Effects of Electrical Current, pH, and Electrolyte Addition on Hydrogen Production by Water Electrolysis

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ABSTRACT

Hydrogen is viewed as one of the most potential energy source in the future. One of methods to produce hydrogen is by electrolysis of water. Variables that was applied in this work were electrical current (0.5 A and 0.9 A), pH (13.47 and 13.69), and electrolyte additions (namely NaOH and KOH) with processing times for 30 minutes. The result of this work were variations of electrical current at 0.9 A, pH at 13.69 and electrolyte NaOH is at 278.394 L with volume rate 154.663 mL/s produced most amount of hydrogen, whereas condition of 0.5 A, pH 13.47 and electrolyte KOH was 75.122 L with volume rate of 41.734 mL/s yielded the lowest amount.

Keywords : Hydrogen, Electrolysis of Water, Current, pH, Electrolyte

1. INTRODUCTION

As the world population increases, so is the energy consumption. However, to met the energy demand, most countries utilizes fossil fuel-based processes, that are relatively inefficient and environmentally unfriendly. Alternative energy is needed to be developed to overcome problems incurred by the consumption and usage of fossil fuel. One of these options is by using hydrogen as new energy source. There are several considerations that are taken into account to choose hydrogen as an alternative energy includes: an overwhelming amount that can be obtained easily, the potential high energy content compared to other fuels, which is equal to 120 MJ / kg. This amount is almost two times as much as the energy content of the gasoline, which accounts only 45.6 MJ / kg (Kelly-Yong et al., 2007).

There are several methods for producing hydrogen: steam reforming of natural gas (SMR), thermal cracking of natural gas, coal gasification, partial oxidation of oil, thermochemical process, fermentation, and the electrolysis of water (Winter, 2009). Electrolysis of water is an environmentally-friendly way to produce hydrogen without emissions. In this work, electrolysis of water to produce hydrogen used variations of electrical current (0.5 A and 0.9 A), pH (13.47 and 13.69) and electrolyte addition (NaOH and KOH).

2. METHODS

2.1. Preparation of Electrolyte Solution

Electrolyte solutions used were NaOH and KOH which were prepared by dissolving the solid compound into 2500 mL of distilled water to obtain solutions with pH 13.47 and 13.69.

2.2. Electrolysis Process

Electrolyte solution was entered into the reactor into the center of the reactor. Electrolysis process was undertaken for 30 minutes. Measurements of the parameters were conducted every 5 minutes. The applied current were 0.5 A and 0.9 A. During this process, hydrogen gas would appear at the cathode while oxygen gas at the anode in the form of gas bubbles. Produced hydrogen and oxygen produced were collected in the gas storage afterwards. Equipment set-up of electrolysis process is shown in Figure 1.

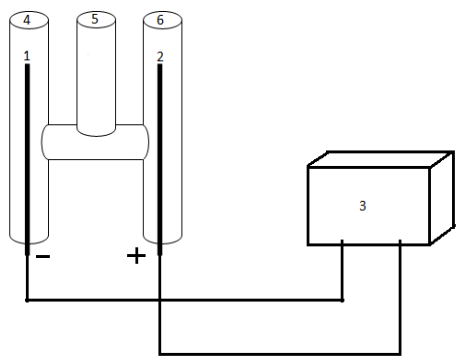

Figure 1. Equipments of Electrolysis Process

Specification:
1 Cathode
2 Anode
3 Power Supply
4 Hydrogen Outlet
5 Electrolyte Input
6 Oxygen Outlet

2.3. Analysis

Analysis of hydrogen production were done by calculating water volume reduction during the electrolysis process. Stages of the analysis were:

1. Calculation of Water Mass Reduction.

Reduced mass of water can be determined through the equation :

$$m = \rho \times V$$

Where: ρ H_2O (30^oC) = 995.647 kg/m^3 (Perry and Green, 1997)

2. Calculation of Water Moles

Moles of water can be obtained using the following equation :

$$mol = \frac{mass}{MW}$$

where MW is Molecular Weight of water (18 g/mol)

3. Calculation of Hydrogen Moles

Moles of hydrogen were obtained from the stoichiometric ratio through the following stoichiometric equation :

$$2H_2O \rightarrow 2H_2 + O_2$$

4. Hydrogen Volume Calculation

When the hydrogen mole obtained, then the volume of hydrogen gas can be obtained by using ideal gas equation :

$$PV = nRT$$

Description:
P = pressure (atm)
V = volume of gas (L)
n = number of moles (mol)
R = the ideal gas constant 0.082 (L.atm / mol K)
T = temperature (K)

