Studies of Aluminium - Air Cell in Alkaline Media

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Al-air cell with Al-anode and graphite cathode in aqueous NaOH gave an open circuit voltage of 1.4 V - independent of alkali concentration. Corrosion of aluminium anode is faster in concentrated NaOH solution (pH > 10.2) but, a gelatineous precipitate of $Al(OH)_3$ formed limits the current output of the cell. Presence of depolarizer (0.1, 0.02, 0.01 M KI solution) or complexing agent, $[HgI_4]^{2-}$, in 2 M NaOH solution gave the cell potential of 1.07, 1.33, 1.36 & 1.25 V respectively at 3.3 kohm load with current density of 1 $A.m^{-2}$. A current density of 1 $A.m^{-2}$ can be drawn for 24 hours without much drop in voltage. OCV of the cell is found to be a function of conductance of the medium. The power output of the cell is found to be 2774 $Wh.kg^{-1}$ which is 85% of the theoretical value.

Electrochemical cells provide pollution-free conversion of chemical to electrical energy directly without an intervening heat cycle, resulting in considerable increase in efficiency of the power sources [1,2]. Aluminium is the most abundant element after oxygen and silicon and several authors have suggested that aluminium is a useful fuel for the electrochemical cell [3-6]. Zaromb [7] was the first to attempt the development of an alkaline aluminium-air cell and found that the open circuit potential against Hg/HgO reference electrode was - 1.75 V at room temperature. The behaviour of this cell in different media [8] is shown in Table 1.

Vielstich and co-workers [9] reported on the aluminium-air cell in neutral medium while Despick and co-wokers [10] investigated aluminium - air cell in neutral sodium chloride solution.

Corrosion current in alkali was found to be negative. In view of this, study was carried out in hydroxide medium.

Table 1

Electrode Potential of Al in Various (1 M) Electrolytes

Electrolyte 1 M	NaCl	Na_2SO_4	Na_2CrO_4	HCl	HNO_3	NaOH	NH_4OH
OCP Volts	0.52	0.16	0.37	0.46	0.15	1.16	0.46

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EXPERIMENTAL

Apparatus

The experimental set up consisted of a graphite cathode (air electrode) and aluminium anode (Surface Area = 3.34×10^{-4} m^2) separated at a distance of 2 cms from each other and were kept in a 250 ml beaker containg 100 ml electrolyte. The electrodes were connected to a variable resistance box and digital microammeter in series and digital d.c. microvoltmeter in parallel.

Current - Voltage Behaviour of the Cell

Aqueous solution of different concentrations (1, 2, 3, 4 and 5 M) were prepared using AR grade NaOH. The current-voltage-resistance data were recorded at the ambient temperature (30°C) using 100 ml of each of these as electrolyte.

KI solutions (0.1, 0.02 and 0.01 M) were prepared using AR grade KI. 50 ml of 2 M NaOH solution was mixed with 50 ml of KI solution and current - voltage data were recorded for each concentration at ambient temperature.

A complex depolarizer was prepared by adding HgI_2 in saturated solution of KI. Requisite amount of 2 M NaOH was added till a clear solution was obtained. 50 ml of this complex solution was mixed with 50 ml of 2 M NaOH solution and current-voltage were recorded as above.

The drop in cell potential for the above setup as a function of time was recorded during continuous running of the cell for 24 hours.

The conductance and pH of the experimental set up were recorded using digital conductivity meter and pH meter.

RESULTS AND DISCUSSION

Experimental observation indicates that the rate of polarization is less when the pH of the electrolyte is less than 10.2, but electrolyte having pH > 10.2 give rise to high rate of corrosion. The current-voltage behaviour of aluminium anode and graphite cathode (Fig 1) shows the open circuit voltage as independent of NaOH concentration (1 - 5

