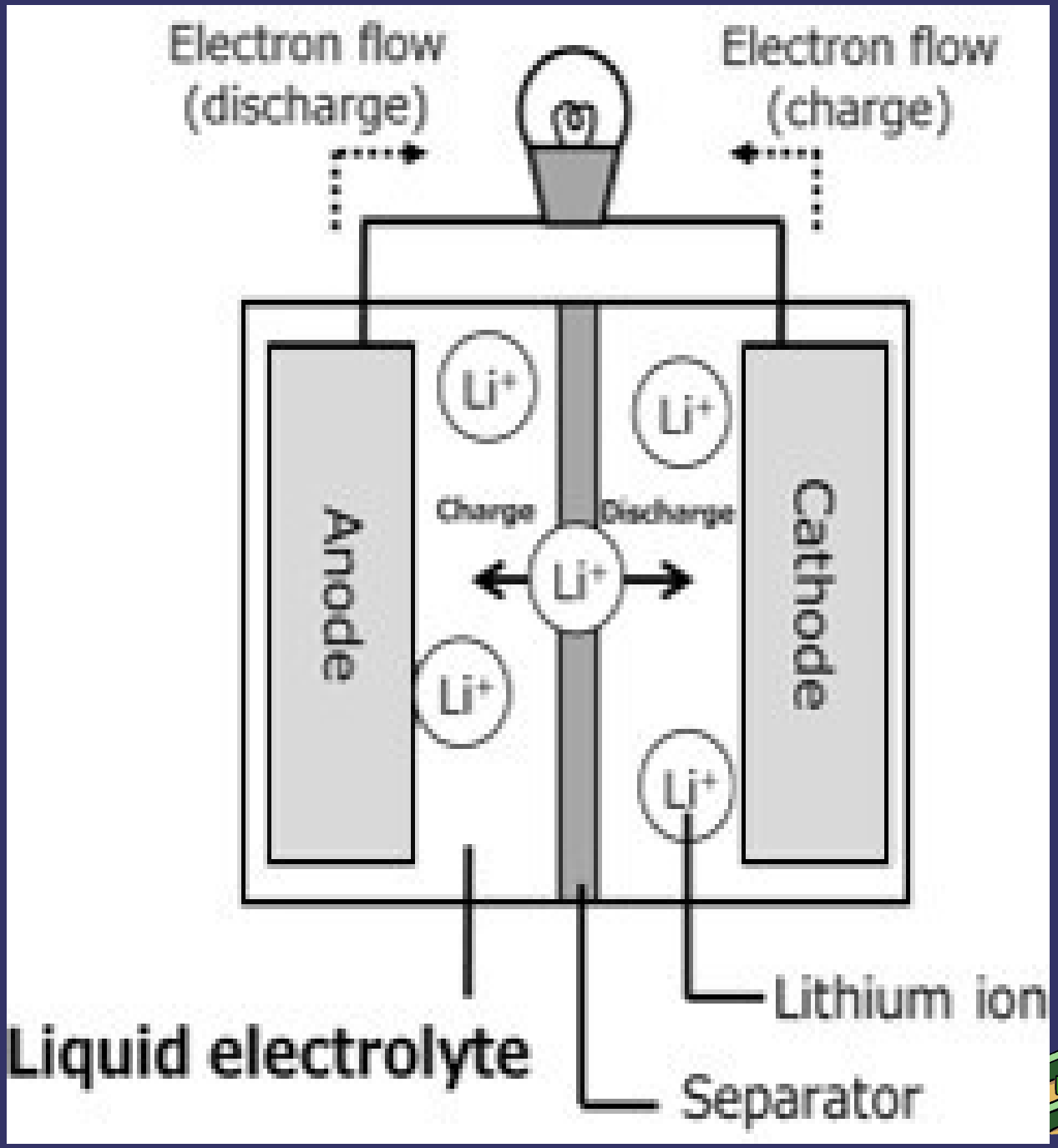
Cathode half reaction :

