STUDY OF LIFETIME OF COPPER AND ALUMINUM ELECTRODES IN ELECTROLYSIS OF SEAWATER PROCESS TO PRODUCE HYDROGEN GAS

Fauzan Abiyyu Aziz[1*], Cecep E Rustana[2], Riser Fahdiran[3]

[1]*Physics Department, State University of Jakarta, East Jakarta, Indonesia*
[2]*Physics Department, Universitas Islam Negeri Maulana Malik Ibrahim, Malang-East Java, Indonesia (65144)*

Received: 17th January 2022 ; Revised:25th March 2022; Accepted: 30th March 2022

ABSTRACT

This study aims to analyze the effect of the type of electrode in the electrolysis of seawater for the production of hydrogen gas. The methods used include two types of electrodes, namely copper and aluminum and also design tools for electrolysis of seawater. Data collection is carried out every 20 minutes, the electrolysis process takes place at a constant voltage of 12 volts. The results obtained showed that the copper electrode produced 732 ml of hydrogen gas and a lifetime of 820 minutes with an average rate of 0.893 ml/minute and the highest hydrogen yield of 3.83% at 400 to 440 minutes while the aluminum electrode produced 693 ml of hydrogen gas. and a lifetime of 680 minutes with an average rate of 1.019 ml/minute and the highest hydrogen yield of 5.92% at 120 minutes.

Keywords: Electrolysis; Hydrogen Production; Electrode; Lifetime.

Introduction

As the human population increases, the need for energy also continues to increase. Currently, the main energy used still relies on fossil energy, one of which is crude oil which is processed into fuel oil (BBM) which is used in world transportation and industry.[1] The increase in energy consumption increased by 1.3% from 2019, a decrease compared to the average annual increase in energy consumption for the past 10 years.[2] Due to the limited availability of fossil energy and in producing carbon dioxide (CO_2) gas emissions in the earth's atmosphere which have an impact on global warming, renewable energy resources that come from nature and are environmentally friendly are needed so that the energy needed by humans can be fulfilled and does not reflect the environment.

There are several renewable energy sources, one of which is hydrogen gas. Hydrogen gas is the gas that has the highest concentration, which is 75% formed in the universe and 90% is inhibited in nature. On earth, hydrogen combines with the element oxygen to form a compound H_2O called water.[3] Hydrogen gas is a better energy storage medium compared to other fuels, because it has a high heat value. The energy density of hydrogen is 140 MJ/kg, while the energy density of solid fuels is generally only 50 MJ/kg.[4]

Hydrogen on earth is not freely available, but is produced industrially.[5] Electrolysis is an effective and simple method for the production hydrogen gas. The hydrogen gas produced has a higher purity level than conventional methods.[6] The level of purity of the gas produced is 99.9% and can be used as a reaction for the industrial sector.[4] Electrolysis is a decomposition reaction in an electrolyte by an electric current. In an electrolytic cell, electrical energy is converted into chemical energy. An electrolyte soluble in a polar solvent (such as

*Corresponding author.
E-Mail: fauzand22@gmail.com

water) dissociates into positive ions (cations) and negative ions (anions). Negative ions due to negative anions due to electrolysis solutions are attracted to a positive charge at the anode while positive ions due to positive ions because they pass through the solution move towards a negative charge.[7] There are several types of electrolysis based on the type of electrolyte, one of which is the alkaline electrolyzer.[8] Water is a weak electrolyte. The addition of electrolytes such as acids, bases, or salts can increase the conductivity of the air so that the electrolysis of water can be faster.[9] The electrochemical equation for the electrolysis of water is as follows:

Anode :

$$4H^+_{(aq)} + 4e^- \rightarrow 2H_{2(g)} \quad (1)$$

Cathode:

$$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^- \quad (2)$$

Complete reaction :

$$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)} \quad (3)$$

And this study, the electrolyte used is seawater, so the electrochemical equation for the electrolysis process is as follows:

Anode :

$$2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^- \quad (4)$$

Cathode :

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)} \quad (5)$$

Complete reaction :

$$2H_2O_{(l)} + 2Cl^-_{(aq)} \rightarrow H_{2(g)} + Cl_{2(g)} + 2OH^-_{(aq)} \quad (6)$$

Several factors that affect the volume of hydrogen gas produced in the electrolysis process are the voltage, the type of electrolyte, and the electrodes used. Based on the calculation of the electrolysis reversible voltage, it is found that the electrolysis of water can be carried out starting with a voltage of 1.23 volts.[9]

Seawater is used as an electrolyte solution in this study because of its abundant availability to be a renewable energy source by producing hydrogen gas with high efficiency and low cost.[10] The chlorine content of salt in seawater causes corrosion of metals to be faster, because it has electrolyte properties that accelerate oxidation-reduction reaction.[11] Corrosion rate is affected by the salinity level of seawater.[12] A good electrode for use in the electrolysis of seawater process is certainly one that is able to conduct electricity well, has an economical price and is resistant to corrosion caused by seawater. Copper and aluminum electrodes were chosen in this study because they are good conductors of electricity. Copper is considered good in the electrolysis process because it has a fairly high oxidation power, good ability to conduct electricity, has good heat resistance, and the price is also economical.

