An Experimental Study on the Coulombic Efficiency of *Bryophyllum pinnatum* Leaf Generated BPL Cell

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**ABSTRACT**

The performance of a primary cell highly depends on the coulombic efficiency of that cell. Being a primary cell, *Bryophyllum pinnatum* leaf generated BPL cell, where electrodes-pair of zinc and copper dipped in the filtered leaf juice, a good efficiency is required. In this paper, we have tried to show the approximate coulombic efficiency of a unit BPL cell on a certain condition.

**Keyword:** - BPL Cell, Electrochemical Cell, Coulombic Efficiency.

**1. INTRODUCTION**

The leaf of *Bryophyllum pinnatum* contains several organic acids like amino acid, syringic acid, caffeic acid, ascorbic acid, mallic acid, iso-citric acid etc. which act like acidic electrolyte and also some metals like copper⁰¹,⁰²,⁰³,⁰⁴,⁰⁷,⁰⁸,⁰⁹. If we place a pair of zinc and copper at the leaf juice, electrons start to flow through the circuit. In this process, the zinc plates give electrons to the circuit and loose mass also. For a rechargeable battery the fraction of the electrical charge stored during charging that is recoverable during discharge.

**Table -1: Coulombic Efficiency for several cells [05].**

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Coulombic Efficiency in percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Acid</td>
<td>70-84</td>
</tr>
<tr>
<td>Lithium Ion</td>
<td>85-95</td>
</tr>
<tr>
<td>Nickel Cadmium</td>
<td>65-85</td>
</tr>
<tr>
<td>Nickel Metal Hydride</td>
<td>65-85</td>
</tr>
<tr>
<td>Polysulphide Bromide</td>
<td>60-65</td>
</tr>
<tr>
<td>Sodium-Sulphur</td>
<td>75-83</td>
</tr>
<tr>
<td>Vanadium Redox</td>
<td>60-80</td>
</tr>
<tr>
<td>Zinc Bromide</td>
<td>60-73</td>
</tr>
</tbody>
</table>
The coulombic efficiency is the ratio of the charge obtained to the total charge (the charge obtained plus the charge lost by local action) supplied by the anode [06], i.e.

\[ \eta_q \% = \frac{Q_{\text{output}}}{Q_{\text{input}}} \times 100\% = \frac{Q_{\text{obtained}}}{Q_{\text{supplied}}} \times 100\% \]  

(1)

If the life time of the cell becomes \( t \), with an outer circuit connection, and the current measured by the ammeter is \( I \). Then the output charge,

\[ Q_{\text{output}} = I t \]  

(2)

Again, the source of electron is the anode where electron produces by the oxidation reaction on the metal used as anode. Thus, the weight of the anode reduces with time because of the cell reaction.

If the weight of the anode used is \( W_1 \), and the weight after time \( t \) is \( W_2 \).

The weight lost = \( W_1 - W_2 = x g \)

Again, the molecular weight of the metal used as anode is \( M \), and the oxidation number is \( n \).

Then the reaction taking place on the anode can be represented as-

\[ A \rightarrow A^{n+} + ne^- \]

Where, “\( A \)” represents anode.

Thus, one mole metal will produce \( n \) mole electron.

So, \( M \) g metal anode (\( A \)) will supply \( n \) mole electron.

\[ x g \text{ metal anode will supply } = \frac{n x}{M} \text{ mole electron} = \frac{n x N_A}{M} \text{ electron} = \frac{n x N_A \times 1.6 \times 10^{-19}}{M} \text{ coulomb charge} \]

\[ = \frac{n x F}{M} \text{ coulomb charge. [where, 1 F = 1 Faraday.]} \]

That is \( x \) gm anode by decaying under oxidation process supply \( \frac{n x F}{M} \) coulomb charge.