$$LiCoO_2 \longleftrightarrow Li_{(1-x)}CoO_2 + x\,Li + x\,e^-$$

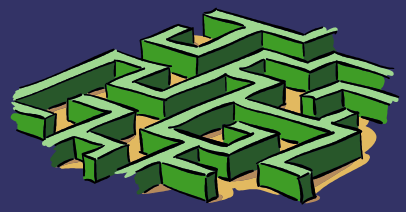
Anode half reaction :

$$x\,Li + x\,e^- + 6C \longleftrightarrow Li_xC_6$$

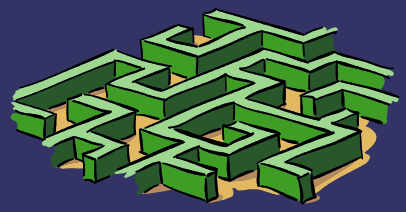



Electron flow
(discharge)
Electron flow
(charge)
Li+
Li+
Charge
Discharge
Li+
Anode
Cathode
Li+
Li+
Lithium ion
Liquid electrolyte
Separator

In lithium ion battery,the lithium ions are transported to and from the cathode or anode,with the transition metal Co in Li (1-x)CoO2 being oxidised from Co+3 to Co+4 during charging and reduced from Co+4 to Co+3 during discharge



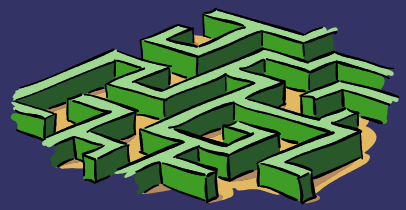
The batteries have a high energy density , no memory effect and low self discharge. .
Depth discharge of Li – ion battery is 80 to 90 %.
Life of Li-ion battery is more than other batteries because its charge-discharge cycle is 188 to 2500.
Depending on materials choices, the voltage ,energy density , life, and safety of a lithium-ion battery can change dramatically.
Pure lithium is highly reactive. It reacts vigorously with water to form lithium hydroxide (LiOH) and hydrogen gas. Thus, a non-aqueous electrolyte is typically used, and a sealed container rigidly excludes moisture from the battery pack.



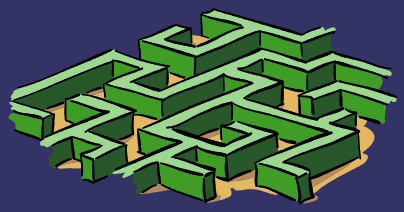
Lithium-ion batteries are more expensive than NiCd batteries but operate over a wider temperature range with higher energy densities.

Applications : Mobiles,laptops,wrist watches,calculators and electric equipments.
Lithium-ion batteries are not to be confused with lithium batteries.

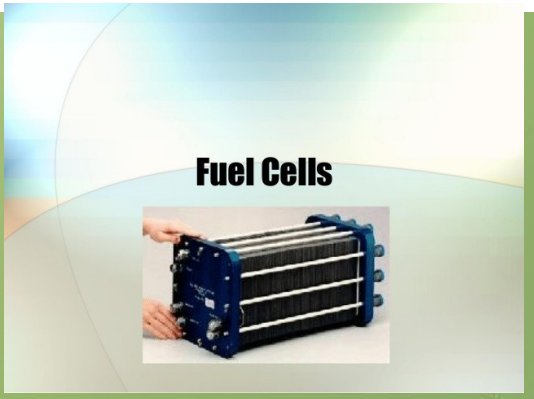
Lithium batteries containing metallic lithium acts as primary batteries while lithium ion batteries are secondary batteries and contain intercalation anode material.