Understanding the abundant availability of seawater and its potential that can be used to produce hydrogen gas through the electrolysis process as well as copper and aluminum electrodes which have good electrical conductivity, corrosion resistance and economical price, this study will discuss and analyze the effect of the type of electrode used in electrolysis seawater on the hydrogen gas produced and the lifetime of the electrodes used.

Method

The electrolysis of seawater process is carried out by varying the type of electrode to determine the volume of hydrogen gas produced and the lifetime of each electrode. The electrolysis process is a decomposition reaction in an electrolyte by an electric current. In an electrolytic cell, electrical energy is converted into chemical energy. An electrolyte soluble in a polar solvent (such as water) dissociates into positive ions (cations) and negative ions (anions). Negative ions are called anions because during electrolysis the solution is attracted to the positive charge at the anode whereas positive ions are called cations because through the solution they move towards a negative charge.This study used copper and aluminum rod electrodes with a diameter and height of 10^{-1} cm and 10 cm, respectively. The potential difference given is constant 12 volts with an AC-DC adapter. A constant voltage of 12 Volts was used because[13] explained that when applying

 ISSN:1979-6374/ EISSN:2460-5999

a voltage of 12 Volt to the electrolysis of water for hydrogen gas production, the volume produced was quite stable. The hydrogen gas produced is accommodated in a 100 ml measuring cylinder. The following is a schematic of the electrolysis of seawater equipment used:

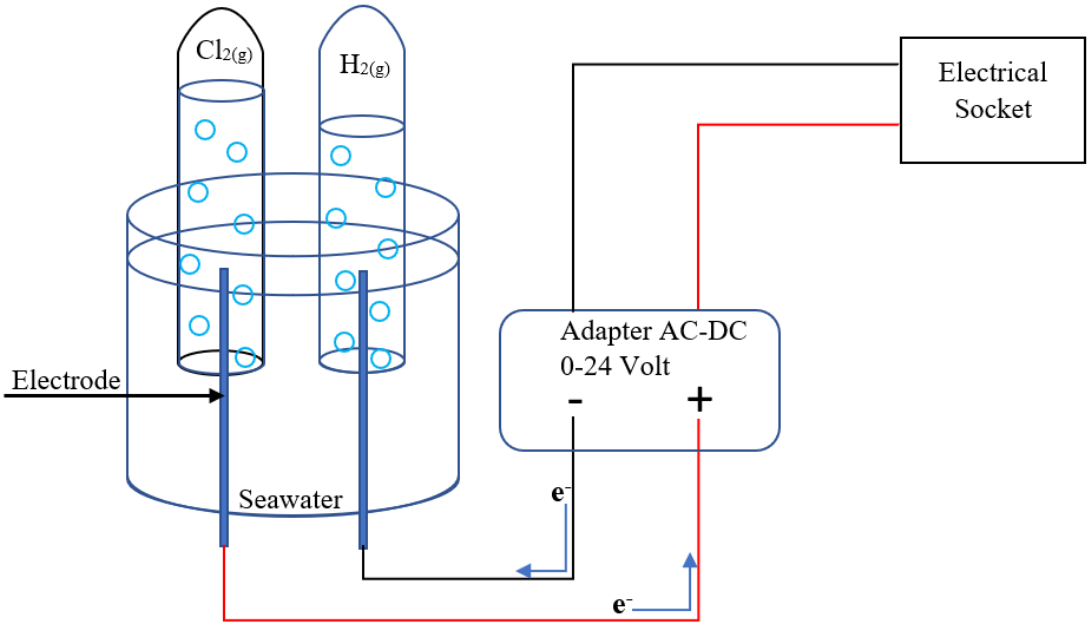

Figure 1. Schematic of electrolysis of seawater

The data collection technique used is the water displacement method. The method of water displacement is to measure the seawater level in the measuring cylinder at the cathode before the electrolysis process. Then do the electrolysis process and measure the seawater level again in the measuring cylinder at the cathode after the electrolysis process. By knowing the change in seawater level in the measuring cylinder and multiplied by its surface area, the volume of hydrogen gas produced can be obtained. Data were collected every 20 minutes until the electrolysis process was no longer visible changes in seawater level in the measuring cylinder at the cathode for each electrode. The data analysis technique used is descriptive quantitative. After the volume of hydrogen gas is known, the rate of hydrogen gas production is calculated using the following equation:

