Investigation of Alkaline Electrolysis of Water

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Abstract: ***Alkaline electrolysis of water is an old age concept and present it is a green pathway for the production of the fuel of future i.e. hydrogen. But this process needs to be optimized by considering different conditions. In the present study, a detailed subject area of alkaline electrolysis of water is discussed. This paper basically deals with the field of electrolysis of alkaline water at different parameters or conditions. The basic parameters considered for this work consist of molarity of KOH, stirring and temperature. Using these different parameters the detailed study of voltage - current profile of the reaction is carried out and the onset voltage for each morality of KOH is then defined. Also the volume of gas collected per unit time is also determined at different parameters.***

Keywords: Arduino Uno; RGB; Speech Recognition

1. Introduction

In the late years, an intensive development is held out to produce a cleaner and greener fuel that is hydrogenated. Hydrogen is basically viewed as the fuel of the future or rather a cleaner or greener fuel because the burning of hydrogen does not contribute to pollution or any other environmental interference. Hydrogen is an important fuel for sustainable development [11-15]. But to make a green fuel the process available should also be greener such that it does not lead to any environmental contamination. Electrolytic hydrogen production is being studied for more than a century. Nowadays, electrolytic hydrogen has only 4% [1, 2] share in the worldwide production of the most abundant element [3]. Electricity expenses, increase the output cost of the electrolytic process [4]. Electrolysis of water is essentially seen as an environmental friendly approach to make this valuable fuel [5,6]. Hydrogen can be produced from water by utilizing different technologies like photocatalysis, thermochemical cycles and so on [16-18]. But to produce hydrogen efficiently by the alkaline electrolysis of water, the reaction must be optimized in terms of the reaction conditions. An optimized reaction can give a better yield of the product. The electrolysis of water can also be taken out using a proton exchange membrane [7]. The overall cost of the reaction increases with the use of this membrane but if the membrane is of few millimetres then it can become affordable [8, 9]. The use of PEM membrane increases the overall efficiency of the system, but the cost becomes the determining agent.

1.Factors Affecting the Efficiency of the Reaction:

The chemical reactions occurring at the electrodes are as follows:

Anodic Reaction

$H_2O\,(l) \longrightarrow \frac{1}{2}O_2\,(g) + 2H^+\,(Aq.)$

Cathodic Reaction

$2H^+(Aq.) + 2e^- \longrightarrow H_2\,(g)$

Net Reaction:

$H_2O \longrightarrow H_2\,(g) + \frac{1}{2}O_2\,(g)$

There are certain factors which govern the reaction efficiency and needs to be optimized to obtain the product at a better rate and at a lower cost. We give a detailed survey of certain major factors which affects the rate of response. The factors examined are as follows:

- Stirring
- Molarity of KOH
- Temperature

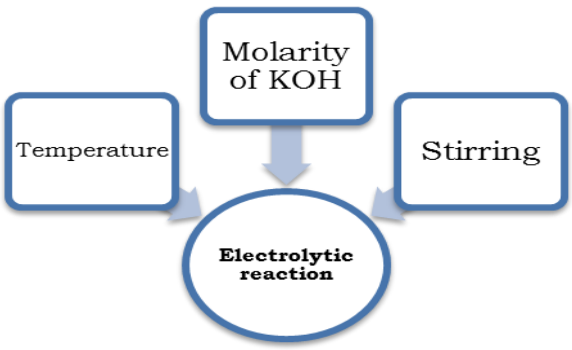

Figure 1 Diagrammatic Representation of Factors Affecting Reaction Efficiency

2. Experimental Study and Methodology:

Reaction vessel: It is a glass vessel with a lid which has opening for the gas outlet and electrode connection. The capacity of this vessel is of 250 ml.
Anode: The conducting component at the anode is one or more metals active towards the electrochemical oxidation of water. Active metals may include Nickel, Co, Fe, Cu, Pt, Ir, Ruthenium, Rhodium, Alloys. In this case the anode is nickel metal. The proportions of the Nickel electrode are as follows: length = 10.7cm and width = 4.3cm.
Cathode: The conducting component of cathode may be copper, cobalt, iridium, iron, nickel, platinum, ruthenium, rhodium, palladium and mixtures and alloys thereof [10].In this case the cathode is copper metal. The proportions of the copper electrode are as follows: length = 10.7cm and width = 3.5cm.
Electrolyte: Solution containing 250 ml of water and equivalent dissolved quantity of KOH as per the morality involved.