Thank You



Fuel cells

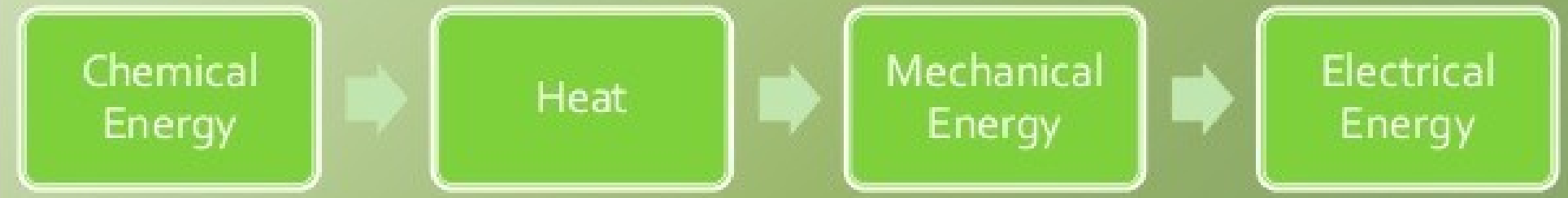


Fuel cells are electrochemical cells consisting of two electrodes and an electrolyte which convert the chemical energy of chemical reaction between fuel and oxidant directly into electrical energy.

❖ Ordinary Combustion process of fuel is

- The process of fuel cell is

- The conventional process to produce electrical energy is as follows:



- But in fuel cell, it directly coverts chemical energy to electrical energy.
- The efficiency of energy conversion in fuel cell approaches 70%. It is only 15-20% in gasoline powered engines and 30 – 35% in diesel engines.

Principle of Fuel Cell:

- Fuel cell consists of electrodes, electrolyte & catalyst to facilitate the electrochemical redox reaction.