3. RESULTS

a. Effects of current to hydrogen production

Effects of current to hydrogen production is shown in Figure 2-5:

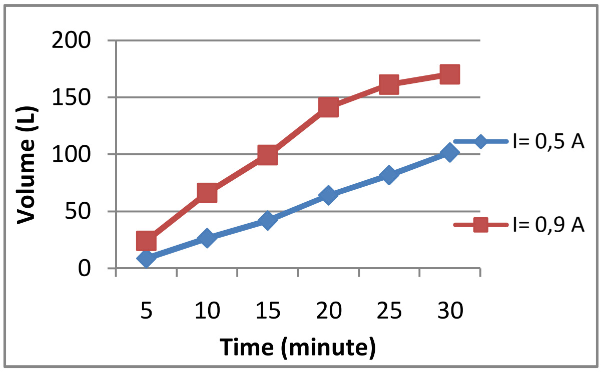

Figure 2. Effect of current to hydrogen production in NaOH solution pH 13.47

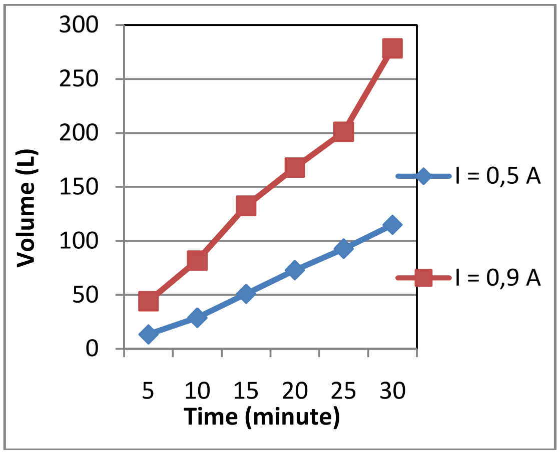

Figure 3. Effect of current to hydrogen production in NaOH solution pH 13.69

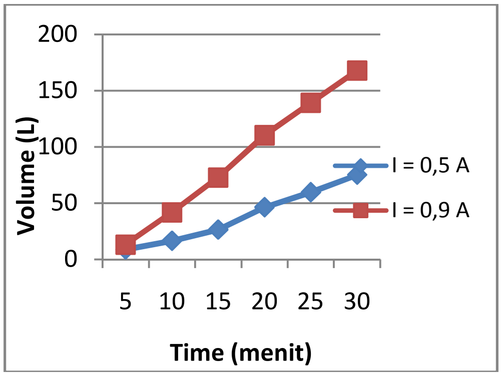

Figure 4. Effect of current to hydrogen production in KOH solution pH 13.47

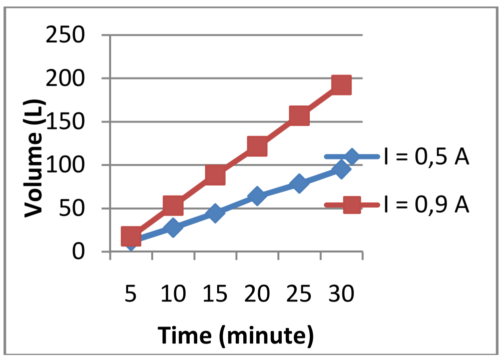

Figure 5. Effect of current to hydrogen production in KOH solution pH 13.69

Figures 2-5 show that increasing current would make potential difference become higher, according to formula :

$V = IR$

where:

V = potential difference (Volt)

I = Current (A)

R = resistance (ohm)

Potential difference would cause migration of ion coming from dissosiation of NaOH and KOH in water, whereby ion Na^+ and K^+ would move to cathode and OH^- to anode. The migrations of ion would make reduction-oxidation reaction whereby in cathode water reduced to hydrogen and in anode ion OH- will be oxidized to be oxygen.

