Challenges for PKL Electrochemical Cell: Chemistry and Technology

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Abstract

A cell is a single arrangement of two electrodes and an electrolytic solution capable of yielding electricity due to chemical action within the cell or of producing chemical action due to passage of electricity through the cell. Each cell is made of two electrodes, one liberates electrons and is called oxidizing electrode (i.e at which oxidation occurs), while the other absorbs electrons and is called reducing electrode (i.e,at which reduction occurs). Examples are Deniell cell, Voltaic cell etc. A battery is a combination of two or more cells arranged in series or parallel. For example, the ordinary 6 volt lead storage battery is a combination of three 2 volt cells connected in series.

Keywords: *Cell, Battery, Electrochemistry, Reducing Electrode, EMF*

I. Introduction

A galvanic cell is a device which converts chemical energy into electrical energy. A galvanic cell is also called an electrochemical cell and denial cell is a well known example of Galvanic or electrochemical cell. The Daniel cell consists of an outer copper vessel containing a solution of copper sulphate. Inside it is a porous pot containing a zinc strip dipping into a solution of zinc sulphate. The cell can be represented as:

Zn | $ZnSo_4$ Solution: $CuSo_4$ Solution | Cu

At Anode - On account of its high electrolytic pressure, zinc passes into the solution as zinc ions, each ion leaves two electrons at the electrode. The process will continue until equilibrium is reached between the electrode and the solution. At equilibrium, there will be potential difference between the electrode and the solution.

$$\mathrm{Zn} \longrightarrow \mathrm{Zn}^{2+} + 2e^- \quad \text{(Oxidizing Electrode)}$$

At Cathode - At this electrode copper ions gain electrons and are reduced to metallic copper which is deposited at the copper electrode. (Reducing Electrode)

When the two electrodes are connected by a wire, the excess electrons on the electrode flow along the wire in order to neutralize the positive charge on the copper electrode. This movement of electrons from zinc to copper produces a current in the circuit. The net cell reaction can be represented as

$$\mathrm{Zn} + \mathrm{Cu}^{2+} \longrightarrow \mathrm{Zn}^{2+} + \mathrm{Cu}$$

In the Galvanic cell, oxidation occurs at anode and reduction at the cathode. Thus metal at anode loses electrons and dissolved (zinc in the above case) and metal at cathode gains electrons and grows. The process of a metal passing into solution as metal ions with the liberation of electrons is known as de-electro nation or oxidation and the electrode where it takes place is the anode or oxidizing electrode. The reverse process of the gain of electrons by an ion with the discharge or deposition of metal is called electro nation or reduction and the electrode where it occurs is the cathode or reducing electrode. Thus oxidation must occur at the negative electrode, where electrons are given off and reaction must occur at the positive electrode, where electrons enter. Hence the electrode at which oxidation takes place is called the negative electrode and the electrode at which the reduction takes place is called positive electrode. In the construction of cell, the electrode with high reduction potential acts as cathode and the electrode with low reduction potential acts as anode. It should be noted that Zn metal can be oxidized by Cu^{2+} ions, but Cu metal can be oxidized by Zn^{2+} ion. Thus if we immerse copper rod in a solution of zinc sulphate, no change take place[1-35].

Fig.1 shows a typical illustration of a Galvanic Cell.

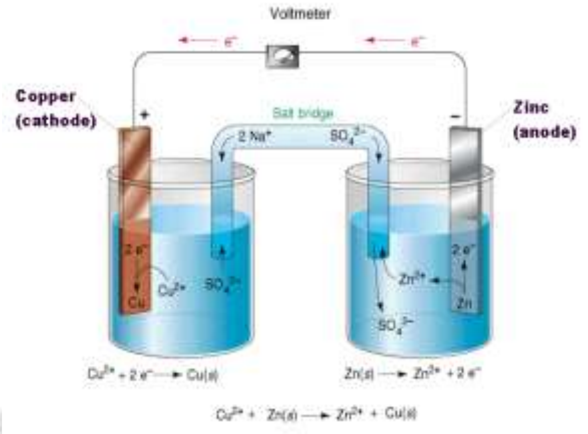

Fig.1: A typical Galvanic Cell.

