Daniell cell: construction and working

JOHN FREDRRIC DANIELL, a British chemist & meteorologist, was the inventor of the daniell cell. He invented it in 1836. He wanted to eliminate the hydrogen bubble problem which is found in the voltaic pile, and his solution was to use a second electrolyte to consume the hydrogen produced by the first. The Daniell cell was a great invention over the existing technology used in the early days of battery development. The Daniell cell was the first truly practical and reliable electric battery that supported many nineteenth century electrical innovations such as the telegraph. A later variant of the Daniell cell called the GRAVITY CELL or CROWFOOT CELL was invented in the 1860s by a Frenchman named Callaud and became a popular choice forelecctrical telegraphy.

WHAT IS A DANIELL CELL?

The Daniell cell consists of a zinc rod dipping in a solution of zinc sulphate, connected by a wire to a copper rod dipping in a copper sulphate (II) solution. Spontaneous oxidation and reduction reactions generate electric current, with electrons passing from the zinc rod to the wire and from it to the copper rod, originating a current along the wire. During the functioning of the battery the following transformations are observed: the zinc rod goes under corrosion and its mass reduces; consequently, concentration of ions Zn2+ increases in the half cell; the copper rod receives a deposit of molecules of metal and its mass increase. Consequently, the concentration of ions Cu2+ in the solution decreases. The functioning of the battery can be demonstrated by a bulb (that shows electric current passing through the wire) and by the colour of the solution in the cathode cell. Dissolved in water copper sulphate produces a blue coloured solution. During the functioning of the battery, this substance disappears and the liquid becomes colourless.

Reaction example:

Zn(s)â†’ Zn2+(aq)+ 2e-(cathode).

Cu2+(aq)+ 2e-â†’ Cu(s)(anode).

The total reaction being:

Zn(s)+Cu2+(aq)â†’ Zn2+(aq) + Cu(s).

Daniellcellis a kind of Cu-Zn battery which employs a porous

barrier between the two metals . In the present time, daniell cell is primarily used in the colleges to explain how batteries work.

PRINCIPLE BEHIND THE DANIELL CELL:

The principle behind the Daniell cell is redox reaction. In the process of the reaction, electrons can be transferred from the corroding zinc to the copper through an electrically conducting path as a useful electric current. Zinc is more negative nature than copper, so when we place zinc and copper metal in solutions of their salts, can cause electrons to flow through an external wire which leads from the zinc to the copper.

Zinc anode: Zn(s)â†’ Zn2+(aq)+ 2e-

Copper cathode: Cu2+(aq)+ 2e-â†’ Cu(s)

The principle used in daniell’s battery & Volta’s battery is the same. In the Volta’s design, liquid solute is called the electrolyte. The brine between the metal plates begins to dissolve the zinc & the copper into positively charged ions. The free electrons remain behind, as the ions leave the metals. The zinc soon contains more electrons, so zinc dissolves more rapidly than the copper. If we connect the both metals with a wire, the migration of electron will start from the zinc to the copper, and thus electric current is produced.

MODEL OF DANIELL CELL:

CONSTRUCTION OF A DANIELL CELL:

In the construction of Daniell cell many chemical and non-chemical materials are used. The materials are given below:

- a strip of copper
- a strip of zinc
- a large beaker, bowl or other suitable container
- a porous vase (as discussed in the Introduction)
- a plastic tube
- cotton
- Copper Sulfate (CuSO4)
- Zinc Sulfate (ZnSO4)
- Potassium Nitrate (KNO3)
- Sodium Chloride (NaCl) if Potassium Nitrate is unavailable
- distilled water
- a voltmeter
- two cables with alligator clips

Prepare a concentrated solution of copper sulfate in distilled water and another solution of similar concentration of zinc sulfate in distilled water. For both of these solutions, use about 10-30 grams of dry chemical per 100cc of distilled water. Construct a setup as shown in figures 4 and 5. Pour the CuSO4 solution in with the copper electrode and the ZnSO4 solution in with the zinc electrode. When you measure the voltage across these electrodes, you should find it to be about 1. 1 volts. Compared to the Lemon Battery, the Daniell's Cell puts out a higher power and lasts much longer. Even so, you would need electrodes with much greater surface area and more concentrated electrolyte to be able to power a very small light bulb with this device. Try instead a LED.

WORKING OF A DANIELL CELL:

The reactions at the electrodes furnish charges that allow the battery to produce electrical current for extended periods. In the Daniell's Cell, the copper strip attracts electrons from the zinc strip. These electrons pass through the wires of our external circuit. As the copper electrode receives electrons, free positive ions in the solution arrive to equalize the charges. Positive copper ions (Cu++) are attracted to the charged copper electrode where they receive two electrons and become neutral and deposit on the electrode in metallic form. The positive zinc ions (Zn++) move to the porous vase. For each copper atom that is deposited on the copper electrode, a zinc atom goes into solution, giving up two electrons to the zinc electrode

The reactions at the electrodes can be represented by this formula:

Zn ==> Zn+++ 2e-

Cu^{++} + 2e-==> Cu

These reactions result in the dissolution of zinc atoms in their ionic form, which corresponds to the deposition of copper ions in their metallic form:

Zn + Cu^{++}==> Zn^{++}+ Cu

The electrons made available by the zinc atoms pass through the lamp filament, produce light through the joule effect and eventually reach the copper electrode. These electrons account for the current that is produced by the battery and is used by the lamp. If we didn’t have the porous vase, the Cu++ ions would go directly to the zinc electrode and pick up free electrons, thereby bypassing the external circuit and stopping the current flow through the wires and lamp. The battery would no longer work. Because the copper electrode attracts electrons from the external circuit, it is considered the positive pole of the battery.

