

The Effect of H₂SO₄ Catalyst and Electric Voltage on Hydrogen Gas Production via the Electrolysis of Distilled Water

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Article Information	ABSTRACT
Article History Received : April 06, 2025 Revised : April 23, 2025 Published : July 02, 2025	Hydrogen is an environmentally friendly alternative energy source with great potential in the renewable energy sector. One efficient method for hydrogen production is water electrolysis, which can be influenced by catalyst concentration and applied electric voltage. This study aims to analyze the effect of varying H₂SO₄ concentrations and electric voltage on hydrogen production via water electrolysis. The concentrations used were 0.05 M, 0.075 M, 0.1 M, 0.25 M, and 0.5 M, while the applied voltages were 16 V, 18 V, 20 V, 22 V, and 24 V. Constant parameters included 500 mL of distilled water and a 2-minute hydrogen collection time. Gas analysis using Gas Chromatography-Thermal Conductivity Detector (GC-TCD) showed hydrogen detection at a retention time of 2.88 minutes. The highest hydrogen content, 11.143% mol, was achieved at 0.075 M H₂SO₄ and 24 V, with a maximum gas volume of 0.000659 m³. Based on RSNI ISO 14687:2019, the minimum fuel-grade hydrogen requirement is 50% mol. Therefore, further optimization is necessary to improve efficiency. Future studies are recommended to explore alternative catalysts, extend electrolysis time, or modify electrodes, as well as include tests without catalysts to evaluate reaction sustainability and compare hydrogen yields with and without catalytic influence.
Keywords: <i>Electric Voltage; Electrolysis; Hydrogen; Renewable Energy; Sulfuric Acid.</i>	

INTRODUCTION

The energy crisis is not only a global concern but also a significant issue in Indonesia (Angkasa & Nugraheni, 2016). Energy can be divided into two categories, non-renewable energy and renewable energy. Both play a significant role in meeting human needs. Non-renewable energy has a limited supply, meaning that once its reserves are depleted, it cannot be replenished. In contrast, renewable energy is derived from natural sources that can be used directly and freely. Moreover, its availability is unlimited and can be utilized sustainably (Sidi, 2016). The most widely used energy in the world is oil fuel from fossil energy. Fossil-based energy is non-renewable and will be depleted in the coming years (Arisandi et al., 2022). To this day, Indonesia continues to rely on fossil fuels, such as petroleum, coal, and natural gas, as its primary energy sources (Wahyono et al., 2017). The combustion of fossil fuels for thermal energy results in the depletion of fossil fuel reserves and a substantial increase in CO₂ emissions. The use of fossil energy contributes to global warming due to combustion residues in the form of CO and CO₂ gases (Taspika, 2015). Renewable Energy (RE) serves as a solution to meet national energy needs while

supporting efforts to mitigate global climate change. Many countries have utilized Renewable Energy to prevent energy shortages (Firdaus & Sudarti, 2022).

Hydrogen is one example of Renewable Energy. Hydrogen gas is recognized as a potential future fuel substitute that can be effectively utilized in fuel cells (Eker & Sarp, 2016). It is estimated that the demand for hydrogen will continue to increase in the future. To anticipate the surge in hydrogen demand, various production technologies are being developed (Purnami et al., 2015). It can be produced from various resources and is also a byproduct of other chemical processes. There are several methods for hydrogen production, such as steam reforming of methane gas or other fossil fuels like coal and petroleum. Approximately 96% of hydrogen production comes from non-renewable fossil fuels, particularly methane. However, the use of fossil fuels for hydrogen production results in lower purity levels and harmful greenhouse gas byproducts (Gani et al., 2020).