$$\frac{Volume\ of\ hydrogen\ gas}{Time\ of\ electrolysis} \quad (7)$$

And calculate the resulting hydrogen yield to determine the percentage of hydrogen gas[12] obtained using the following equation:

$$\frac{Current\ volume - Previous\ volume}{Total\ volume}\ x\ 100\% \quad (8)$$

after the change in seawater level is no longer visible in the measuring cylinder at the cathode in the last 20 minutes, the lifespan of each electrode used is obtained.

Result and discussion

The figure shows the results of measuring the volume of hydrogen gas produced

The figure describes the volume of hydrogen gas produced and the lifetime of each electrode as well as the production rate of hydrogen gas produced by the electrolysis of seawater with a constant voltage of 12 volts. When electrolysis takes place, there is a change in the color of seawater in the electrolysis container when using copper or aluminum electrodes. The color change

 ISSN:1979-6374/ EISSN:2460-5999

occurs due to a chemical reaction between seawater and each electrode used. When using copper electrodes, the redox reaction equation is:

$$2H_2O_{(l)} + Cu_{(s)} + 2Cl^-_{(aq)} \rightarrow H_{2(g)} + Cl_{2(g)} + CuCl_{2(aq)} + 2OH^-_{(aq)} \quad (9)$$

Meanwhile, when using aluminum electrodes, the redox reaction equation is:

$$6H_2O_{(l)} + 2Al_{(s)} + 2Cl^-_{(aq)} \rightarrow 3H_{2(g)} + 2Cl_{2(g)} + 2Al(OH)_{3(aq)} \quad (10)$$

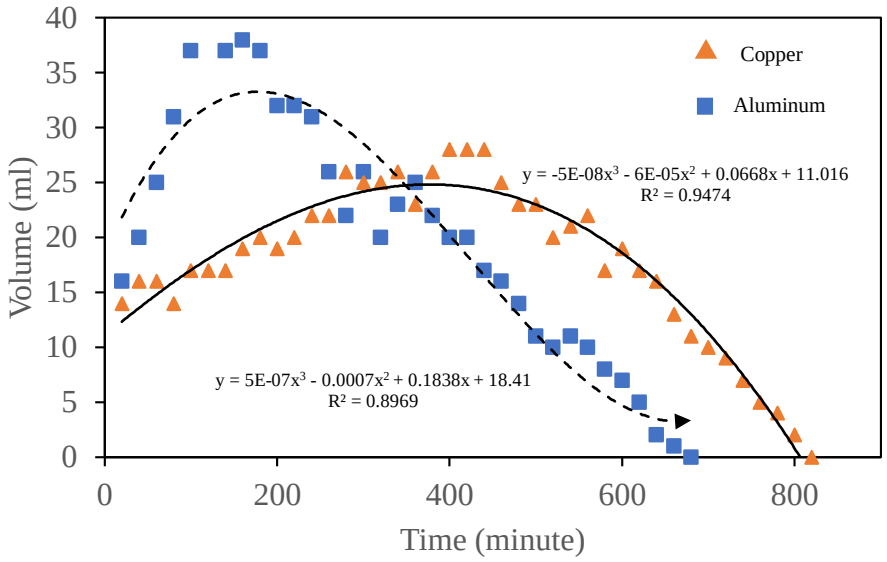

Figure 2. Graph of the volume of hydrogen gas (ml) vs time (minutes) of electrolysis process of seawater

