Electrochemical Cell

- An **electrochemical cell** is a device in which a **redox reaction is utilized to get electrical energy**. Commonly referred to as **voltaic or galvanic cell**.
- The electrode where **oxidation** occurs is called **anode** while the electrode where **Reduction** occurs is called **Cathode**.
- An **electrolytic cell** is one in which the electrical energy is converted to chemical energy and resulting in a chemical reaction.

⇒ **Battery:** A device that consists of **one or more electrochemical cells** connected in series or parallel or both and **converts the chemical energy by means of an electrochemical oxidation-reduction reaction** depending on their desired output voltage and capacity

- Zn Electrode dipped in ZnSO4 solution: **Oxidation**
- Cu Electrode dipped in CuSO4 solution: **Reduction**
- Each electrode is referred to as half cell which are connected through a salt bridge

$$Zn(s) \mid ZnSO_4(aq) \,\|\, CuSO_4(aq) \mid Cu(s)$$

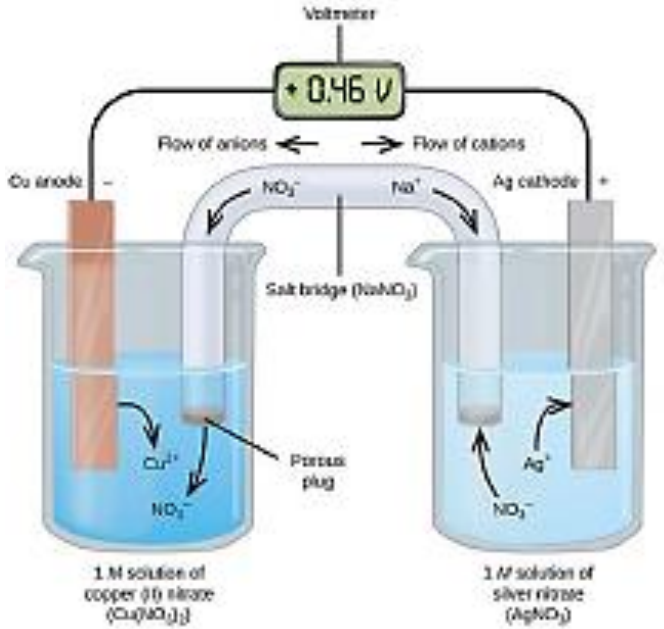
Cell/Battery

- The cell consists of three major components:

A. **The anode or negative electrode:** It gives up electrons to the external circuit and is oxidized during the electrochemical reaction.

B. **The cathode or positive electrode:** It accepts electrons from the external circuit and is reduced during the electrochemical reaction

C. **The electrolyte:** It is the ionic conductor which provides the medium for transfer of charge, as ions, inside the cell between the anode and cathode



- **Basic Concepts of Cells and Batteries**
  - All battery cells are based mainly on the following basic principles:

- When two dissimilar metals are immersed in an electrolyte, there will be a potential difference produced between these metals
- If they are immersed in same electrolyte solution, one of them will gain electrons and the other will release electrons. As a result, there will be a difference in electron concentration between these two metals.
- This difference of electron concentration causes an electrical potential difference to develop between the metals or compounds.
- This electrical potential difference or emf can be utilized as a source of voltage in any electronics or electrical circuit.

Cell/Battery

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- **Representation of galvanic cell**
  - Anode is written on the left-hand side
  - Electrode on the left, Metal| Electrolyte (conc.)
  - # $Zn|ZnSO_4$ (1M)
  - Cathode is written on the right hand side
  - Electrode on the right, Electrolyte (conc.)| Metal
  - # $CuSO_4$ (1M)|Cu
  - A salt bridge is indicated by two vertical lines, separating the two half cells

$$Zn|Zn^{2+}\ (1M) \parallel Cu^{2+}\ (1M)|Cu$$

- **Important applications: It has wide variety of applications & there market is very potential**
  - ✓ Car batteries – Pb/acid cell
  - ✓ Portable electronics – secondary battery
  - ✓ Low power applications – primary battery
  - ✓ From military applications to medical applications

- **Primary battery (Primary cells):** The cell reaction is not reversible. When all the reactants have been converted to product, no more electricity is produced and the battery is dead.
  - # Example: Lechlanche Cell (Dry Cell), Alkaline Cell and Lithium batteries.
- **Secondary battery (secondary cells):** Cell reactions can be reversed by passing electric current in the opposite direction. Thus it can be used for a large number of cycles.
  - # Example: Lead acid batteries, Ni-Cd batteries, Ni-Metal Hydride batteries, Lithium ion batteries.
- **Flow battery and fuel cell:** Materials (reactants, products, electrolytes) pass through the battery, which is simply an electrochemical cell that converts chemical to electrical energy.
  - # Example: Hydrogen-oxygen fuel cell (HOFC), Alkaline fuel cell (AFC), Solid oxide fuel cell(SOFC), etc.