Hydrogen gas has great potential as an energy source due to its environmentally friendly nature. One method to obtain H_2 gas is through water electrolysis. Water electrolysis is the process of decomposing water into H_2 and O_2 gases using an electric current passing through the water (Hasan & Hidayat, 2022). Electrolysis is a chemical process that converts electrical energy into chemical energy. This process requires electrodes and an electrolyte solution (Nisa & Fatimah, 2020). An electrolyte solution is a homogeneous mixture consisting of two or more substances, in which one acts as the solute while the others act as the solvent. This solution has the ability to conduct electricity (electrolyte) or not conduct electricity (non-electrolyte) (Bengi et al., 2018). Based on their electrical conductivity, electrolyte solutions are divided into two types, strong electrolytes and weak electrolytes. A strong electrolyte solution is one in which the solute is completely ionized, forming positive and negative ions that allow electric current to flow efficiently. On the other hand, a weak electrolyte solution is only partially ionized, resulting in lower electrical conductivity (Pandia et al., 2021). The electrolysis process for breaking down water molecules is relatively slow, so a catalyst is needed to accelerate the reaction and increase the amount of hydrogen gas produced. In water electrolysis, catalysts help facilitate or speed up the decomposition of water into hydrogen and oxygen because catalyst ions influence the stability of water molecules, making it easier to convert them into H^+ and OH^- ions. This occurs due to a reduction in activation energy (Bow et al., 2020).

Acidic substances (H_2SO_4 solution) contain a high concentration of H^+ ions when dissolved in water, whereas basic substances ($NaHCO_3$ and KOH solutions) contain a high concentration of OH^- ions (Aziz et al., 2018). The higher the acidity level of an electrolyte solution, the greater the number of electrons generated during the electrolysis process. An increased number of electrons facilitates electron transfer, which in turn enhances the volume of gas produced. A higher amount of H^+ ions plays a crucial role in accelerating the breakdown of water molecule bonds into their constituent monomers, making electrolysis more efficient (Lestari et al., 2022). Therefore, in the electrolysis of H_2O , using H_2SO_4 as a catalyst produces more H_2 gas compared to adding $NaHCO_3$ or KOH as catalysts. Based on this explanation, the electrolysis of H_2O into H_2 gas is conducted with the addition of H_2SO_4 as a catalyst to determine the optimal conditions for hydrogen production by varying the concentration of H_2SO_4 and the applied electrical voltage.

RESEARCH METHODS

This research was conducted to analyze the effect of sulfuric acid (H_2SO_4) concentration and electrical voltage on the electrolysis process for hydrogen gas production. The methodology includes the preparation of materials, the setup of the electrolysis system, variations in experimental conditions, and the analysis of the generated hydrogen gas.

Materials and Equipment

The primary materials used in this research were distilled water (aquadest) and sulfuric acid (H_2SO_4), obtained from a chemical supplier. The electrolysis system utilized stainless steel electrodes and a DC power supply connected via a DC barrel jack connector (commonly known

as a DC plug). The electrolysis cell was designed to hold the electrolyte solution and enable hydrogen gas collection effectively.

To ensure safety during the experiment, personal protective equipment (PPE) such as lab coats, nitrile gloves, and safety goggles were used. The entire electrolysis process was conducted in a well-ventilated area with access to a fume hood, and proper handling of acid and gases followed standard laboratory safety protocols.

Experimental Setup and Procedure

1. Preparation of Electrolyte Solution :
 - a. A specific volume of distilled water (500 mL) was measured and placed into the electrolysis cell.
 - b. H_2SO_4 was added at varying concentrations (0.05 M, 0.075 M, 0.1 M, 0.25 M, and 0.5 M).
2. Electrolysis Process :
 - a. Stainless steel electrodes were immersed in the prepared electrolyte solution.
 - b. The power supply (via DC barrel jack) was connected to the electrodes. Voltage levels of 16 V, 18 V, 20 V, 22 V, and 24 V were applied to observe their effect on hydrogen gas production.
 - c. The system was run for a fixed duration (2 minutes) for each test condition.
3. Data Collection and Analysis :
 - a. The flow rate and volume of hydrogen gas produced were measured and recorded.
 - b. Gas Chromatography (GC) analysis was conducted to determine the purity and composition of the generated hydrogen gas.