- The basic arrangement in a fuel cell can be represented as follows:

Fuel cell consist of

Anode

- A layer of anodic catalyst.

Electrolyte

- A layer of cathodic catalyst.

Cathode

Fuel cell consist of

Anode & Cathode

- Materials which have high electron conductivity & zero proton conductivity in the form of porous catalyst (porous catalyst or carbon).

s

Catalyst

- Platinum

Electrolyte

- High proton conductivity & zero electron conductivity.

➢ Fuel Cell System:

1. The fuel (direct H_2 or reformed H_2) undergoes oxidation at anode and releases electrons.

2. These electrons flow through the external circuit to the cathode.

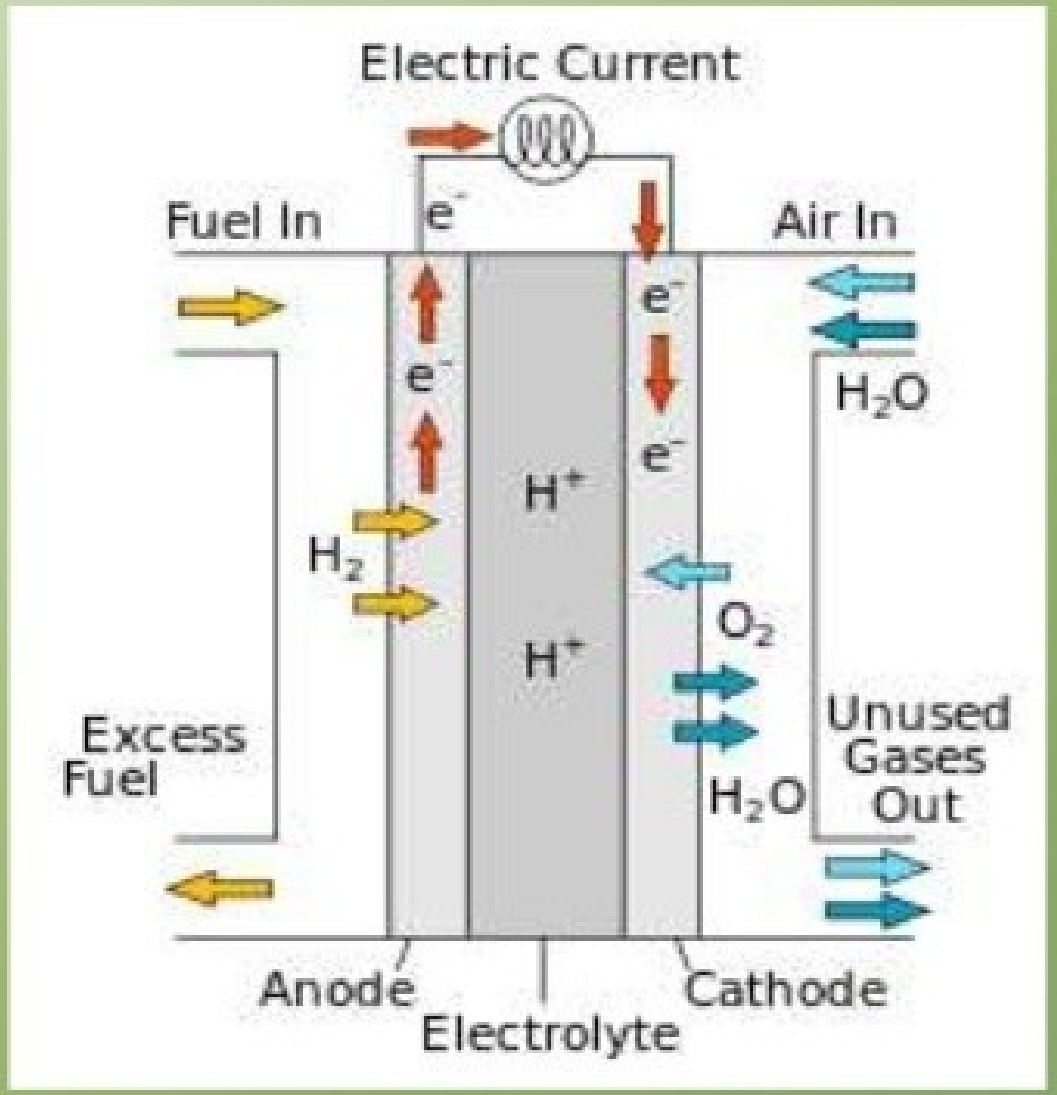
3. At cathode, oxidant (O_2 from air) gets reduced.

