Batteries:

When Galvanic cells are connected in series to obtain a higher voltage the arrangement is called "Battery". Any cell or Battery (more than one cells connected in series) that we use daily as a source of electricity in basically a galvanic cell in which chemical energy of spontaneous redox reactions is converted into electrical energy.

An ideal battery should have following desirable characters.

- **It should be reasonably light and compact**
- **Its voltage should not drop much during its use. There are mainly three types of cell**

(a)Primary Batteries

(b) Secondary batteries

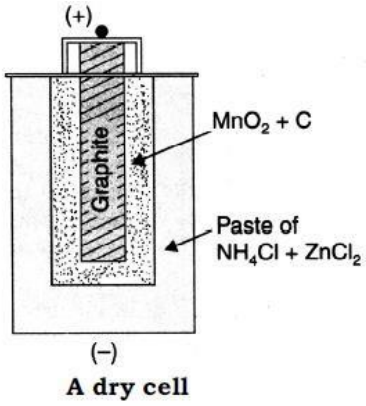
(c) Fuel cell

Primary Batteries

In this type of cell, once the chemicals have been consumed, further reaction is not possible. It cannot be regenerated by reversing the current flow through the cell using an external source of electrical energy. The most common example of this type is dry cell which is used in clocks etc. and Mercury cell.

Dry cell

It consists of a zinc container (that acts as anode) and cathode is a carbon (graphite) rod surrounded by powdered Manganese dioxide (MnO2) and carbon. A moist mixture of ammonium chloride, manganese dioxide, zinc chloride and porous inert filler occupy the space between the paper lined zinc container and the carbon rod. The cell is sealed with a material like wax. Reactions are:



A dry cell

Anode: $Zn\ (s) \rightarrow Zn^{2+} + 2e^-$

Cathode: $MnO_2 + NH_4^+ + e \rightarrow MnO(OH) + NH_3$

(Manganite)

NH3 produced forms a complex with Zn2+ to give $[Zn(NH_3)_2]^{2+}$ (diammine zinc (II) cation) .The cell has a potential of nearly 1.5V.

Secondary Batteries (Lead Storage Battery)

A secondary cell after use can be recharged by passing current through it in the opposite direction so that it can be used again eg. Lead storage Battery, Ni-Cd battery. Lead storage battery:

It is the most frequently used battery in automobiles. It consists of six voltaic cells connected in series. The anode and cathode plates are separately connected to each other so as to increase the electrode area in contact with electrolyte solution. When the cell discharges; it operates as a voltaic cell.

It consists of lead anode and a grid of lead packed with lead dioxide (PbO2) as cathode. A 38% solution by mass of H_2SO_4 is used as electrolyte.

Discharging Reactions:

Anode:

$$Pb\,(s) + SO_4^{2-}\,(aq) \rightarrow PbSO_4\,(s) + 2e^-$$

Cathode:

$$PbO_2\,(s) + SO_4^{2-}\,(aq) + 4H^+ + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$$

Overall Reaction:

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

Recharging the battery

To recharge the cell it is connected with a cell of higher potential and this cell behaves as an electrolytic cell and the reactions are reversed, $PbSO_4$(s) is converted into Pb and PbO_2 at anode and cathode respectively. H_2SO_4 is consumed while discharging and is regenerated while re-charging, thus increasing the specific gravity during recharge of the battery.

Cathode (–ve):

$$PbSO_4\,(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}\,(aq)$$

Anode (+ve):

$$PbSO_4\,(s) + 2H_2O\,(l) \rightarrow PbO_2\,(s) + SO_4^{2-}\,(aq) + 4H^+\,(aq) + 2e^-$$

Net reaction:

$$2PbSO_4\,(s) + 2H_2O\,(l) \rightarrow Pb(s) + PbO_4\,(s) + 4H^+\,(aq) + 2SO_4^{2-}(aq)$$

Fuel Cell

These are galvanic cells. A fuel cell differs from an ordinary battery in the sense that reactants are not contained inside the cell but are externally supplied from an external reservoir. The main disadvantage of a primary cell is that it can deliver current for a short period only. This is due to the fact that the quantity of oxidising agent and reducing agent is limited. But the energy can be obtained indefinitely from a fuel cell as long as the outside supply of fuel is maintained.

Hydrogen-Oxygen Fuel Cell

The cell consists of three compartments separated by a porous electrode. Hydrogen gas is introduced into one compartment and oxygen gas is fed into another compartment. These gases then diffuse slowly through the electrodes and react with an electrolyte that is in the central compartment. The electrodes are made of porous carbon and the electrolyte is a resin containing concentrated aqueous sodium hydroxide solution. Catalysts like finely divided Pt or Pd metal are incorporated into the electrodes for increasing the rate of electrode reactions.

Hydrogen is oxidised at anode and oxygen is reduced at cathode. These type of cells are used in space-crafts. Fuel cells are efficient and pollution free. The overall cell reaction produces water.

Anode: $2H_2\,(g) + 4OH^-\,(aq) \rightarrow 4H_2O\,(l) + 4e^-$

Cathode: $O_2\,(g) + 2H_2O\,(l) + 4e^- \rightarrow 4OH^-\,(aq)$

Overall Reaction:

$$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(l)$$

Efficiency of cell is about 70% to produce electricity in comparison to thermal plants whose efficiency is about 40%.