Lithium Primary Batteries

- Lithium batteries have high charge density & long life
- Lithium cells can produce voltages from 1.5 V – 3.7 V (comparable to a Zn-C or alkaline battery)
- Lithium cells are primary cells in which lithium acts as anode and the cathode may differ.

❑ The main attractions of lithium as an anode material is

- Most electropositive metal in electrochemical series
- It has very low density
- Largest amount of electrical energy per unit weight

❑ Li can't be used with traditional aqueous electrolytes

- Very vigorous corrosive reaction between Li & water
- Flammable hydrogen as the product.

❑ Lithium-Manganese Dioxide Cell

✓ The electrolyte in this system is a solid

✓ The active cathode material consists of a specially prepared [treated @ 300 °C] mixture of electrolytic MnO_2 and other specific components. It yields an outstanding volume/capacity ratio.

⇒ Anode: Lithium metal

⇒ Cathode: Carbon in contact with MnO_2

⇒ Electrolyte: $LiBF_4$ salt in a mixture of propylene carbonate and dimethoxy ethane.

⇒ Voltage: 3 V

✓ $Li|Li^+$ (nonaqueous)/nonaqueous Li salt paste$|MnO_2^-|MnO_2$, C

or, Li/Li^+(nonaqueous)$|MnO_2$

❑ Reactions:

→ @ Anode: $Li \rightarrow Li^+ + e^-$,

→ @ Cathode: $MnO_2 + e^- \rightarrow MnO_2^-$

→ Net reaction: $Li^+ + MnO_2^- \rightarrow LiMnO_2$

Lithium Primary Batteries

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❑ **Lithium-Manganese Dioxide Cell: Alkaline medium**

➢ The cell is represented as

Li|Li^+(nonaqueous)|KOH(paste)|MnO_2,$Mn(OH)_2$,C

➢ The electrolyte is a paste of aqueous KOH.

→ @ anode:

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

→ @cathode:

$$MnO_2 + 2H_2O + e^- \rightarrow Mn(OH)_2 + OH^-$$

→ **Net reaction:**

$$Li + MnO_2 + 2H_2O \rightarrow Li^+ + Mn(OH)_2 + OH^-$$

❑ **Applications**

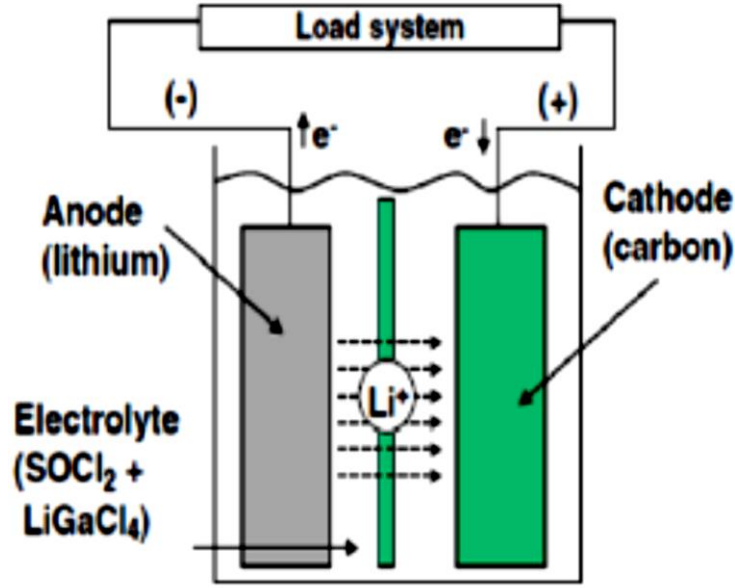
➢ The coin type cells are used in watches and calculators.

➢ Cylindrical cells are used in fully automatic cameras

❑ **Li-$SOCl_2$ Cell**

➢ It consists of high surface area carbon cathode, a non-woven glass separator.

➢ Thionyl chloride ($SOCl_2$) acts as an electrolyte & as a cathode.



❑ Sometimes $LiGaCl_4$ is added to avoid its decomposition

❑ **Cell reaction:**

⇒ @ Anode: $Li \rightarrow Li^+ + e^-$

⇒ @Cathode: $4Li^+ + 4e^- + 2\,SOCl_2 \rightarrow 4\,LiCl + SO_2 + S$

⇒ Net reaction: $4\,Li^+ + 2\,SOCl_2 \rightarrow 4\,LiCl + SO_2 + S$

❑ Li-$SOCl_2$ Cell is an example of liquid cathode. The co-solvents used are acrylonitrile or propylene carbonate (or) mixture of the two with SO_2 in 50% by volume.

$$2\,Li + 2\,SO_2 \rightarrow Li_2S_2O_4$$