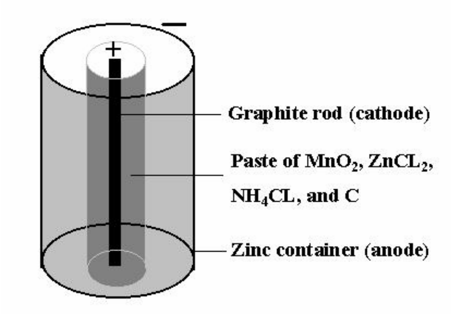
Batteries

A **battery** is a device consisting of a galvanic cell or a series of combined galvanic cells that can be used to derive a direct electric current at a constant voltage. Even though, battery is galvanic in nature, it has one advantage; it is self-contained and requires no salt bridge. Here few common batteries are discussed.

The Dry Cell Battery

This is a most common dry cell battery without any fluid component and is known as a *Leclanche' cell* that is used in flashlights, toys, transistor radios.



It consists of zinc (Zn) container as anode that is in contact with paste of manganese dioxide (MnO_2), zinc chloride ($ZnCl_2$), ammonium chloride (NH_4Cl), and carbon (C). The cathode consists of graphite or a carbon rod placed in the center. The simplified cell reactions from a complex process are:

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

Cathode : $2MnO_2(s) + NH_4^+(aq) + 2\ e^- \rightarrow Mn_2O_3(s) + 2\ NH_3(g) + H_2O(l)$

Overall: $Zn(s) + 2MnO_2(s) + NH_4^+(aq) \rightarrow Zn^{+2} + Mn_2O_3(s) + 2\ NH_3(aq) + H_2O(l)$

Further, Zn^{+2} ion and ammonia form a complex ion, $Zn(NH_3)_4^{+2}$.

Voltage: This dry cell produces about 1.5V.

Advantage: Low price and works normally without a leak.

Disadvantage: Low self-life due to the build up of ions around electrodes preventing further redox reaction and can't be recharged.

A more popular and latest version of *Leclanche'* battery is **alkaline battery** or **alkaline dry cell** that uses alkaline electrolyte (basic). It also uses Zn and MnO_2 as reactants but in basic medium that eliminates the problem producing $Zn(NH_3)_4^{+2}$ complex ion. The cell reactions are:

Anode: $Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

Cathode: $2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$

Overall: $Zn(s) + 2MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$

Voltage: Produces about 1.54 V.

Advantage: Longer self-life, slightly higher current for a longer period of time due to no ions are produced and there is no build up of ions around electrodes.

The Mercury Battery

The mercury battery is more expensive than the common dry cell and mainly used in electronic and medical devices, such as, hearing aids, electronic watches, and pacemakers. This battery consists of a stainless steal container with zinc amalgamated with mercury (Zn(Hg)) as anode, which is in contact with a strong alkaline electrolyte of zinc oxide and mercury(II) oxide. The cell reactions are:

Anode: $Zn(Hg) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$

Cathode: $HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2OH^-(aq)$

Overall: $Zn(Hg) + HgO(s) \rightarrow ZnO(s) + Hg(l)$

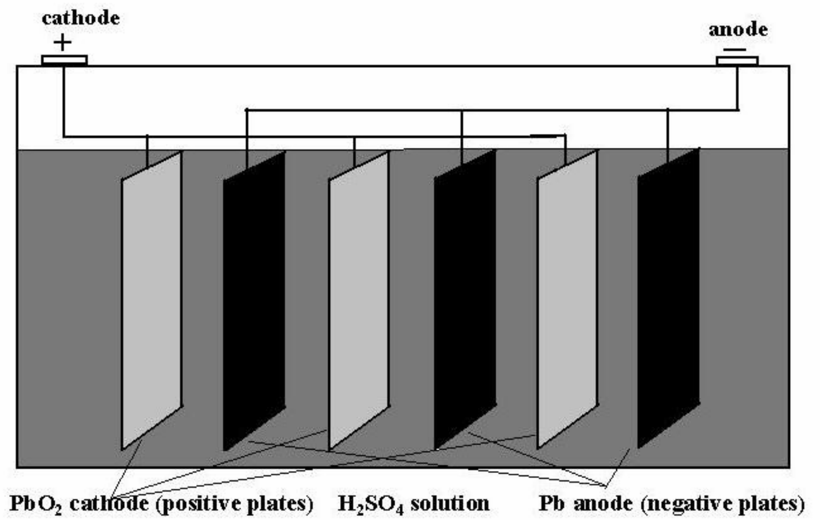
Voltage: It provides a constant voltage of 1.35V than *Leclanche' cell*.

Advantage: Longer self-life and higher capacity, only solid substances are involved as reactants.

The Lead Storage Battery

The lead storage battery is commonly used in automobiles consists of identical cells connected in series. Each cell provides 2V and when they are connected in series, their voltages are additive. Most automobile batteries contain six cells to give a total of 12V. But batteries with 6V, 24 V, and 32V are also available.

Each cell has anode and cathode. Anode consisting of set of lead (Pb(s)) plates and cathode composed of a set of lead plates covered with lead oxide (PbO_2). Both electrodes are immersed in an electrolyte, a mixture of water and highly concentrated solution of sulfuric acid (H_2SO_4 (aq)). Schematic diagram is shown below:



The cell reactions are:

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

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

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

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

Voltage: This cell produces 2 V.

Advantage: The lead storage battery delivers large amounts of current. Unlike Leclanche' cell, it is rechargeable.

Disadvantage: It is very heavy and contains corrosive sulfuric acid that can spill.