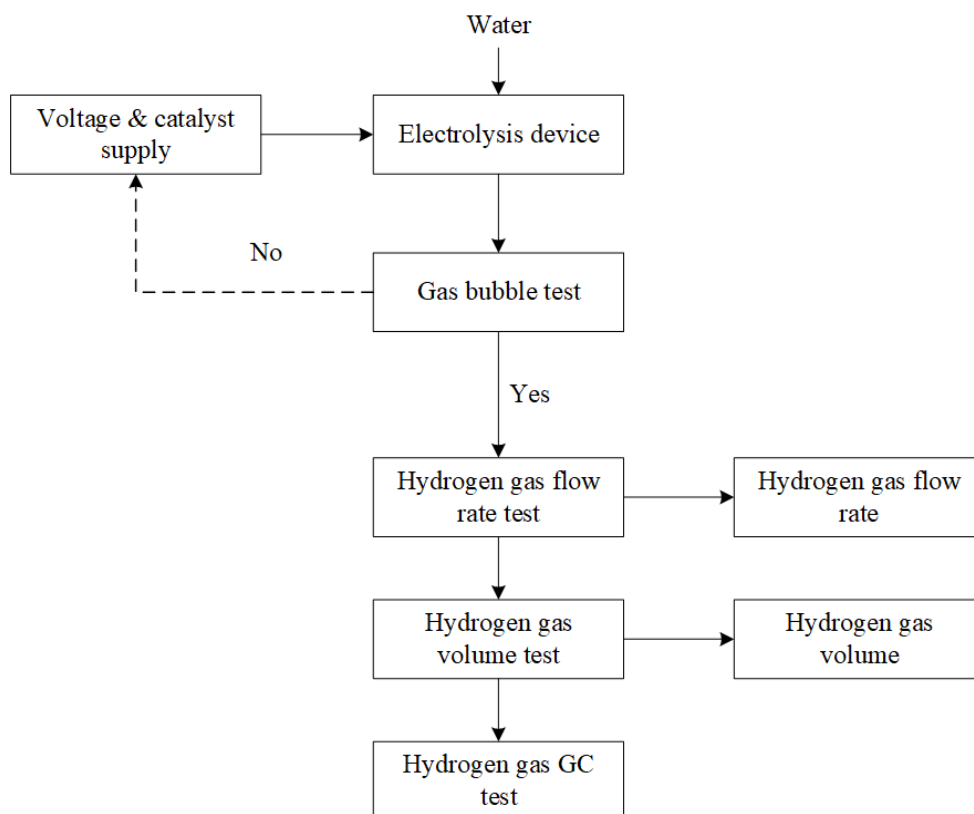


Figure 1. Flowchart of Hydrogen Gas Production

Data Analysis

The collected data were analyzed to determine the optimal conditions for hydrogen production, considering the effect of sulfuric acid concentration and voltage on the efficiency of

the electrolysis process. The relationship between these variables and hydrogen yield was evaluated based on observed trends in gas volume, flow rate, and purity. This methodology ensures a systematic approach to understanding the role of catalyst concentration and electrical parameters in optimizing hydrogen gas production through water electrolysis.

RESULTS AND DISCUSSION

In this study, hydrogen gas was produced through the electrolysis of distilled water (aquadest) with the assistance of sulfuric acid as a catalyst and an applied electric voltage. The analysis of the electrolysis process and the characteristics of the produced hydrogen gas included the evaluation of flow rate and hydrogen volume based on variations in catalyst concentration and electric voltage, gas bubble analysis, and Gas Chromatography (GC) analysis.

