Chemistry 201

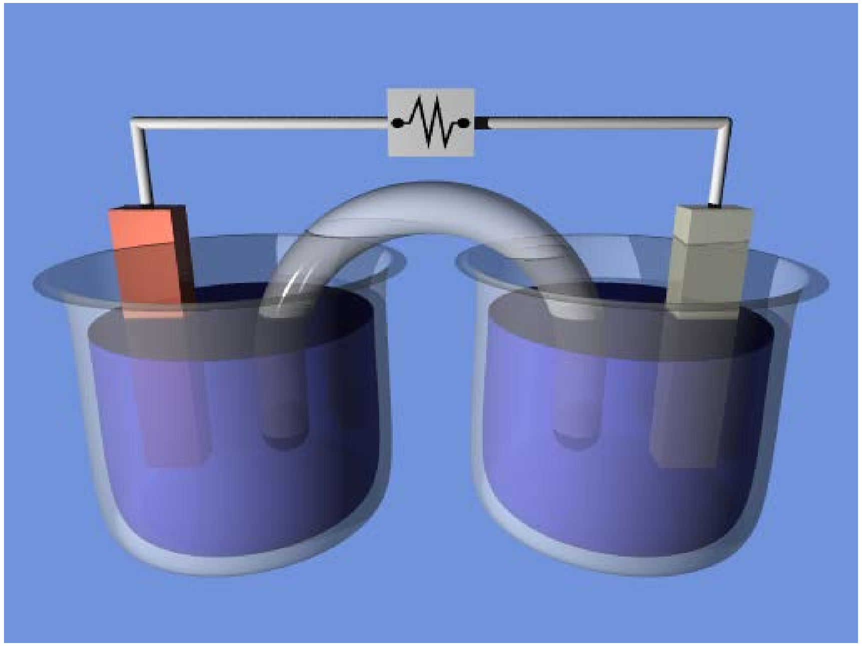
Batteries: an example of a galvanic cell

NC State University

Battery: voltaic cell application ($E_{cell} > 0$)

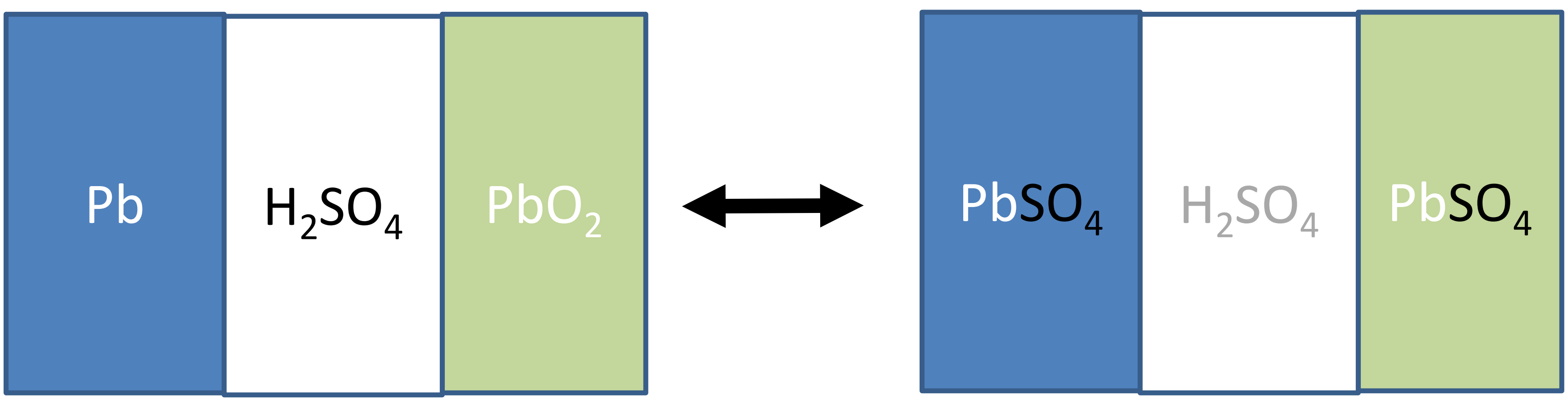
A battery is a device that converts chemical energy into electrical energy. It consists of one or more connected voltaic cells. Each voltaic cell consists of two half cells connected in series by a conductive electrolyte containing anions and cations. The half Cells contain the anode (-) and cathode (+).