The photo of the experimental setup is as shown below:

Figure 2: Experimental Setup

Figure 1 shows the schematic diagram of the experimental setup. The setup consists of cylindrical vessel made of glass with a lid. The lid is provided with four outlets as shown in the diagram. The overall height of the cylindrical vessel is around 15.9cm. The diameter of the cylindrical vessel is 7.3 cm and that of the lid is 5.9cm. Outlet 1 is required for the association of the electrodes and outlet 2 is the gas exit. To prevent the gas leak the outlet is properly sealed using silicon gel or clay. Silicon gel is also applied to the mouth of the lid so that it fits properly in the vessel. The setup consists of anode and cathode which are hung by means of copper wire passed through the outlet.

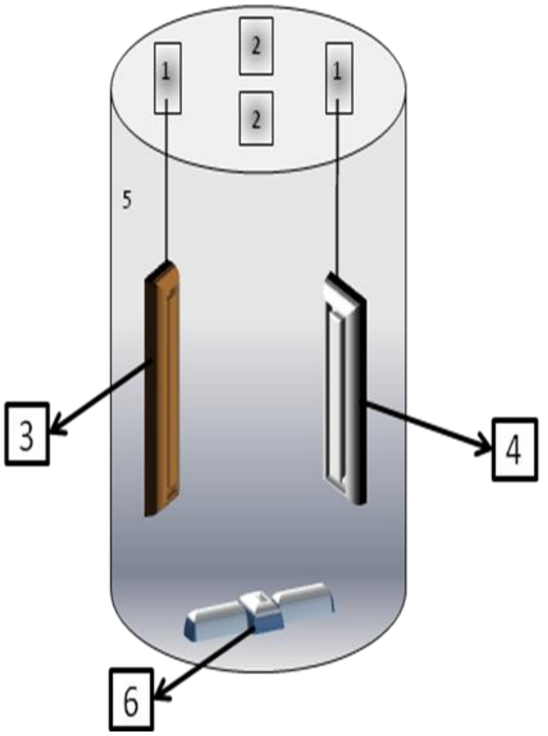

Figure 3: Schematic Diagram of Setup

The wire left free for its connection to the voltage supply. The space between the electrodes is 4cm and it is kept constant. So the entire setup is made airtight and it is put along the magnetic stirrer device. The needle numbered 6 is a magnetic stirrer which helps in stirring the electrolyte at a fixed RPM. DC power supply 0-30V and 0-5A with a resolution of 10mA is used to supply the potential necessary for the electrolytic reaction. For studying the reaction at higher temperatures, oil bath cum magnetic stirrer device is used. The device has a maximum temperature range of 300 ^{o}C with a resolution of 1 ^{o}C with an accuracy of ± 1 ^{o}C. The sensor used in this device is PT- 100 RTD Sensor and it has a maximum speed of agitation of 1000 rpm.
The three conditions which are made variable for the alkaline electrolysis of water are as follows:

1. Molarity of KOH- It is kept as 1M, 3M, 5M and 7M.
2. Speed of Agitation – At a rate of 200, 400 and 800 rotations per minute.
3. Temperature – At 30^{0}C, 40^{0}C, 50^{0}C, 60^{0}C

The reactions are carried out in a batch of 250ml and the current-voltage profile is determined for all the mentioned molarities of KOH. The process of electrolysis is carried out to determine the onset voltage for each morality of KOH mentioned. Also the gas liberation v/s time profile is too determined for all the conditions noted above.