Similarly in the Galvanic cell,

$Cu \mid Cu^{2+} \parallel Ag^{+} \mid Ag$

Copper will dissolve because oxidation occurs at anode and reduction at cathode. The metal at anode loses electrons and get dissolved and metal at cathode gains electrons and grows. Thus copper metal is oxidized to copper ions and Silver ions are reduced in solution to silver metal.

$$Cu \longrightarrow Cu^{2+} + 2e^{-} \quad \text{(Oxidation)}$$

$$2Ag^{+} + 2e^{-} \longrightarrow 2Ag \quad \text{(Reduction)}$$

The cell reaction (redox reaction) is

$$Cu + 2Ag^{+} \longrightarrow +Cu^{2+} + 2Ag$$

Hence copper metal can be oxidized by Ag^{+} ions, but silver metal cannot be oxidized by Cu^{2+} ions [18].
This field covers:
-Electrolytic processes: Reactions in which chemical changes occur on the passage of an electrical current
-Galvanic or Voltaic processes: Chemical reactions that result in the production of electrical energy.
An electrochemical cell typically consists of:
-Two electronic conductors (also called electrodes)
-An ionic conductor (called an electrolyte)
Modes of charge transport:
Charge transport in the electrodes occurs via the motion of electrons (or holes),
Charge transport in the electrolyte occurs via the motion of ions (positive and negative)

II. Methodology

II A. (i) Electrochemical Cells

An electrochemical cell is a device which can produce electrical work in the surroundings. It may be used to perform two functions:

(a) To convert chemical energy into electrical energy. (b) To convert electrical energy into chemical energy.

Not only the various electrodes but also their possible combinations can be classified according to the nature of the electrode reaction. There are three principle types of electrochemical cells or electrochemical systems[36-49].

Cells of first type consist of two chemically identical electrodes with the same electrode reaction. The EMF of such systems would be equal to zero if the physical properties of both electrodes and hence their standard potentials are identical [50-64].

Cells of second type consist of two electrodes having same physical properties qualitative chemical composition and the nature of the reaction, hence the concentrations or more correctly the activities of the participants in the respective electrode reactions are different.

Electrochemical cells of the third type are cells in which the electrodes may differ both in their chemical and physical properties. The electrochemical cells of this type are called chemical cells. In these cells, the source of electrical energy is the chemical reactions taking place in them[65-70].

II.B Physical Cells

There are various types of physical cells, like gravitational cells, allotropic cells etc. A short description of which as as below:

IIC. Gravitational Cells

These cells usually considered of two liquid electrodes of different heights made of the same metal. The electrode is measured in a solution of a salt of the given metal. The electrode of greater height has an increased amount of free energy compared with the electrode of smaller height[71-80]. The spontaneous reaction goes on proceeding until the heights of the two electrodes become equal.

Hence gravitational cells are the electrochemical systems in which the mechanical energy is due to the difference in the gravity of the electrodes and chemical energy is transformed into electrical energy as a result of the electrochemical reactions taking place in them.

II D. Allotropic Cells

Cells of this type consist of two electrode materials of the same metal immersed in a solution or a metal of its ion-conducting compound. At a particular temperature, unless it is the transition temperature at which the two modifications are in equilibrium, only one modification of the metal is stable and the other is in a metastable state. An anode made of a metal in a metastable state will passes an increased amount of free energy. It acts as a negative electrode in the cell and supplies metal ions to the solution[]81-92].

The overall reaction indicates that there is an electrochemical transformation of the unstable modification into the stable one. From the knowledge of free energy change[93-100]. Which corresponds to the allotropic transformation, it is possible to calculate the EMF of the system if energy of an allotropic transformation can be determined from the EMF.

II E. Concentration Cells

Concentration cells are galvanic cells consisting of two similar electrodes immersed into solution of the same substance with different concentrations, or they are galvanic cells with metallic electrode. Which are an alloy of two metals immersed in a salt solution of one of the metals, the concentration of this metal being different in the electrodes[101-109].

In these cells the electrical energy is derived from the energy change accompanying the transfer on a substance from a system of which of high concentration of that of low concentration. Concentration cells are of two types:

(a) **Electrode concentration Cell:** These are those cells in which the electrode materials yielding the ions are of different concentration. Amalgam cells and gas concentration cells belong to this class.