Cathode : $4H_2O + 4e \rightarrow 2H_2 + 4OH^-$

Anode : $4OH^- \rightarrow O_2 + 2H_2O + 4e$

From the aforementioned reactions at the electrodes, the increasing of current would increase hydrogen production. Under the condition of pH 13.47, electrolyte NaOH with current 0,5 A hydrogen produced 101,636 L with volume rate 56,464 mL/s. At the same conditions with current 0,9 A, hydrogen production is 170,130 L with volume rate 94,516 mL/s.

b. Effects of pH to hydrogen production

Effects of pH to hydrogen production is shown in Figure 6-9 :

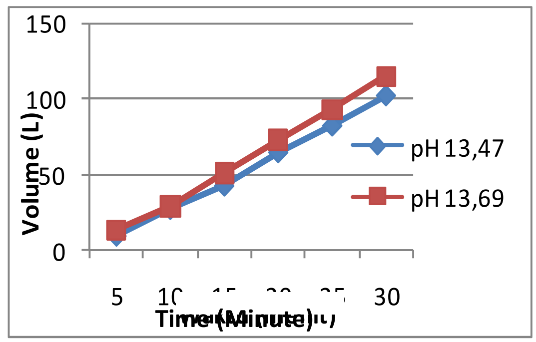

Figure 6. Effect of pH to hydrogen production at 0.5 A in NaOH solution

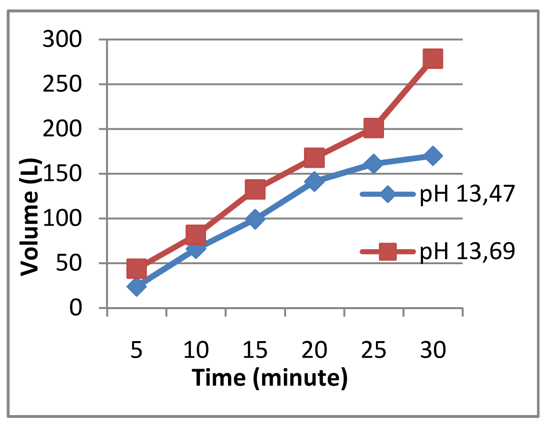

Figure 7. Effect of pH to hydrogen production at 0.9 A in NaOH solution

From Figure 6-9, it is seen that pH condition affected the amount of hydrogen gas produced. The greater pH condition is, the more hydrogen gas volume obtained. pH condition relates with concentration of H^+ ion (acidic condition) or OH^- (base condition) in solution. In base condition, the greater pH condition indicates the most OH^- ions dissolved. It can be determined from this equation :

$$pH = 14 + \log [OH^-]$$

If the most total OH^- ion dissolved, the little resistance caused by water, so that electrons will move quickly and reduction-oxidation reaction (redox) occurred. As a result, water would be reduced at cathode produces hydrogen while OH^- ion will be oxidized to oxygen at anode.

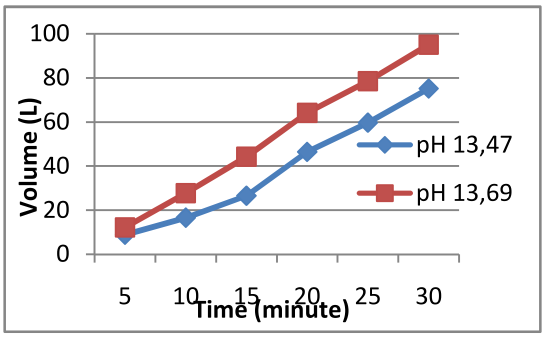

Figure 8. Effect of pH to hydrogen production at 0.5 A in KOH solution

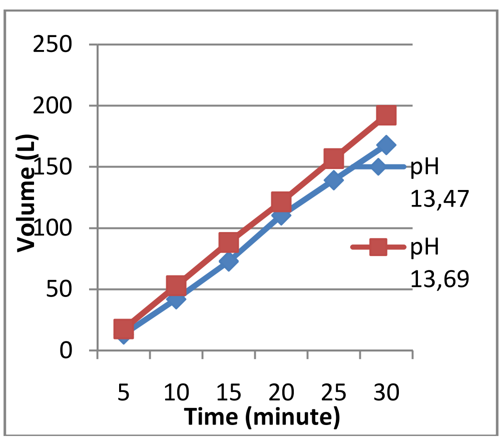

Figure 9. Effect of pH to hydrogen production at 0.9 A in KOH solution

In pH 13.69, additions of NaOH and KOH increased hydrogen production, compared to pH condition 13.47. From the measurement of NaOH solution 0.5 A, hydrogen production at pH 13.69 is 114.893 L with volume rate 63.829 mL/s, higher than at pH 13.47 is 101.636 L with volume rate 56.464 mL/s. Meanwhile at 0.9 A, the hydrogen production at pH 13.69 is 278.394 L with volumerate 154.663 mL/s and pH 13.47 is 170.130 L with volume rate 94.516 mL/s.