So, the input charge, \( Q_{\text{input}} = \frac{n x F}{M} \) coulomb charge........ (3)

From Equations-(1), (2) and (3), we get,

\[ \eta_q \% = \frac{Q_{\text{output}}}{Q_{\text{input}}} \times 100\% = \frac{I t}{\frac{n x F}{M}} \times 100\% = \frac{I t M}{n x F} \times 100\% \]

So,

\[ \therefore \eta_q \% = \frac{I t M}{n x F} \times 100\% \]  

(4)

By putting the values of the quantities in Equation-(4) we can calculate the coulombic efficiency.

2. METHODOLOGY

To construct *Bryophyllum pinnatum* leaf fuelled BPL cell, we need to collect the plant first which grows anywhere without any nursing. We collected fresh leaf, washed by water and then dried after weighing. The electrodes are collected from local market and then shaped comparing the dimension of the container. The juice was made using
blender with the addition of water and CuSO₄·5H₂O as secondary salt. The whole procedures and the related dimensions are given below.

Collection of Bryophyllum pinnatum Leaf

![Bryophyllum pinnatum leaf and plant](image1)

**Fig -1:** Bryophyllum pinnatum leaf and plant

Sap Preparation

BPL in the sap was 85.308%, water was 14.214% and CuSO₄·5H₂O was 0.4739% approximately.

![Juice in the blender](image2)

**Fig -2:** Juice in the blender.

Electrode Preparation

Copper plates are used as cathode and Zinc plates as anode. The average height, length, thickness and mass of anode were 105.56mm, 53.12mm, 0.71mm and 27.71g respectively and for cathode 105.39mm, 53.26mm, 0.17mm and 6.77g respectively.

![Electrodes](image3)

**Fig -3:** Electrodes.

Design of BPL Test Cell

A small rectangular box made of glass was used, where the length of the cell was 10cm, width 6cm, height 12cm and inner volume was 720cm³.

![Glass container](image4)

**Fig -4:** Glass container.
3. EXPERIMENTAL SET-UP

The total anodic (Zn plates) area was twice the area of cathode (Cu plates). The connections are given in the schematic diagram below.

![Schematic diagram of the experimental setup](image)

We have found that the pH of the juice with the malt decrease below 7.0 after shaking well [04] [08]. During the experiment, we have found the Ah rating of this cell was 0.396 [08]. For this, the weight of the anode used was measured \( W_1 \) first. When the cell became dead (assumed), the metal used as anode was separated, cleaned with distilled water and then dried. The weight of the dried metal plate was measured \( W_2 \). We also calculated here the ampere-hour of that unit cell during the study.

4. EXPERIMENTAL DATA

The weight of four unused Zn anodes in the cell was 111.02g.
The weight of four Zn anodes of that cell was 106.93g after the study.
So, the reduction of Zn from the anodes \( = (111.02 - 106.93)g = 4.09g \).
Approximate ampere-hour of that cell was 0.396Ah.

5. CALCULATIONS OF COULOMBIC EFFICIENCY (\( \eta_Q \% \) )

The reaction taking place on anode (zinc plates)
\[
\text{Zn} \quad \rightarrow \quad 2e^- \quad \rightarrow \quad \text{Zn}^{2+}
\]
1mol \quad 2mol \quad 1mol
Thus, 65.4g zinc produces total of charge $= 2F = 193000C$

So, 4.09g zinc produces total of charge $= \frac{193000 \times 4.09}{65.4} C = 12069.878C$

Thus, the input charge $= 12069.878C$

Again, the output charge $= 0.396 \times 3600 = 1425.6C$

So, the columbic efficiency $= \frac{1425.6C}{12069.878C} = 0.11811 = 11.811\%$.

6. RESULT AND DISCUSSIONS

The columbic efficiency of this BPL cell found 11.811% which cannot be considered very efficient. However, this can’t be exact measurement of this efficiency. Because, addition of copper sulphate affects the cell performance as well as the cell capacity of the BPL cell. Moreover, the impurities of the electrodes, temperature, percentage of water in the filtered juice, juice filtration process found very effective in cell enactment. This means, by adjusting those parameters, we can expect to get a better result. The purpose of this kind of cell is to provide some electrical energy at remote places, so, this value of efficiency is less important in front of the resolutions considering the socio-economic inefficiency of on-grid supply.

7. REFERENCES