During the hydrogen gas production process through electrolysis of distilled water using sulfuric acid as a catalyst at various concentrations, the obtained hydrogen gas flow rate and volume were as follows :

Table 1. Analysis Results of Hydrogen Gas Flow Rate and Volume with Variations in H₂SO₄ Catalyst Concentration and Electric Voltage

Voltage (V)	Concentration of H ₂ SO ₄ (M)	Flow Rate (L/minute)	Volume of Hydrogen (m ³)
16	0,05	0,1890	0,000378
	0,075	0,1915	0,000383
	0,1	0,1785	0,000357
	0,25	0,1745	0,000349
	0,5	0,170	0,000340
18	0,05	0,2125	0,000425
	0,075	0,2175	0,000435
	0,1	0,2030	0,000406
	0,25	0,1930	0,000386
	0,5	0,1870	0,000374
20	0,05	0,2230	0,000446
	0,075	0,2290	0,000458
	0,1	0,2115	0,000423
	0,25	0,2055	0,000411
	0,5	0,1980	0,000396
22	0,05	0,2595	0,000519
	0,075	0,2650	0,000530
	0,1	0,2445	0,000489
	0,25	0,2320	0,000464
	0,5	0,220	0,000440
24	0,05	0,3240	0,000648
	0,075	0,3295	0,000659
	0,1	0,2935	0,000587
	0,25	0,2810	0,000562
	0,5	0,2750	0,000550

The volume of hydrogen gas in the electrolysis process is significantly influenced by the concentration of H₂SO₄ as a catalyst. The higher the catalyst concentration in the electrolyte solution, the more easily the solution becomes saturated, making it more difficult for ions in the electrolyte to move when conducting electric current (Bow et al., 2020).

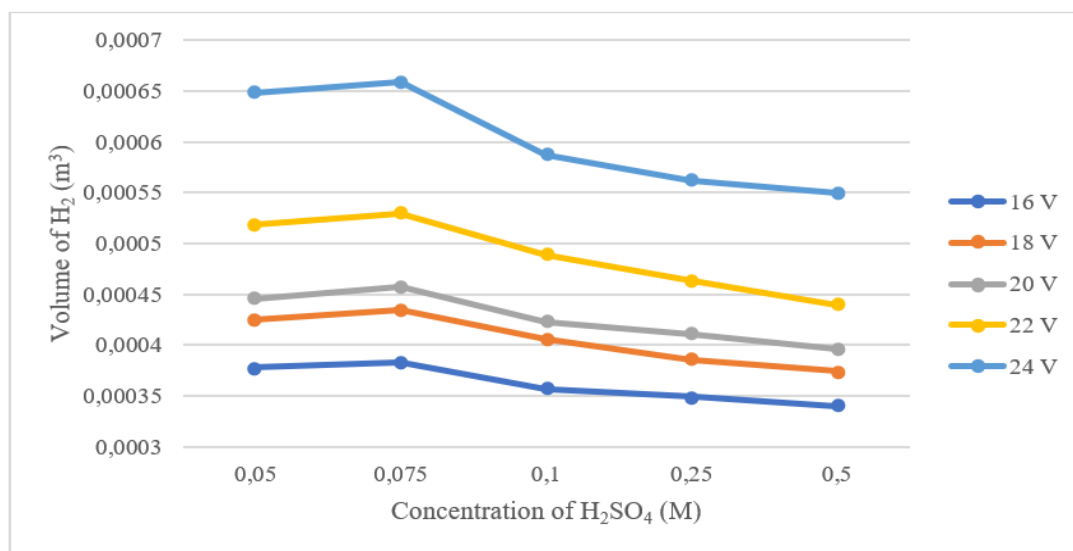


Figure 2. Graph of the Effect of H₂SO₄ Catalyst Concentration on Hydrogen Gas Volume

Based on the graph, at lower catalyst concentrations (0,05 M to 0,1 M), the volume of hydrogen gas produced was higher compared to higher concentrations. This is due to the lower number of ions in the solution, which reduces resistance to the movement of H⁺ ions toward the electrode, thereby optimizing the electrolysis reaction. The increased mobility of H⁺ ions accelerates reduction at the cathode, leading to higher hydrogen gas production. Additionally, at lower catalyst concentrations, the hydrogen gas flow rate is also higher, contributing to an overall increase in hydrogen gas volume. The higher the concentration of H₂SO₄ used, the lower the flow rate of the generated hydrogen gas (Hakim et al., 2023).