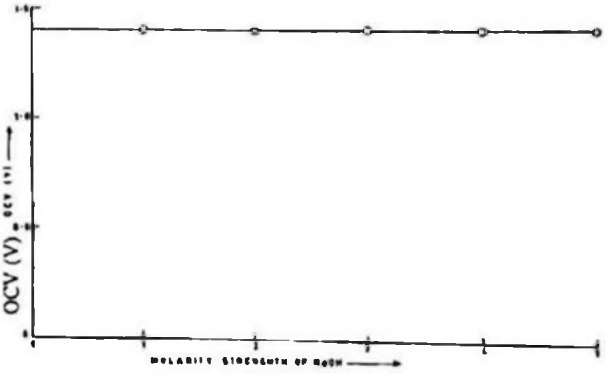


Fig 1. OCV of Al-Air Cell at Different Concentrations of NaOH

M). The rate of corrosion of aluminium is faster in concentrated solution than dilute solution. But a precipitate of $Al(OH)_3$ is formed in concentrated electrolyte which limits the current output and performance of the cell whereas this precipitate dissolves in

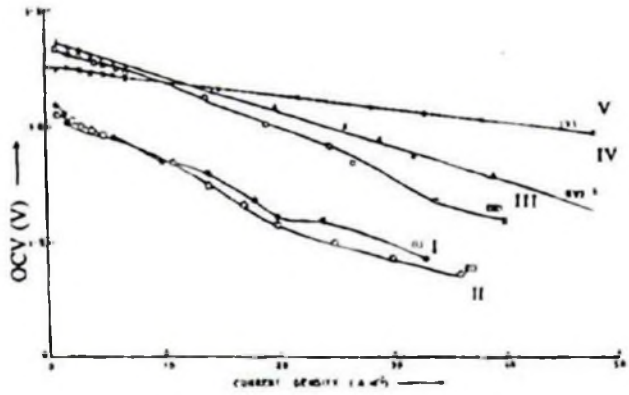


Fig 2. Current - Voltage of Al-Air Cell in 2 M NaOH with Depolarizers
Depolarizer (I) nil; (II) 0.1 M KI; (III) 0.02 M KI; (IV) 0.01 KI and (V) $[HgI_4]^{-2}$

dilute solution of NaOH (2M); the current output increases; performance of the cell improves.

Fig 2 indicates the current-voltage behaviour of the cell in 2 M NaOH solution with and without the presence of depolarizer. On addition of depolarizer, the OCV of the cell is slightly lowered but the polarization of the cell is controlled. Presence of $[HgI_4^{-2}]$ shows nearly ideal condition; on drawing a current density of 30 $A.m^{-2}$, the drop in voltage of the cell is only 0.13 V (curve v). This is probably due to amalgamation of the anode (Al) under this condition resulting in lower hydrogen evolution. Use of KI solution also affects the cell performance and polarization - particularly in 0.01 M KI (curve iv). This is due to high conductance of the electrolyte solution under which the ionic mobility is faster and this prevents the precipitation of $Al(OH)_3$ formed during reaction and makes the system univarient so as to control the polarization of the cell. On drawing a current

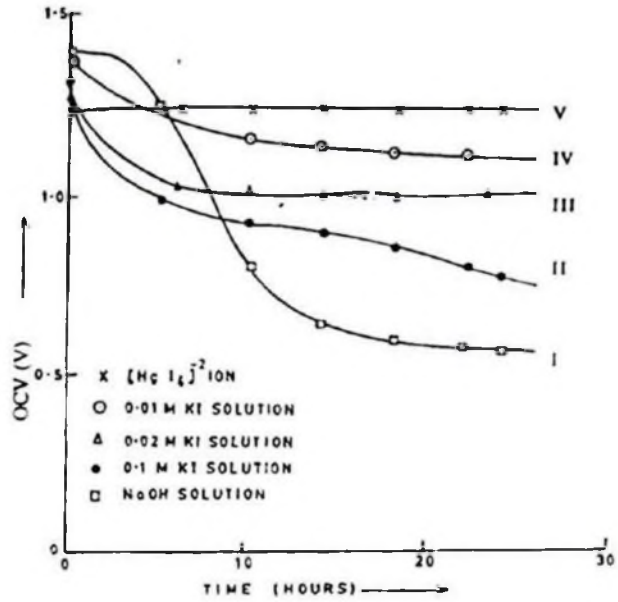


Fig 3. Voltage of the Cell with Time under Continuous Run at 1 $A.m^{-2}$

density of 30 $A.m^{-2}$, the drop in voltage in this condition is only 0.44 V.