In a battery, there is always a flow of electrons in the external circuit (the electrical circuit or device) and a corresponding flow in the internal circuit (the electrolytic circuit). Like any battery, the Daniell Cell does not last forever, but only as long as there are Cu++ions available and the zinc electrode is not consumed. In reality, the production of current diminishes as the concentration of the electrolyte bathing the zinc electrode increases and that bathing the copper electrode decreases. In fact, the positive ions produced by the zinc electrode need SO4ions to balance the charges. The exact opposite occurs in the copper solution, which becomes scarce of positive ions.

Since the electromotive force of a battery is dependant not only upon the nature it’s components, but also upon the concentration of it’s electrolytes, the gradient of concentrations that results from the production of electricity causes the battery to generate lower and lower voltages and currents until finally it is considered dead. At the end, Zn++ ions finally reach the copper electrode, surrounding it and blocking any further movement of Cu++ ions by polarizing the electrode.

CALCULATION OF ELECTRODE POTENTIAL:

The left side and Cu+2 in the right is 1 m (standard condition) then the measured voltage (which is also called electromotive force, emf) is 1. 10 V at 25 C. As the reaction proceeds more Zn+2 is produced and the amount of Cu+2 decreases and the voltage of the cell decreases. At equilibrium the cell voltage is zero. As we willsee, the voltage is a measure of the thermodynamic driving force of a reaction (Î” G). The current is a function of the kinetics, so (for example) increasing the surface area of the zinc and copper metal will increase the current.

In this reaction the equilibrium lies strongly to the right (see later, K = 1. 5×1037) because zinc is a much more electroactive than copper. If one would attach an external battery which will overcompensate the voltage produced by Daniell cell, one can turn the current in the opposite direction and the whole cell will operate in reverse.

Standard Electrode Potentials (half-reactions) It would be convenient to be able to measure the potential of a single electrode, but second one is required for a cell to operate. As a standard electrode normally a hydrogen electrode (i. e. platinum electrode immersed in 1m solution of hydrogen ions at 25C and 1 bar pressure) is used.

H2 â†’ 2H+ + 2eâˆ’

emf of such electrode is considered to be zero. Standard electrode can be used as a left one and in such a case the measured emf is standard electrode potential Eo or standard reduction potential. it also can be used as a right electrode then measured emf is standard oxidation potential. The absolute values of emf will be the same, but the sign of the potentials will be the opposite (negative for oxidation potential).

Given :

Zn(s) â†’ Zn2+(aq) + 2e- , Eo= 0. 3419v

Cu2+(aq) + 2e- â†’ Cu(s) , Eo=-0. 7618V

On combining the reactions, we get___

Zn + Cu++ ==> Zn++ + Cu , Eo= 1. 104V

Note that E0 always per electron, and in combining E0values do not multiply by the number of electrons.

USE OF SALT BRIDGE:

Salt bridge is a device of “ U” shaped. This device is filled with saline solution. We can make one with the plastic tube called out in the materials list earlier. Fill the tube with a Potassium Nitrate (KNO3) or Salt (NaCl) dissolved in distilled water (about 10 grams of chemical per 100 cc of water).

Plug the ends with the cotton so that the saline solution will remain in the bridge and not mix with the electrolytes. The bridge serves the same purpose as the porous vase, acting as a barrier between the two different electrolytes while allowing the flow of charges.

Schematic of a Daniell cell with a salt bridge

IMPORTANCE & USES OF DANIELL CELL:

A large number of metals, sodium hydroxide, chlorine, fluorine and many other chemicals are produced by electrochemical methods. The reactions carried out electrochemically can be energy efficient and less polluting. The transmission of sensory signals through cells to brain and vice versa and communication between cells are known to have electrochemical origin.

A galvanic cell is an electrochemical cell that converts the chemical energy of a spontaneous redox reaction into electrical energy. In this device the gibbs energy of the spontaneous redox reaction is converted into electrical energy which may be used for running a motor or other electrical gadgets like heater, fan, geyser, etc.

Daniel cell is also a type of galvanic cell. The redox reaction of a Daniel cell is…..

Zn(s) + Cu2+(aq) â†’Zn2+(aq) + cu (s).

This cell converts the chemical energy liberated during the redox reaction to electrical energy and has an electrical potential equal to 1. 1 V when concentration of Zn2+ and Cu2+ ions is unity. If an external opposite potential is applied and increased slowly, the reaction continues to take place till the opposing voltage reaches the value 1. 1 v.

The redox reaction of the cell is a combination of two half reactions whose addition gives the

Over all cell reaction:

i.

Cu2+ + 2e- â†’ Cu (s) (reduction half reaction)

ii.

Zn (s) â†’ Zn2+ + 2e- (oxidation half reaction)

These reactions occur in two different portions of the daniell cell. The reduction half reaction occurs on the copper electrode while the oxidation half reaction occurs on the inc electrode. These two portions of the cell are also called half-cells or redox couples. The copper electrode may be called the reduction half cell and the zinc electrode, the oxidation cell.

UNINTERPRETABLE POWER SUPPLY:

Stationary battery systems are widely used in the information and telecommunications technology business, often as back-up safety systems to compensate for loss of electricity supply from the grid. These systems must be designed to close the supply gap for several hours and in some cases high power outputs must be available immediately or within minutes. As back-up systems for power outages, the systems must be durable and reliable even if they are rarely put to use

Intermittent storage of solar energy is another area of application. For example, for autonomous photovoltaic systems, the battery sub-system must be designed to cope with wide fluctuations of input and output currents. The average electricity consumption of powered units and the average availability of solar radiation need to be balanced using site and application specific battery systems.