In water electrolysis with H₂SO₄ as a catalyst, reducing the catalyst concentration to a certain limit can enhance hydrogen gas production. However, if the H₂SO₄ concentration is too low (below 0.05 M), the number of H⁺ ions in the solution becomes very limited, causing a drastic decline in electrolysis efficiency due to the reduced availability of ions for reduction at the cathode. Lower catalyst concentrations can improve system stability and reduce the risk of electrode degradation but may also lower process efficiency (Babay et al., 2023). This is due to the reduced electrolyte conductivity, which limits hydrogen production. Therefore, an optimal H₂SO₄ concentration exists that maximizes hydrogen production before efficiency decreases at either lower or higher concentrations.

Based on the experiment, the optimal value was obtained at a concentration of 0.075 M with an electric voltage of 24 V, producing a hydrogen gas volume of 0,000659 m³. At concentrations between 0,1 M and 0,25 M, the hydrogen gas volume still increased but not as significantly as at lower concentrations. This indicates that the ion concentration in the solution is already high, but excessive ions can cause resistance in the electrolysis process. Increasing electrolyte concentration can enhance electrical conductivity and accelerate electrochemical reactions; however, at excessively high concentrations, saturation occurs, hindering ion movement and slowing electron transfer, thereby reducing system efficiency (Bow et al., 2020). At higher H₂SO₄ concentrations (0,25 M to 0,5 M), the volume of hydrogen gas produced actually decreases. This decline is caused by ion saturation in the solution, which obstructs H⁺ ion mobility toward the electrode, thereby reducing the hydrogen gas flow rate. A lower flow rate results in a decreased hydrogen gas volume due to the reduced efficiency of the electrolysis reaction. Additionally, high H₂SO₄ concentrations increase the risk of electrode corrosion, which can lower electrolysis efficiency. At high concentrations, the hydrogen gas flow rate tends to be lower because increased ion interactions in the solution slow down electrochemical reactions.

The volume of hydrogen gas in electrolysis is also influenced by the applied electric voltage. The higher the voltage, the more hydrogen gas is produced (Aditya et al., 2023).