As the cell discharges (means the overall electrochemical reaction takes place as written above), sulfuric acid is consumed thereby decreasing its concentration that provides a suitable method for checking the condition of the battery by measuring its density with a device known as **hydrometer**. The density of the fluid in a fully charged battery (healthy battery) should be greater than or equal to 1.290 g/cm^3 (38 % H_2SO_4 by weight). When the density falls below this value, the battery becomes weaker; the degree of weakness is directly correlated with the decrease in density.

The weak battery can be rejuvenated by recharging that means reversing the above overall reaction by applying the voltage from an external source (electrolysis process) to regenerate original materials. The overall reaction that does this is

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

Modern Battery Chemistry

(taken from http://electronics.howstuffworks.com/battery2.htm)

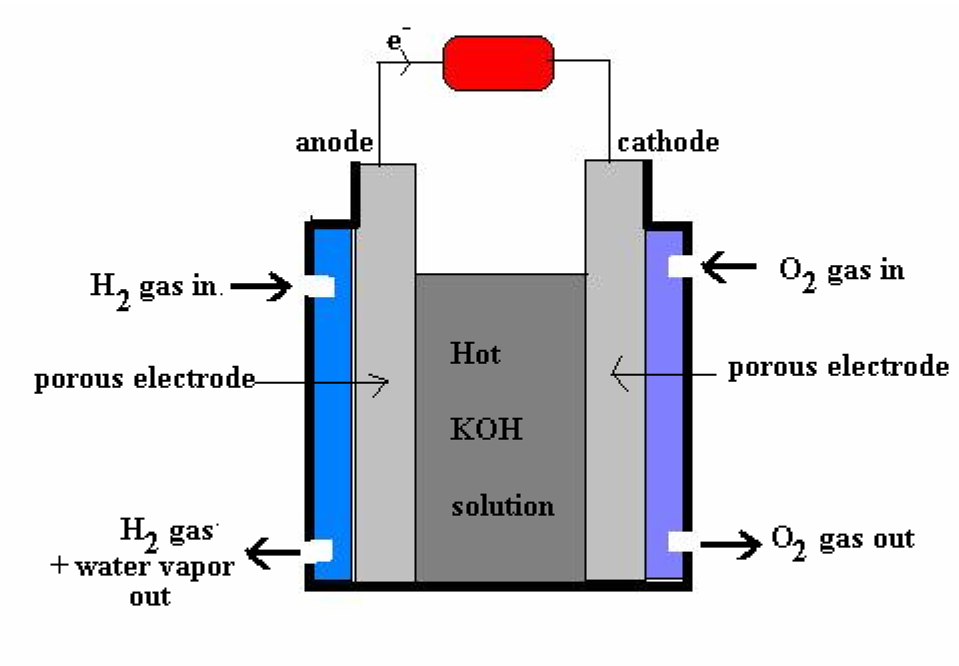
Modern batteries use a variety of chemicals to power their reactions. Typical battery chemistries include:

- **Zinc-carbon battery** - Also known as a **standard carbon** battery, zinc-carbon chemistry is used in all inexpensive AA, C and D dry-cell batteries. The electrodes are zinc and carbon, with an acidic paste between them that serves as the electrolyte.
- **Alkaline battery** - Used in common Duracell and Energizer batteries, the electrodes are zinc and manganese-oxide, with an alkaline electrolyte.
- **Lithium photo battery** - Lithium, lithium-iodide and lead-iodide are used in cameras because of their ability to supply power surges.
- **Lead-acid battery** - Used in automobiles, the electrodes are made of lead and lead-oxide with a strong acidic electrolyte (rechargeable).
- **Nickel-cadmium battery** - The electrodes are nickel-hydroxide and cadmium, with potassium-hydroxide as the electrolyte (rechargeable).
- **Nickel-metal hydride battery** - This battery is rapidly replacing nickel-cadmium because it does not suffer from the memory effect that nickel-cadmiums do (rechargeable).
- **Lithium-ion battery** - With a very good power-to-weight ratio, this is often found in high-end laptop computers and cell phones (rechargeable).
- **Zinc-air battery** - This battery is lightweight and rechargeable.
- **Zinc-mercury oxide battery** - This is often used in hearing-aids.
- **Silver-zinc battery** - This is used in aeronautical applications because the power-to-weight ratio is good.
- **Metal-chloride battery** - This is used in electric vehicle

Fuel Cells

The galvanic cells discussed above are wonderful but produce power for a limited time because electrolytes are eventually exhausted. On the other hand, fossil fuels, our major source of energy, are very inefficient; the most modern electric plants can harness only about 35 - 40% of the chemical energy in coal, natural gas or oil. The rest of the energy is lost to the surrounding in the form of heat. Considering these facts, the fuel cells become more attractive.

Fuel cells are also electrochemical cells in which reactants are supplied on a continuous basis to make them operate endlessly as long as supply of reactants is maintained. One such a fuel cell is **hydrogen-oxygen fuel cell**, which consists of two inert electrodes immersed in an electrolyte of hot potassium hydroxide solution. Oxygen and hydrogen gases are bubbled through the anode and cathode compartments.



Anode : Oxidation

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

Cathode: Reduction

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

Over all: $2H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$

The standard cell potential can be calculated using the table as follows:

$$E^0_{cell} = E^0_{Ox} + E^0_{Red} = 0.40\ V + 0.83\ V = 1.23\ V$$

Advantage: About 70% efficient. Free of all problems associated with conventional power plants, such as, noise, heat transfer, thermal pollution, etc.

Disadvantage: Lack of cheap electro-catalysts.

So far, fuel cells have been successfully utilized in space vehicles. It has been forecasted that the world fuel cell industry will amount to well over 23 billion dollar by year 2010.