4. The electrons produce electricity while passing through the external circuit. Electricity is generated continuously as long as fuel and the oxidant are continuously and separately supplied to the electrodes of the cell from reservoirs outside the electrochemical cell.

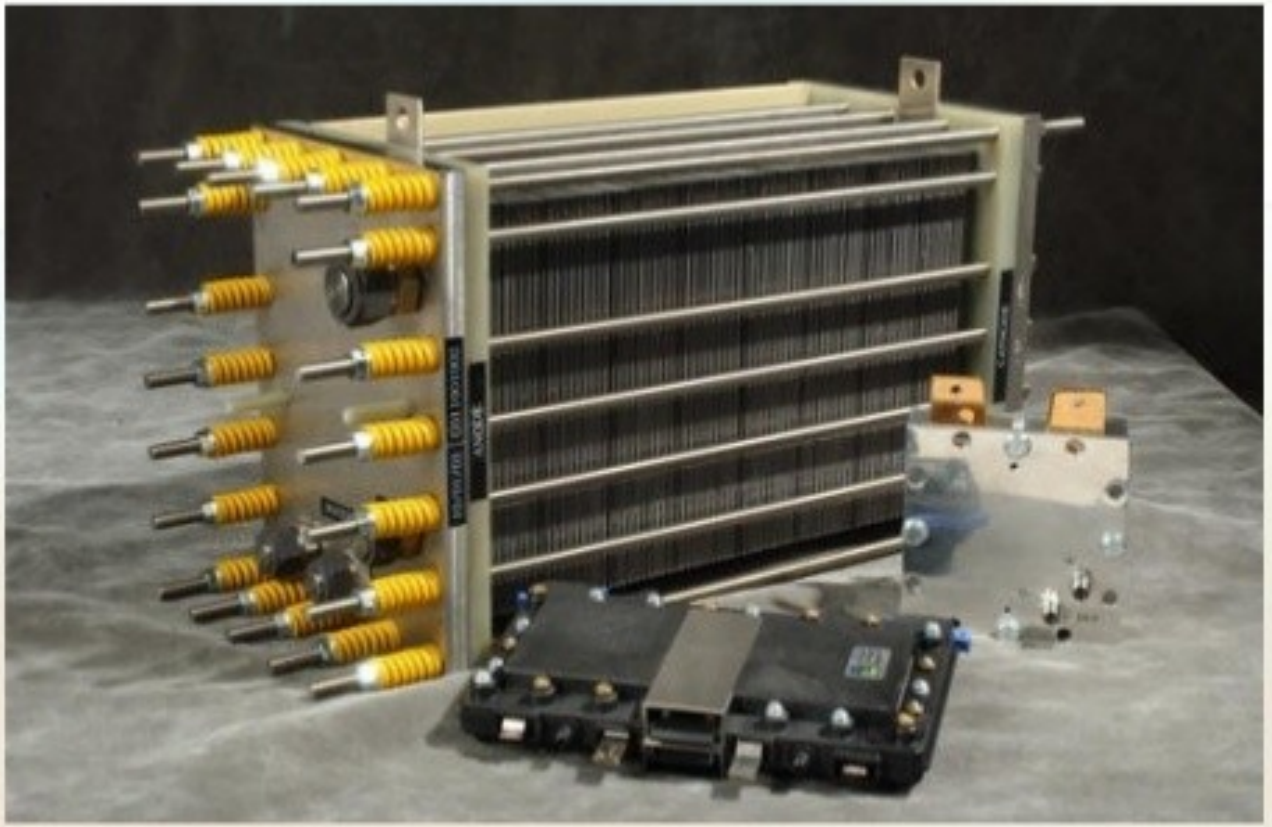
➢ The Fuel cell can be represented as:

At anode	• $2H_2 \rightarrow 4H^+ + 4e^-$
At Cathode	• $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
Overall Reaction	• $2H_2 + O_2 \rightarrow 2H_2O$

➢ Large number of these cells are stacked together in series to make a battery called as fuel cell battery or fuel battery.


Electric Current
Fuel In
Air In
e⁻
e⁻
e⁻
e⁻
H₂O
H⁺
H₂
H⁺
O₂
Excess Fuel
Unused Gases Out
H₂O
Anode
Cathode
Electrolyte

Fuel Cell Stack



http://www.nrel.gov/hydrogen/photos.html

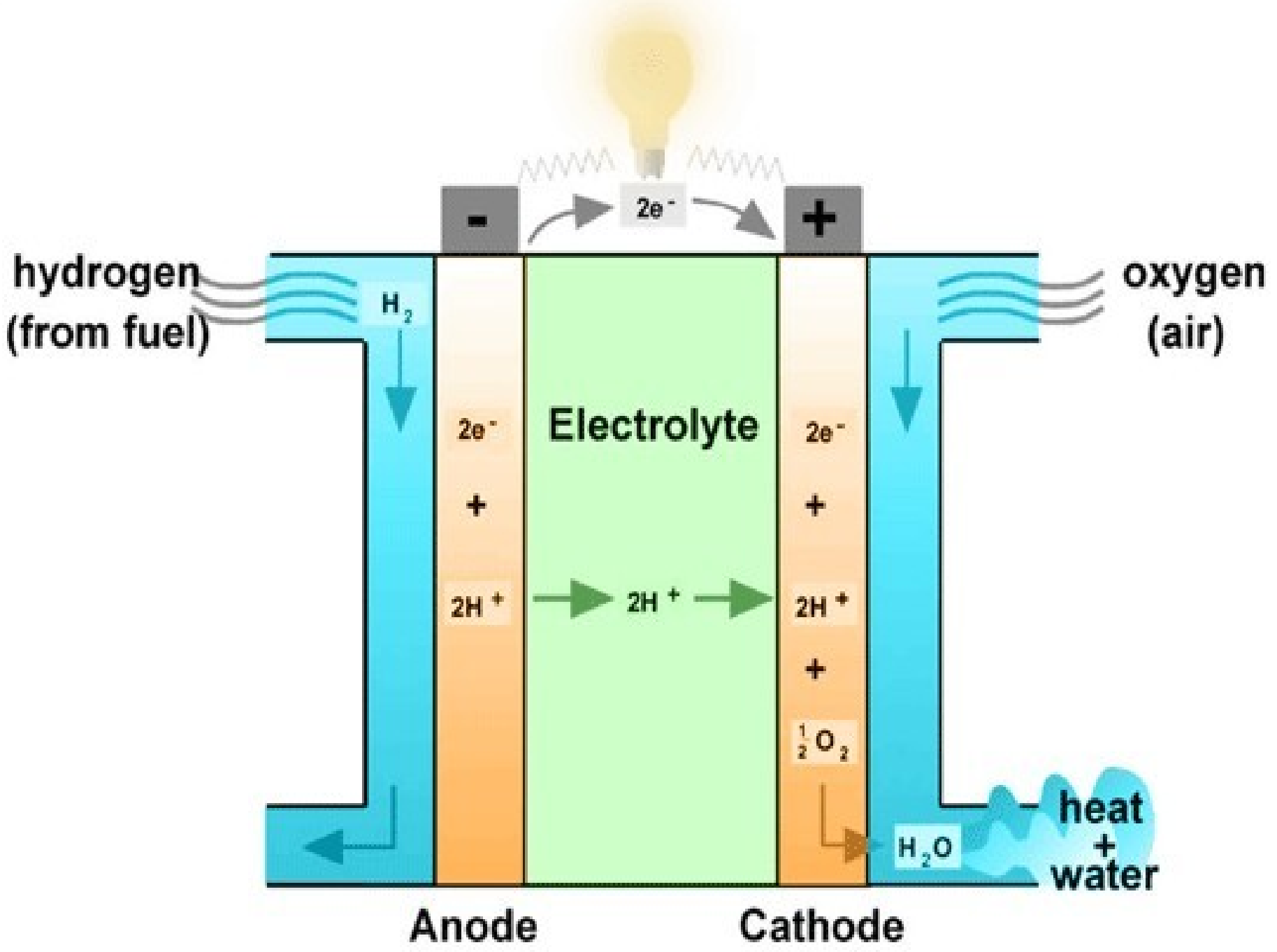


Fig. 2. Schematic of a PEM fuel cell operation. Source: World Fuel Cell Council.

Parts of a Fuel Cell

Anode

- Negative post of the fuel cell.
- Conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit.
- Eached channels disperse hydrogen gas over the surface of catalyst.

Cathode

- Positive post of the fuel cell
- Etched channels distribute oxygen to the surface of the catalyst. Conducts electrons back from the external circuit to the catalyst
- Recombine with the hydrogen ions and oxygen to form water.