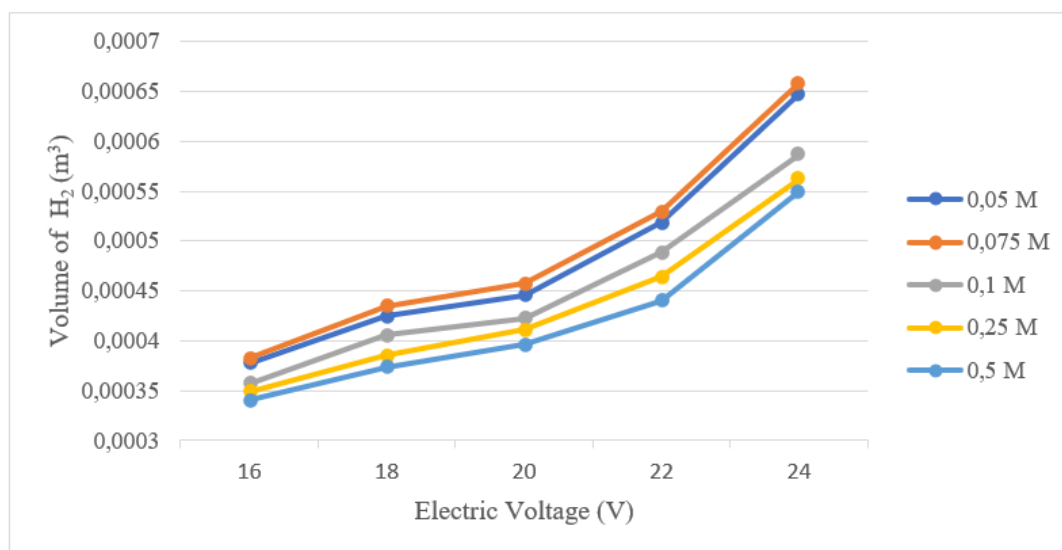


Figure 3. Graph of the Effect of Electric Voltage on Hydrogen Gas Volume

At higher electric voltages (22 V and 24 V), the hydrogen gas volume increases significantly. This occurs because higher voltage increases the current carried by free ions in the solution. Electric voltage provides a driving force for electrons; the greater the voltage, the stronger the push, resulting in a higher current flow. A higher current allows more ions to participate in electrical conduction (Wahyono et al., 2017). The greater the number of ions involved in conducting electricity, the faster the reaction rate and the higher the number of hydrogen gas molecules produced, meaning more hydrogen gas is formed.

Based on the experiment, the optimal value was obtained at 24 V with an H_2SO_4 concentration of 0,075 M, producing a hydrogen gas volume of 0,000659 m^3 . At each voltage variation, there was an increase in hydrogen gas production, although at lower voltages, the increase was not as significant as at higher voltages. The electric current applied to the positive electrode (anode) and negative electrode (cathode) creates a potential difference, ionizing water molecules into positive and negative ions. Positive ions migrate to the negative electrode and absorb electrons, while negative ions move to the positive electrode and release electrons. The greater the applied voltage, the larger the resulting current, facilitating ion movement during electrolysis. The highest voltage used in this study was 24 V, as using voltages above 24 V could lead to overvoltage. Overvoltage can cause degradation of electrical equipment (reducing its lifespan) and damage (Putri et al., 2022).

From the graph, the highest hydrogen volume was obtained at the highest voltage, 24 V. This result aligns with previous research, which found that higher applied voltage leads to greater hydrogen gas production (Aditya et al., 2023). Electrolysis is a chemical process that converts electrical energy into chemical energy. External energy is required to drive the electrolysis process by applying electric current to the electrolyte solution. The higher the voltage, the greater the hydrogen gas formation rate, leading to an increased hydrogen gas volume.



Figure 4. Results of Hydrogen Gas Bubble Test

Throughout the electrolysis process, using various voltage levels and sulfuric acid catalyst concentrations, gas bubbles were observed at the electrodes. These bubbles strongly indicate that the electrolysis reaction successfully produced hydrogen gas. According to the theory of water electrolysis, at the cathode (negative electrode), H^+ ions accept electrons and undergo reduction to form hydrogen gas (H_2), which appears as bubbles around the electrode (Ramadhan & Ali, 2024). Additionally, the number of bubbles formed is influenced by the applied voltage and catalyst concentration. Higher voltage accelerates the electrochemical reaction rate, increasing hydrogen gas production (Aditya et al., 2023). Similarly, sulfuric acid (H_2SO_4) enhances electrolyte solution conductivity. Observing gas bubbles during the electrolysis process confirms that this experiment successfully generated hydrogen gas as the primary product of water electrolysis.