Fig. 3 gives the drop in cell potential as a function of time on drawing a current of 1 $A.m^{-2}$ at a load of 3.3 kohm continuously. The

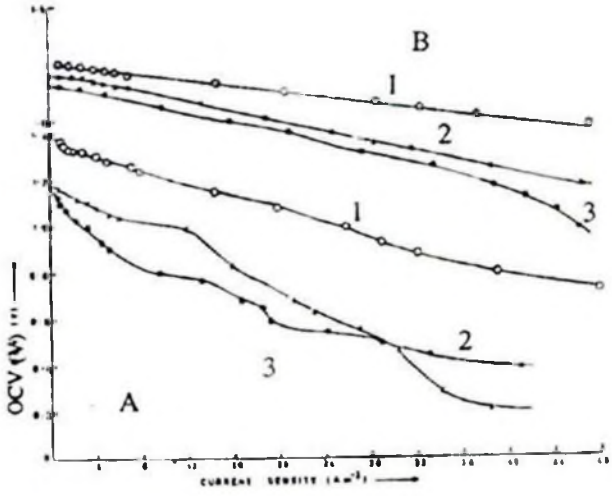


Fig 4. Current - Voltage of Al-Air Cell in 2 M NaOH with Depolarizer under Continuous Run
(a) 0.01 M KI; (b) $[HgI_4]$ ion
1. 8 hrs. 2. 12 hrs. 3. 24 hrs.

figure clearly indicates fast polarisation in 2 M NaOH solution. This can be controlled by using depolazier like KI solution or $[HgI_4]$ complex. After 24 hours of the continuous run of the cell in 2 M NaOH solution, the drop in voltage was 0.85V, 0.57V, 0.36V, 0.28V in presence of 0.0 M, 0.1 M, 0.02 M, and 0.01 M KI solution respectively. There is negligeble drop in voltage in presence of $[HgI_4]$ ion complex under similar condition.

Fig. 4 indicates the current-voltage behaviour of the cell during continuous run up to 24 hrs in presence of 0.01 M KI and 0.022 M $[HgI_4]^{-2}$. Cell polarization in presence of KI solution is only concentration polarisation but there is only ohmic polarisation in case $[HgI_4]^{-2}$ complex.

Fig. 5 (the OCV of the cell as a function of molar conductance of the electrolyte) indicates that higher the conductance, higher the OCV of the cell. In lower conductance case, internal resistance of the cell reduces the current output.

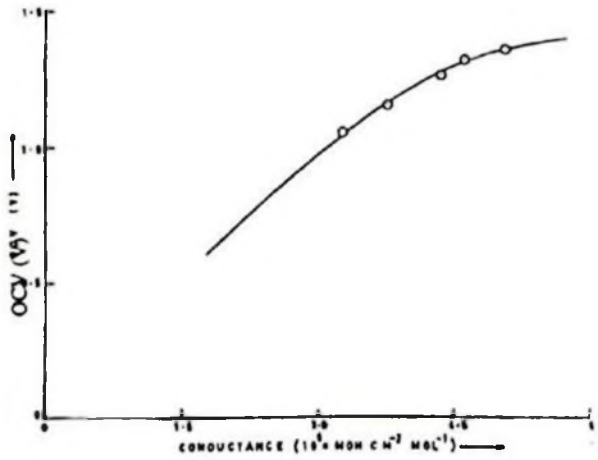


Fig 5 OCP vs Conductance

The theoretical power output of the Al-elecrochemical cell was about 3263 $wh.kg^{-1}$ and the watt output of the present cell was found to be 2774 $wh.kg^{-1}$. This indicates 85% efficiency for the cell.

CONCLUSION

The cell constructed in this laboratory has following characteristics:

(i) The OCV and SCC of the cell is 1.4 V and 80 $A.m^{-2}$ respectively.
(ii) The electrodes of the cell can be prepared easily.
(iii) There is nearly no polarisation in case of $[HgI_4]^{-2}$ depolariser.
(iv) OCV of the cell is not a function of the molar concentration of NaOH solution.
(v) The cell has 85 % of power output to that of the theoretical value.

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