In the redox reaction that powers the battery, cations are reduced at the cathode, while anions are oxidized at the anode.



Automotive battery

An automotive battery is a rechargeable battery that supplies electric energy required to start the turnover of a motor or as the main power source in an electric car.
They are lead-acid batteries made of six galvanic cells in series to provide a 12 volt potential. Each cell provides 2.1 volts for a total of 12.6 volt at full charge. Heavy vehicles such as highway trucks or tractors, often equipped with Diesel engines, may have two batteries in series for a 24 volt system, or may have parallel strings of batteries.



Automotive battery

Lead-acid batteries are made up of plates of lead and separate plates of lead dioxide, which are submerged into an electrolyte solution of about 35% sulfuric acid and 65% water. As the battery discharges, the acid of the electrolyte reacts with the electrode surface to form lead sulfate. When the battery is recharged the lead sulfate reforms into lead oxide and lead.

Negative plate reaction:

$$Pb(s) + \ HSO_4^-(aq) \rightarrow PbSO_4(s) + H^+(aq) + 2e^-$$

Positive plate reaction:

$$PbO_2(s) + \ HSO_4^-(aq) + 3\,H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2\,H_2O(\ell)$$

Net reaction:

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

The dry cell battery

The most common type of battery used today is the "dry cell" battery. There are many different types of batteries ranging from the relatively large "flashlight" batteries to the minaturized versions used for wristwatches or calculators. Although they vary widely in composition and form, they all work on the sample principle. A "dry-cell" battery is comprised of a metal electrode or graphite rod (elemental carbon) surrounded by a moist electrolyte paste enclosed in a metal cylinder.
In the most common type of dry cell battery, the cathode is composed of a form of elemental carbon called **graphite**, which serves as a solid support for the reduction half-reaction.

The dry cell battery

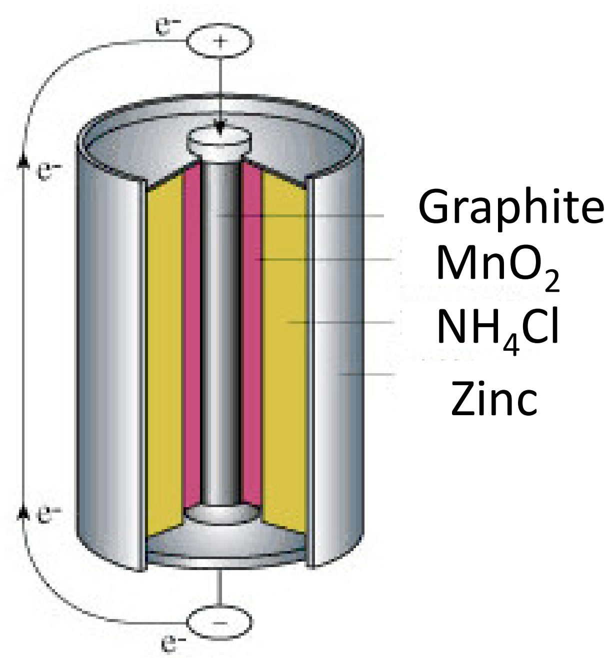
In an acidic dry cell, the reduction reaction occurs within the moist paste comprised of ammonium chloride (NH_4Cl) and manganese dioxide (MnO_2):

$2\ NH_4^+ + 2\ MnO_2 + 2e^- \text{----> } Mn_2O_3 + 2\ NH_3 + H_2O$

A thin zinc cylinder serves as the anode and it undergoes oxidation:

$Zn\ (s) \text{-----> } Zn^{+2} + 2e^-$

This dry cell "couple" produces about 1.5 volts, but can be linked in series to boost the voltage produced.



The alkaline battery

In the **alkaline** version or **"alkaline battery"**, the ammonium chloride is replaced by KOH or NaOH

$$Zn + 2\ OH^- \text{ -------> } ZnO + H_2O + 2e^-$$

$$2\ MnO_2 + 2e^- + H_2O \text{ -------> } Mn_2O_3 + 2\ OH^-$$

Since these batteries have magic power we will need to use a modified Nernst equation that includes the a magic power correction.