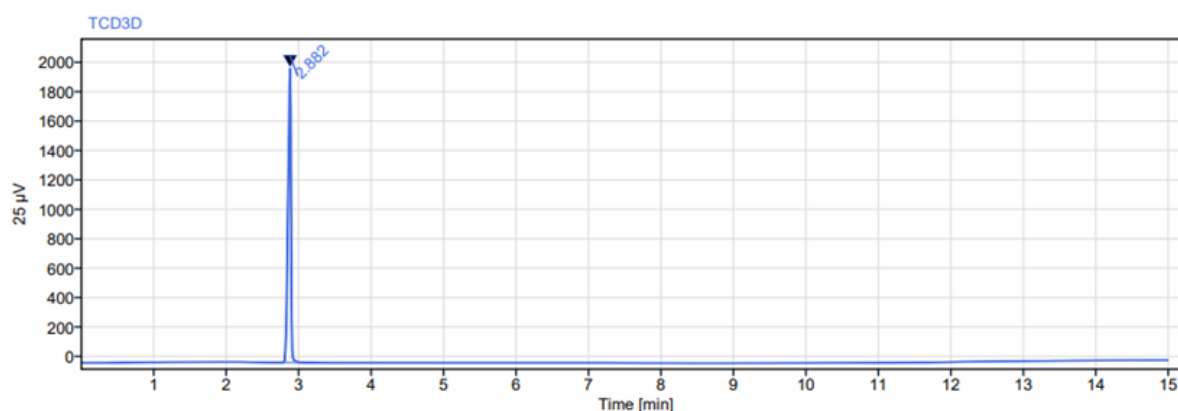


Figure 5. Results of Hydrogen Gas GC (Gas Chromatography) Test

Gas chromatography (GC) analysis was used to determine the composition of the hydrogen gas produced through water electrolysis using sulfuric acid (H_2SO_4) as a catalyst. This qualitative and quantitative analysis assessed the success of hydrogen production in the electrolysis process. In this study, the GC-TCD (Gas Chromatography-Thermal Conductivity Detector) analysis of water electrolysis with sulfuric acid as a catalyst detected hydrogen gas at a retention time (RT) of 2,88 minutes with a concentration of 11,143% mol. The chromatogram displayed a primary peak at 2,882 minutes.

The sulfuric acid concentration used as an electrolyte plays a crucial role in increasing solution conductivity, thereby accelerating the electrolysis reaction rate. However, excessively high concentrations can cause electrode corrosion and increase the risk of unwanted by-products.

Additionally, using stainless steel electrodes in an acidic medium like H_2SO_4 can lead to electrode corrosion, reducing hydrogen production efficiency. The H_2SO_4 concentration affects the corrosion rate of stainless steel electrodes. Higher H_2SO_4 concentrations lead to increased corrosion rates, thereby lowering hydrogen production efficiency.

Based on this study, the produced hydrogen content was relatively low, at 11,143% mol. According to RSNI ISO 14687:2019, the hydrogen fuel index (minimum molar fraction) for Type I, Class E, Category 1 is 50%. This indicates that the produced hydrogen does not yet meet the SNI standard for fuel use. Further optimization of electrolysis parameters such as selecting more corrosion-resistant electrodes, adjusting the optimal electrolyte concentration, and controlling voltage during the process is necessary to improve hydrogen production efficiency.

CONCLUSION

The electrolysis of water using sulfuric acid (H_2SO_4) as a catalyst demonstrated varying effectiveness in hydrogen gas production. Higher catalyst concentrations tended to decrease the flow rate and volume of H_2 produced, while lower catalyst concentrations improved hydrogen production efficiency. The highest hydrogen gas volume, 0,000659 m^3 , was achieved at an H_2SO_4 concentration of 0,075 M. Additionally, electrical voltage played a crucial role in increasing the amount of hydrogen produced. Higher voltage levels directly enhanced the hydrogen gas flow rate, with optimal results obtained at 24 V. However, excessive voltage can cause overvoltage effects, potentially damaging the electrodes and reducing system efficiency. Gas Chromatography (GC) analysis indicated that the hydrogen concentration produced in this study was 11,143% mol, which does not yet meet the hydrogen fuel standard according to RSNI ISO 14687:2019. Therefore, further optimization of electrolysis parameters, including selecting more corrosion-resistant electrodes and adjusting the electrolyte concentration, is necessary to improve hydrogen production efficiency. The result of this study present practical implications for the development of small-scale hydrogen generators for educational or laboratory purposes. Moreover, with further refinement, the findings may contribute to the advancement of low-cost, eco-friendly hydrogen production technologies that support sustainable energy transition initiatives.

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