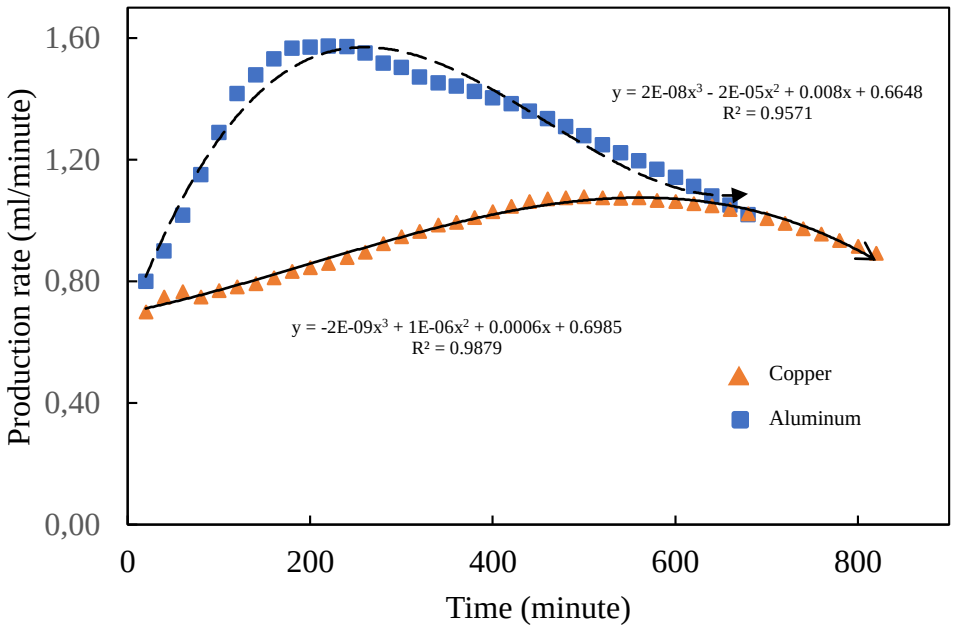

Figure 3. Graph of the rate of hydrogen production gas (ml) vs time (minute) of electrolysis process of seawater

Table 1. Table of lifetime, hydrogen yield, and total volume of hydrogen gas produced with copper and aluminum electrodes

Electrode	Lifetime (Minute)	Total Volume of Hydrogen gas (ml)	Hydrogen Yield (%)	R^2
Copper	820	732	3.83	0.947
Aluminum	680	693	5.89	0.897

Table 2. Table of the average rate of production of hydrogen gas produced.

Electrode	Average rate (ml/minute)	R^2
Copper	0.893	0.957
Aluminum	1.019	0.988

In Figure 2, the volume of hydrogen gas produced using copper electrode increased for 400 minutes and then decreased after 440 minutes, while at the aluminum electrode the volume of hydrogen gas increased for 120 minutes and then decreased. In line with that,[14] explained that in general the volume of hydrogen gas produced from the electrolysis process is affected by the time of the electrolysis process. With the process of electrolysis of seawater which causes oxidation at the anode and the process runs for a long time, the copper and aluminum electrodes are corroded by chlorine. When using aluminum electrodes, $Al(OH)_3$ compounds are formed. These compounds are classified as weak electrolytes, the longer the electrolysis process takes place, the more these compounds will affect the volume of hydrogen gas produced. This is in accordance with[15] which explains that after a few hours the electrolysis process takes place, there is a decrease in the production of hydrogen gas.

In Figure 3, the rate of hydrogen gas production using copper electrodes decreased after 520 minutes. Meanwhile, the rate of hydrogen gas production with aluminum electrodes decreased after 240 minutes. Interestingly, although the total volume of hydrogen gas produced using copper electrodes is more than that of aluminum electrodes, but in table 2, the average rate of hydrogen gas production using aluminum electrodes is higher than using copper electrodes, this is because the service life of copper electrodes is much longer than aluminum electrodes in the electrolysis of seawater process[15] explained that the lifespan of copper electrodes is longer than that of aluminum electrodes in the electrolysis of seawater process. Although by using aluminum electrodes the hydrogen gas production rate is faster, the volume of hydrogen gas produced tends to decrease compared to copper electrodes and the coefficient of determination value at copper electrodes is higher which indicates that the production rate is more stable than aluminum electrodes. In Figure 3, the hydrogen gas production rate from each electrode decreased but not to 0 ml/min. This is because the electrolysis process is still ongoing, but there is no visible change in seawater level in the measuring cylinder in the last 20 minutes. This is possible because very little hydrogen gas is produced, whereas in this study, hydrogen gas was accommodated in the form of a measuring cylinder with a capacity of 100 ml and an accuracy of ±1 ml so that no change in the seawater level was seen in the measuring cylinder.

With a diameter and height of 10^{-1} cm and 10 cm, respectively, the copper electrode is capable of producing 732 ml of hydrogen gas while the aluminum electrode is capable of producing 693 ml. These results are consistent with[15] which explains that the copper electrode produces more hydrogen

 ISSN:1979-6374/ EISSN:2460-5999

gas than the aluminum electrode in the electrolysis of seawater process. It is also influenced by the electrical conductivity properties of the two electrodes. The electrical conductivity of copper is higher than that of aluminum.