c. Effects of Electrolyte to Hydrogen Production

In this work, the authors used sodium hydroxide (NaOH) and potassium hydroxide (KOH) as electrolyte additives. Figures 10-13 show that at the same conditions of current and pH, hydrogen obtained with electrolyte NaOH higher than KOH due to the fact that Na atom has potential cell value higher than K atom.

E_{cell} Na = -2,711 V
E_{cell} K = -2,925 V
E_{cell} H_2O = -0,823 V

$$E_{cell} = E_{reduction} - E_{oxidation}$$

Na has potential cell value higher than K, causing Na to be easily reduced and migrate to cathode to produce hydrogen. Electrolysis process with electrolyte NaOH would subsequently produce more hydrogen than KOH.

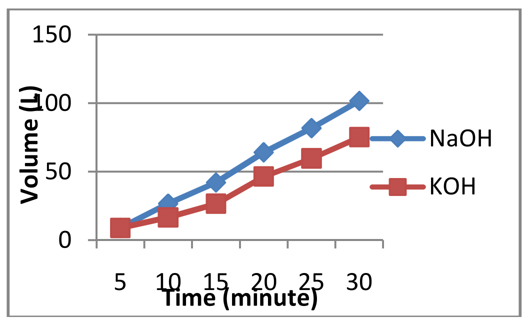

Figure 10. Effect of Electrolyte to Hydrogen Production at 0.5 A pH 13.47

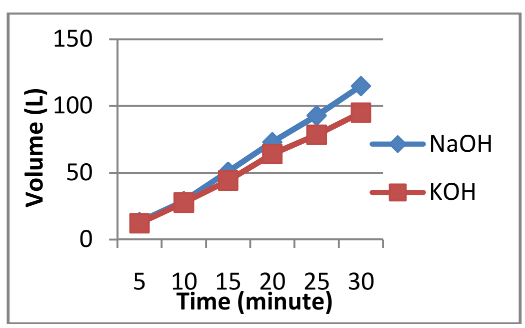

Figure 11. Effect of Electrolyte to Hydrogen Production at 0.5 A pH 13.69

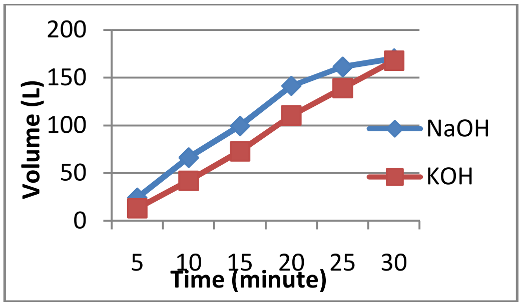

Figure 12. Effect of Electrolyte to Hydrogen Production at 0.9 A pH 13.47

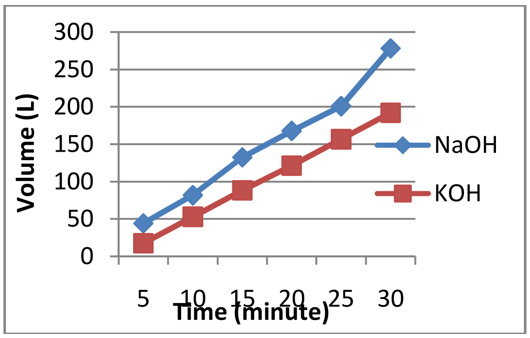

Figure 13. Effect of Electrolyte to Hydrogen Production at 0.9A pH 13.69

4. CONCLUSION

1. Current influences hydrogen production whereby higher current will increase hydrogen obtained.
2. The greater pH will increase the hydrogen obtained,
3. Electrolyte NaOH produce hydrogen higher than electrolyte KOH at the same conditions.
4. The highest hydrogen obtained at condition current 0.9 A, pH 13.69, and electrolyte NaOH is 278.394 L with volum erate 154.663 mL/s.
5. The lowest hydrogen obtained at condition current 0.5 A, pH 13.47and electrolyte KOH is 75.122 L with volume rate 41.734 mL/s

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