Electrolyte

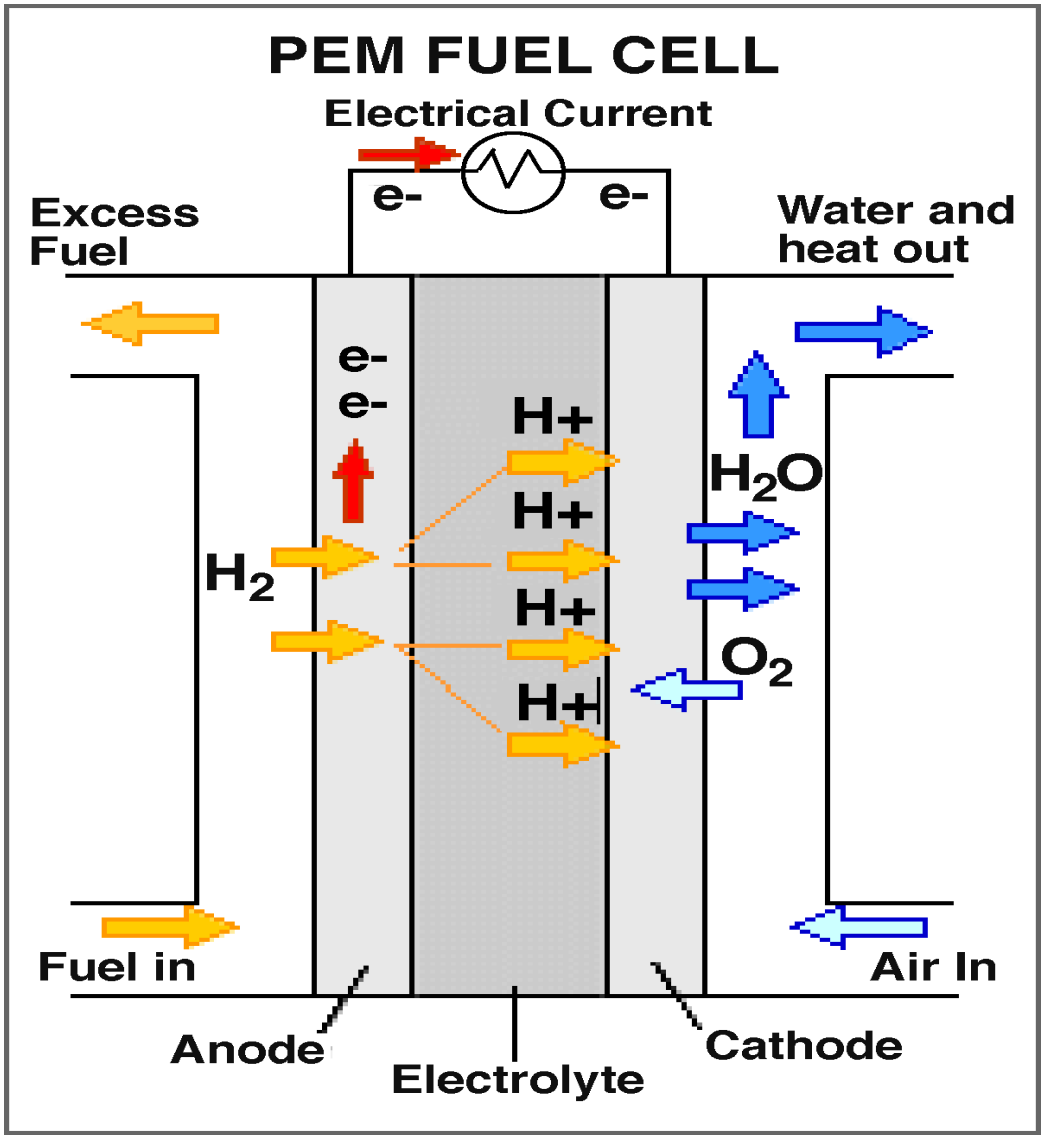
- Proton exchange membrane.
- Specially treated material, only conducts positively charged ions. Membrane blocks electrons.