(b) **Electrolyte concentration cells:** These are those cells in which the solution and therefore the active ions are of different concentrations.

Both types of concentration cells may or may not involve a liquid junction. The cell may or may not involve transference.

II F. Chemical Cells

Those cells in which the EMF is due to a chemical reaction taking place within the cell, are called chemical cells. They can be classified into simple and complex chemical cells. In simple chemical cells electrode is reversible with respect to the cations of the electrolyte and other to the anions. In complex cells condition is not observed.

1: Simple Chemical Cells

Cells of this type are great interest in connection with the problem of direct conversion of chemical energy of fuels into electrical energy.

Standard Weston cell is an example of chemical cell and can be represented as,

$$Cd, Hg \mid CdSo_4 \mid Hg_2So_4, Hg$$

The EMF of this cell is extremely stable and has a small temperature coefficient.
The EMF of the standard Weston cell at room temperature can be determined from the equation, $E_t = 1.0183 - 4X10^{-5}(t - 20)$

2: Complex Chemical Cells
Lechlanche cell is an example of complex chemical cell. For Lechlanche cell

$$Zn \mid NH_4Cl, ZnCl_2 \mid MnO_2, C$$

The probable current, producing reaction may be denoted as,

$$Zn + 2NH_4Cl + 2MnO2 \longrightarrow Zn(NH_3)_2Cl_2 + Mn2O_3 + H_2O$$

II G. Gas Cells
Electrodes in which metal of the electrode is not involved in potential determining reactions are called gas electrodes and the galvanic cells composed of two gas electrodes are known as Gas cells.
The gas cell composed of hydrogen and chlorine electrodes in a hydrochloric acid solution can be represented as,

$$(-)\ Pt, H_2 \mid HCl \mid Cl_2, Pt(+)$$

Hydrogen – Oxygen cell using hydrogen and oxygen electrodes immersed into a sulphuric acid solution is another example of gas cell.

IIH. Fuel cells

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent. Hydrogen is the most common fuel, but hydrocarbons such as natural gas and alcohols like methanol are sometimes used.

In 1838, German physicist Christian Friedrich Schönbein invented the first crude fuel cell. A year later Welsh physicist William Grove developed his first crude fuel cells in 1839. The first commercial use of fuel cells was in NASA space programs to generate power for probes, satellites and space capsules. Since then, fuel cells have been used in many other applications. Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are used to power fuel-cell vehicles, including automobiles, buses, forklifts, airplanes, boats, motorcycles and submarines[110-114].

There are many types of fuel cells, but they all consist of an anode, a cathode and an electrolyte that allows charges to move between the two sides of the fuel cell. Electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. Fuel cells are classified by the type of electrolyte they use. Fuel cells come in a variety of sizes. Individual fuel cells produce relatively small electrical potentials, about 0.7 volts per cell. In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions[115-116].

Fig.2 shows a typical illustration of a Fuel Cell.

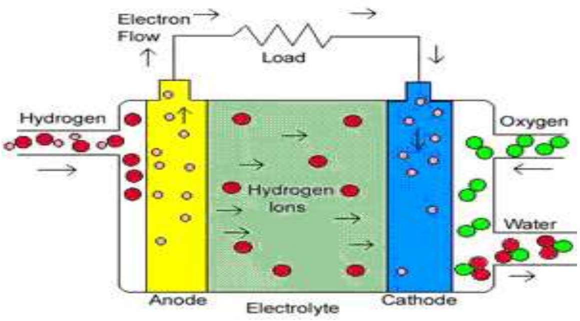

Fig.2: A typical fuel cell.

III. Conclusion

Finally it can be concluded that the amount of chemical change is proportional to the amount of current passed. There are a lot of electrochemical cells which have been mentioned in the study. Except this there are also some new cells and batteries which are known as Quasi Voltaic cells or modified Voltaic cells. These kinds of cells are known as PKL cells and some other vegetative cells.

Acknowledgement

The authors are grateful to the PKL electricity research group named Dr. M A Latif, Dr. Md. Sajjad Hossain, Dr. Md. Fakrul Islam, Dr. Bapy Guha, Md. Mehdi Hassan, Dr. Jesmin Sultanaand Prof. Dr.Mesbah Uddin Ahmed for their valuable suggestions and whole hearted cooperation during research work.

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