3. Results and Discussions:

i. Molarity of KOH:

The VI graph for various molarities of KOH is as follows:

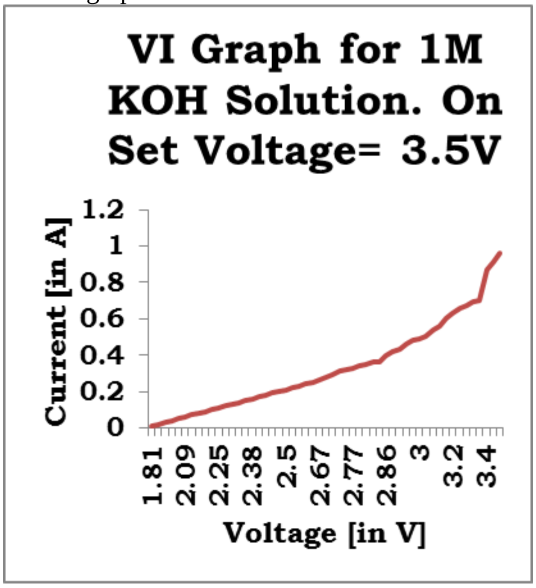

Figure 4(a)

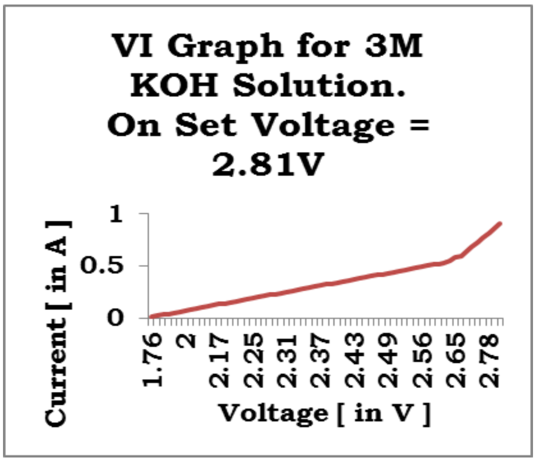

Figure 4(b)

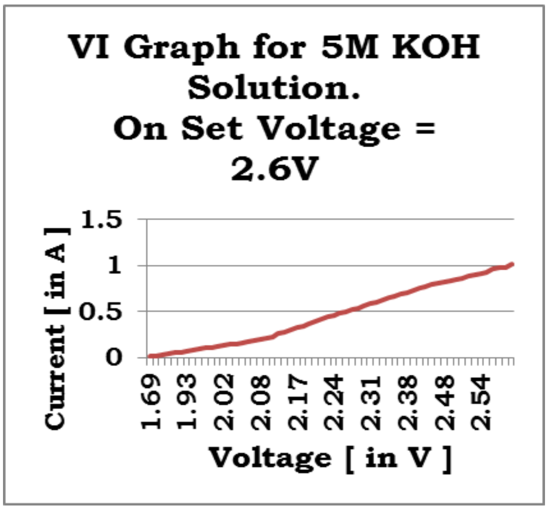

Figure 4(c)

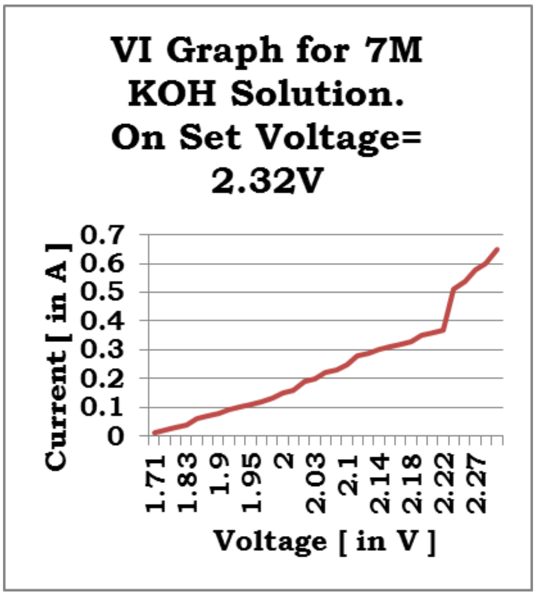

Fig. 4(d)