With a diameter and height of 10^{-1} cm and 10 cm, respectively, the copper electrode is capable of producing 732 ml of hydrogen gas while the aluminum electrode is capable of producing 693 ml. These results are consistent with[15] which explains that the copper electrode produces more hydrogen gas than the aluminum electrode in the electrolysis of seawater process. The results obtained in this study indicate that the copper electrode is better than the aluminum electrode which is in accordance with the results of the study[15] which concluded that the copper electrode is superior to aluminum in terms of efficiency.

Conclusion

From the analysis of the data obtained in this study, it can be concluded that with a voltage of 12 volts the copper electrode is superior to the aluminum electrode in terms of efficiency in the electrolysis of seawater to produce hydrogen gas. And until there is no visible change in sea level in the measuring cylinder, the lifetime of the copper electrode is longer than that of the aluminum electrode. And the total volume of hydrogen gas produced in seawater electrolysis using copper electrodes is more than the total volume of hydrogen gas produced using aluminum electrodes. And the highest yield of hydrogen produced using copper electrodes was 3.83% at 400 to 440 minutes while on aluminum electrodes it was 5.92% at 120 minutes.

References

1. Fazlunnazar M, Hakim L, Meriatna M, Sulhatun S. PRODUKSI GAS HIDROGEN DARI AIR LAUT DENGAN METODE ELEKTROLISIS MENGGUNAKAN ELEKTRODA TEMBAGA DAN ALUMUNIUM (Cu DAN Al). Jurnal Teknologi Kimia Unimal. 2020 May 1;9(1):58-66.
2. Looney B. Statistical review of world energy, 2020|. Bp. 2020 Jun;69:66.
3. Afief A, Isana SY. Produksi Gas Hidrogen Menggunakan Elektroda Stainless Steel/Fe-Co-Ni Dengan Media Tepung Biji Rambutan (Nephelium lappaceum l.). InProsiding Seminar Nasional Kimia UNY 2017 (pp. 259-268).Chi, J., & Yu, H. (2018). Water electrolysis based on renewable energy for hydrogen production. Chinese Journal of Catalysis, 390-394.
4. Chi J, Yu H. Water electrolysis based on renewable energy for hydrogen production. Chinese Journal of Catalysis. 2018 Mar 1;39(3):390-4.
5. Vanags M, Kleperis J, Bajars G. Water electrolysis with inductive voltage pulses. Electrolysis.–Riga: InTech. 2012 Oct 17:19-44.
6. de Fátima Palhares DD, Vieira LG, Damasceno JJ. Hydrogen production by a low-cost electrolyzer developed through the combination of alkaline water electrolysis and solar energy use. International Journal of Hydrogen Energy. 2018 Mar 1;43(9):4265-75.
7. Rustana CE, Salam IN, Sugihartono I, Sasmitaningsihhiadayah W, Madjid AD, Hananto FS. Preliminary Study on The Effect of Time on Hydrogen Production from Electrolysis of The Seawater. InJournal of Physics: Conference Series 2021 Oct 1 (Vol. 2019, No. 1, p. 012095). IOP Publishing.
8. Dincer, I., & Alzahrani, A. A. 4.25 Electrolyzers. In Comprehensive Energy Systems (Vol. 4). Elsevier. 2018.
9. Rustana CE, Muchtar SJ, Sugihartono I, Sasmitaningsihhiadayah W, Madjid AD, Hananto FS. The effect of voltage and electrode types on hydrogen production from the seawater electrolysis process. InJournal of Physics: Conference Series 2021 Oct 1 (Vol. 2019, No. 1, p. 012096). IOP Publishing.

 ISSN:1979-6374/ EISSN:2460-5999

10. Nikolaidis, P.,& Poullikkas, A. In Renewable and Sustainable Eenergy Reviews. 2017
11. Utomo S. Pengaruh Konsentrasi Larutan $NaNO_2$ sebagai Inhibitor terhadap Laju Korosi Besi dalam Media Air Laut. Jurnal Teknologi. 2015 Jul 30;7(2):93-103.
12. Afiah, S. Studi Karakteristik Daya Listrik Air Laut dengan Prinsip Sel Volta dan Efek Korosi Elektroda. Makasar: FMIPA Universitas Hasanudin; 2017
13. Yuvaraj AL, Santhanaraj D. A systematic study on electrolytic production of hydrogen gas by using graphite as electrode. Materials Research. 2014 Feb;17(1):83-7.
14. Rahmi HI. DESAIN SISTEM REAKTOR DAN PENGUKURAN H2 BERBASIS ELEKTROLISIS DENGAN KATALIS CO_2. Universitas Negeri Jakarta, Jakarta. 2019.
15. Slama RB. Hydrogen production by water electrolysis effects of the electrodes materials nature on the solar water electrolysis performances. 2013

 ISSN:1979-6374/ EISSN:2460-5999