



## Electric Batteries and Electrochemical Cells

### Tags:

- **GS Paper - 3**
- **Scientific Innovations & Discoveries**
- **Growth & Development**

For Prelims: Electrochemical Cells, Electric vehicles, Voltaic Cells, Lithium-ion Technology, Nobel Prize in Chemistry for 2019, Applications of Electric Batteries.

For Mains: Electrochemical Cells, Evolutionary Trajectory of Batteries.

### Why in News?

The electric batteries and electrochemical cell advancements have garnered significant attention for revolutionizing technology across sectors like transport and energy, steering us toward a sustainable future.

### What are Electric Batteries and Electrochemical Cells?

#### ▪ **Electric Batteries:**

- An **Electric battery** is a device that **stores chemical energy** and converts it into electricity.
  - Batteries are made up of **one or more electrochemical cells** that are connected to **external inputs and outputs**.
- Electric batteries have transformed our world, **enabling the proliferation of motorization and wireless technology**.
- **Major Applications:**
  - **Portable Electronics:** Powering smartphones, laptops, tablets, and wearable devices.

- Transportation: Driving electric vehicles (EVs) for both personal and public transportation, reducing reliance on fossil fuels.
- **Renewable Energy Storage:** Storing energy **generated by** solar panels **and wind turbines for later use.**
- **Electricity for Remote Areas:** Providing **electricity in remote or off-grid locations** where conventional power sources are unavailable or unreliable.
- **Major Types of Batteries:**
  - **Solid-state battery:** It is a battery that uses solid electrodes and a solid electrolyte instead of a liquid or polymer gel electrolyte.
    - Solid-state batteries are used in a variety of devices, including: **pacemakers, radio frequency identifications (RFID) and wearable devices.**
  - **Nickel–Cadmium battery (Ni-Cd):** They are used for **Cordless electronic appliances, drills, camcorders** and other small battery-operated devices requiring an even power discharge.
  - **Alkaline Battery:** This is a type of primary battery that uses zinc and manganese dioxide as electrodes.
    - It is used for applications that require low cost and reliable power, such as **flashlights, toys, radios, and remote controls.**
  - **Lithium-ion Battery:** The Li-ion battery's groundbreaking principles earned its developers the Nobel Prize in Chemistry **in 2019**, underscoring its profound impact in the 20th and 21st centuries.
    - Li-ion batteries are versatile, **powering portable devices like phones and laptops** as well as fueling electric vehicles such as **cars and bikes.**
- **Electrochemical Cells:**
  - **Electrochemical cells** are devices that can **convert chemical energy into electrical energy, or vice versa.**

- They can produce an electric current through chemical reactions, or they can use electrical energy to facilitate chemical reactions.
- Electrochemical cells, like **voltaic or galvanic cells**, operate via **redox reactions** wherein **electrons are liberated during oxidation and utilized during reduction**.
  - A standard cell comprises two sections accommodating metal electrodes immersed in specific electrolytes.
    - The electrodes, namely the **anode and the cathode, conduct electricity**.
    - The **anode, where oxidation occurs**, and the **cathode, where reduction takes place**, form the fundamental components of the cell.
  - **Electrons flow from the negatively charged anode to the positively charged cathode** through an external circuit, providing power for a variety of uses.
    - Connecting these halves is a wire and a salt bridge, facilitating the movement of ions between them.
  - The **energy carried by electrons dictates the source voltage**, steering the electron flow within the circuit.
    - In ideal conditions, the **source voltage is equal to the terminal voltage**, ensuring an efficient power supply.
  - Advancements in cell design and materials, seen in **nickel-cadmium, zinc-copper, and modern** lithium-ion cells, showcase increased voltages and enhanced efficiency.
- **Related Challenges:**
  - One of the well-known challenges affecting the efficiency of electrochemical cells is corrosion. For instance, in **environments with high humidity**, electrodes can gather water droplets.
    - If the atmospheric carbon dioxide levels are elevated, the **combination of water and gas leads to the formation**

of **carbonic acid**, causing **corrosion** on the electrode surfaces.

- Another issue arises from **galvanic corrosion**, where one of the electrodes within a cell **deteriorates faster in the electrolyte due to its higher reactivity**.
  - For instance, in a **carbon-zinc battery**, the zinc electrode erodes more rapidly during the battery's usage.

## What is the Evolutionary Trajectory of Batteries?

### ▪ Galvani's Experimentation (1780):

- Luigi Galvani's experiment **involving metals and frog legs** revealed a curious connection between **electrical energy and muscle movement**, laying the groundwork for future battery development.

### ▪ Voltaic Pile (1800):

- Alessandro Volta's voltaic pile marked a significant step, **generating a steady current using metal plates and electrolytes**.
  - However, its functionality remained a mystery.

### ▪ Faraday's Insights (Early 19<sup>th</sup> Century):

- Michael Faraday's groundbreaking work deciphered the mechanisms behind the cells, unveiling the roles of components like anode, cathode, and electrolyte.

### ▪ Lithium-Ion Batteries: This battery functions as both a voltaic and an electrolytic cell, capable of converting chemical energy into electrical energy and vice versa, enabling recharging.

- In lithium-ion cells, **lithium metal oxide and graphite act as cathode and anode**, respectively, with a semisolid polymer gel electrolyte separating them.
- The intercalation process enables charge and discharge phases.

**Note:** The Nobel Prize in Chemistry for 2019 was awarded to **John B. Goodenough, M. Stanley Whittingham, and Akira Yoshino** for their contributions to the development of the lithium-ion battery.

**UPSC Civil Services Examination, Previous Year Question (PYQ)**

Q. Which one of the following pairs of metals constitutes the lightest metal and the heaviest metal, respectively? (2008)

- (a) Lithium and mercury
- (b) Lithium and osmium
- (c) Aluminium and osmium
- (d) Aluminium and mercury

Ans: (b)