Fig. 4 (a, b, c & d): Current-Voltage Profile of Alkaline Water at various concentration of KOH

The VI graph for the various molarities depict that for higher molarites there is a drop in the onset voltage but the current density does not remain constant over longer periods of time. The current density was found to be quite stable for 3M KOH. When the gas collection profile was checked for 1M, 3M, 5M, it was found that best gas collection was achieved for 3M KOH solution. The graph of Volume of gas collected v/s time for various molarities of KOH is as follows:

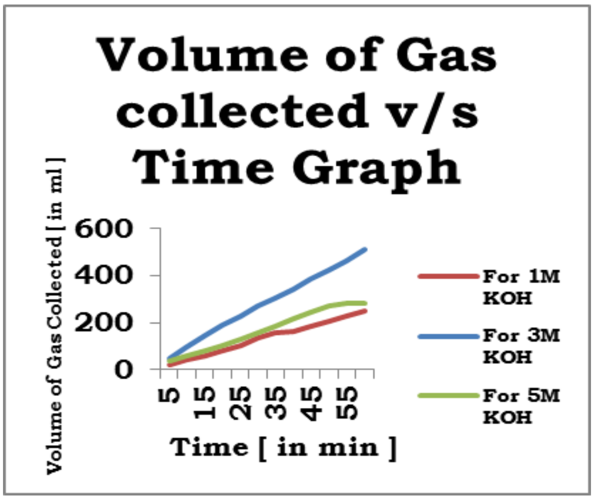

Figure 5: Volume of Gas v/s Time for various KOH Concentration

ii. Speed of Agitation:

Merely for the reaction to proceed in the forward direction, it is necessary to apply some agitation to the system. Agitation helps in the faster removal of the bubbles which gets trapped in the electrode cavities and it also aids in the easy mingling of the electrolyte [19]. For 3M KOH solution, it was observed that when the system was being agitated at 800 rpm, the gas collection was at its peak. The graph of gas collection v/s time for various speed of agitation is as follows:

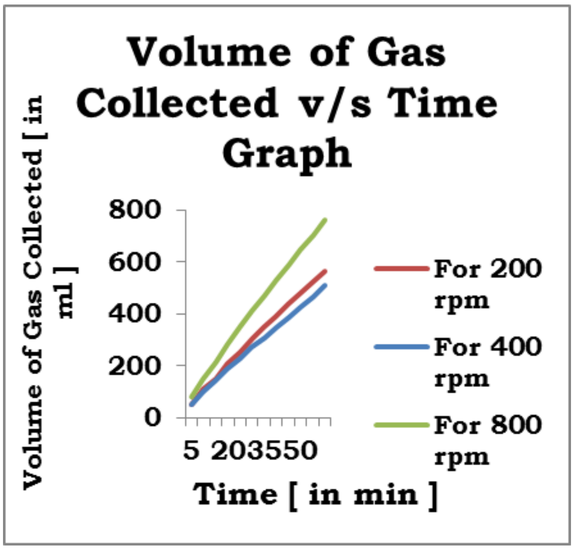

Figure 6: Volume of Gas v/s Time at various speeds of agitations

iii. Electrolysis at Optimized Condition:

An optimized reaction was carried out at room temperature for 3M KOH solution agitated at a speed of 400 rotations per minute. The volume of hydrogen collected at the end of six hours of experiment is approximately 4 litres for 250ml of solution. So for 1 litre of water the hydrogen produced is approximately 16 litres.

4. Conclusion:

From the experimental study it can be concluded that 3M KOH gives the highest yield of gas as compared to any other any higher concentrations. Speed of agitation does not affect the reaction yield but the temperature appears to affect the reaction yield to a considerable rate. So the optimum condition for the best yield of the reaction is a moderate speed of agitation and at room temperature. There are still certain other parameters which need to be addressed to make this process a totally effective and optimum one so that the best outcome can be obtained at a lower cost and low energy use.

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