Parts of a Fuel Cell

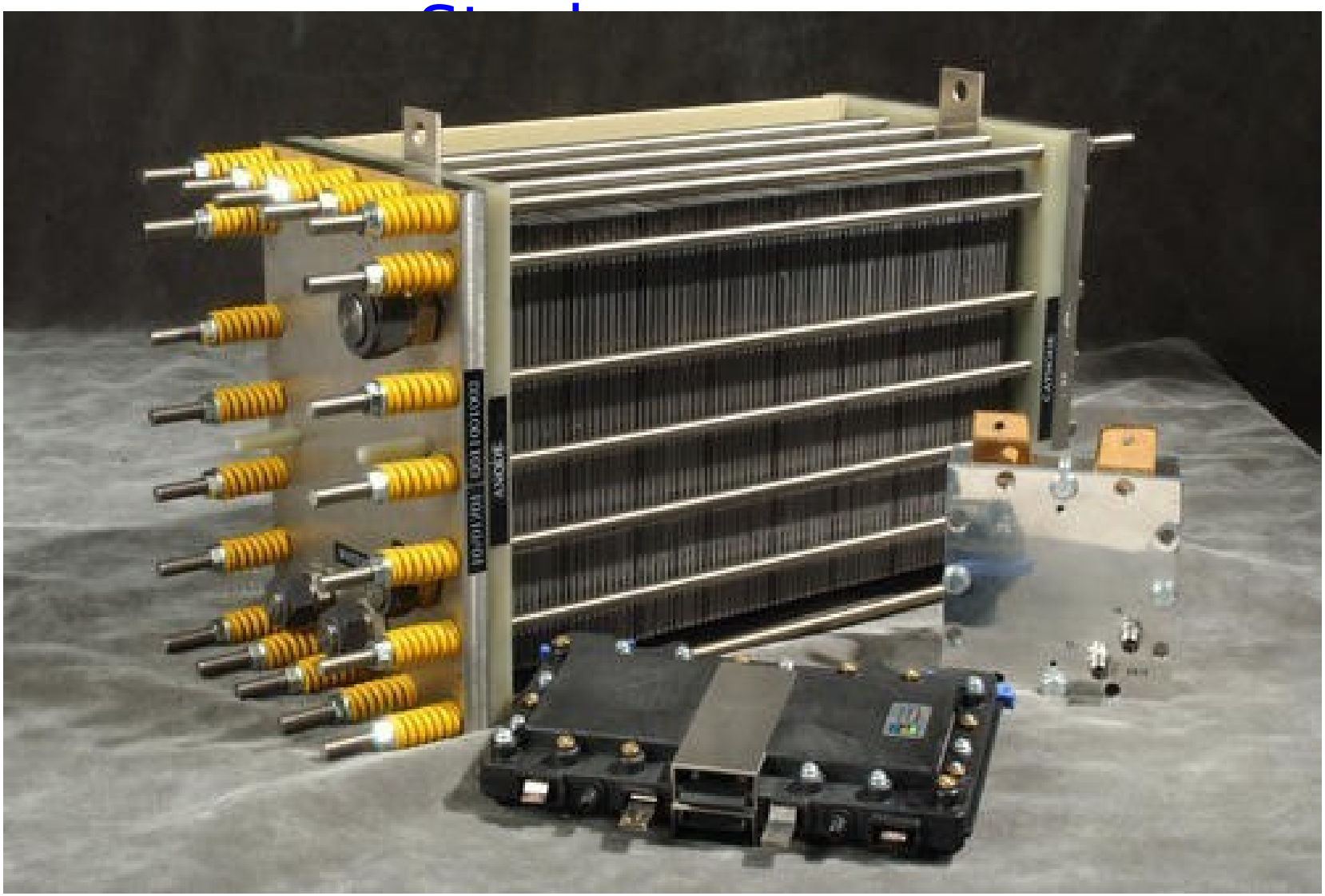
Catalyst

- Special material that facilitates reaction of oxygen and hydrogen Usually platinum powder very thinly coated onto carbon paper or cloth.
- Rough & porous maximizes surface area exposed to hydrogen or oxygen The platinum-coated side of the catalyst faces the PEM.

Proton-Exchange Membrane Cell



Fuel Cell



Advantages of Fuel Cells

1. High efficiency of energy conversion (approaching 70%) from chemical energy to electrical energy.
2. Low noise pollution & low thermal pollution.
3. Fuel cell power can reduce expensive transmission lines & minimize transmission loses for a disturbed system.
4. Fuel cells gives excellent method for efficient use of fossil fuels hence saves fossil fuels.
5. Fuel cells are less polluting. The chemical process involved in it is clean. It does not produce polluting exhaust. Mostly the byproducts are water & waste heat, which are environmentally acceptable when hydrogen & air are used as reactants.

Advantages of Fuel Cells

6. In case of fossil fuels, when used as reactants, environmentally undesirable NO_x are not produced since there is no combustion in the process.
7. Hydrogen-Oxygen fuel cells produce drinking water of potable quality.
8. Designing is modular, therefore the parts are exchangeable.
9. Low maintenance cost.
10. Fuel cell performance is independent of power plant size. The efficiency does not depend on the size of power plant. It remains same for the plants of MW or kW or W size.

Disadvantages of Fuel Cells

- High initial cost.
- Life times of the cells are not accurately known.
- Large weight and volume of gas fuel storage system.
- High cost of pure hydrogen.
- Hydrogen can be stored in lesser volume by liquefaction but liquefaction itself require 30% of the stored energy.
- Lack of infrastructure for distributing hydrogen.

Applications of Fuel Cells

- The first commercial use of fuel cell was in NASA space program to generate power for satellites and space capsules.
- Fuels are used for primary and backup power for commercial, industrial and residential buildings in remote and inaccessible area.
- They are used to power fuel cell vehicles including automobiles, aeroplanes, boats and submarines.


Thank
you