Hydrogen Production from Waste Aluminum Foil Hydrochloric Acid

Abdullah Mousay Saeid[1*], Aliya Idris Eghbili[2], Bubker A. Bader[3]

[1]Department of Chemistry, Faculty of Sciences, University of Gulf Sidra, Bin Jawad, Libya
[2]Department of Chemistry, Faculty of Engineering Sciences, University of Bright Star, Braga, Libya.
[3]Department Operations, Power Plant, Zueitina Gas Station , Libya.
abdmu445@gmail.com

Abstract. The purpose of this research is to investigate the creation of hydrogen as an energy source through the interaction of aluminum with hydrochloric acid. only in the presence of hydrochloric acid, which acts as a catalyst, does this reaction occur. The following are the primary benefits of employing aluminum for indirect energy storage: recyclability, non-toxicity, and simplicity of forming. various sizes ranging from 1 cm to 2 cm were used. the aluminum foil samples were tested with acid, and the findings revealed that the reaction is quite powerful. affected by surface volume, where the larger the volume, the larger the hydrogen generated. therefore, the hydrogen generated at a very large volume was 2 cm3 (320 ml) at 45°C, while in the other volumes the hydrogen produced was In proportions close to 270 ml. the reaction time and the reaction time were very close, and there is no significant difference between them: 39 s, 44 s, 45 s at 27°C, 30°C, and 37°C, respectively. this is attributed to the reaction surface's size.

Keywords: hydrogen; Aluminum, Hydrochloric acid.

1 Introduction

As the world strives to transition away from fossil fuels, several academics are researching whether clean hydrogen fuel may play a larger role in sectors ranging from transportation and manufacturing to buildings and power generation. It might be utilized in fuel cell automobiles, heat-generating boilers, electricity-generating gas turbines, renewable energy storage systems, and other applications. hydrogen produced by the interactions of aluminum and water can be utilized to power mobile equipment for portable applications such as emergency generators and laptop computers. there is also a suggestion. the goal of this white paper is to explain and test the abilities of aluminum and water interactions to create hydrogen, which is focused on on-board hydrogen vehicle applications.

Hydrogen generated through the chemical reactions of aluminum and water can be utilized to power portable electronics such as emergency generators and computer laptops. There is

I. U. Ahad (ed.), *Proceedings of the 4th International Conference on Key Enabling Technologies (KEYTECH 2024)*, Atlantis Highlights in Engineering 35,
https://doi.org/10.2991/978-94-6463-602-4_27

also a proposal that the interactions of aluminum and water can be employed to store hydrogen aboard fuel cell-driven automobiles over there. The goal of this white paper is to explain and assess the capability of aluminum and water processes to create hydrogen. hydrogen is a clean fuel that generates just water whenever used in a fuel cell. natural gas, nuclear power, biomass, and renewable energy sources such as the sun and wind may all be used to make hydrogen. these characteristics make it an appealing fuel choice for transportation and power production applications. It may be utilized in automobiles, housing, portable power, and a variety of other applications.

2 Literature review

(Xingyuan Gao and S. Kawi et al., 2022) to make a research paper titled " Catalytic Hydrogen Production " The summary of this study was deals with various reaction systems to thermally convert fossil fuels into hydrogen gas with heterogeneous catalysts, which consists of thermo catalytic conversions of fossil fuels including methane and other hydrocarbons by cracking, partial oxidation, steam reforming, dry reforming, and auto thermal reforming. Processes discussed here are related to their reaction mechanisms, advantages, limitations, catalyst developments, and reactor designs. This paper can build up the knowledge of thermo catalytic hydrogen production in heterogeneous catalysis, which benefits both scientific research and industry development.

(James G. Speight et al., 2020) to make a research paper titled “Hydrogen Production” The summary of this study was: as hydrogen use has become more widespread in refineries, hydrogen production has moved from the status of a high-tech specialty operation to an integral feature of most refineries. hydrogenation processes for the conversion of petroleum and petroleum products may be classified as destructive and nondestructive. the most common feedstock for steam reforming are low boiling saturated hydrocarbon derivatives that have a low sulfur content; including natural gas, refinery gas, liquefied petroleum gas, and low-boiling naphtha. assuming assiduous feedstock purification and removal of all of the objectionable contaminants, the chemistry of hydrogen production can be defined. the chapter discusses various chemical processes for hydrogen production such as auto thermal reforming, combined reforming, dry reforming, and steam- methane reforming. hydrogen plants are one of the most extensive users of catalysts in the refinery. the various catalysts used are reforming catalysts and shift conversion catalysts.

3 The products of the aluminum-Water Reaction

Structural forms are governed by crystalline structure, but for our research, we are only interested in molecular composition, which reveals the ratios in which each element is present in each molecule. The less hydrogen in the by-product, the better. the products of the aluminum -water reaction. aluminum -water interactions produce three stable by-products: aluminum hydroxide (Al(OH)3), aluminum hydroxide oxide (AlOOH), and aluminum oxide (Al2O3). Each of these by-products has several

$$Al(s) + 3H_2O_{(l)} + Al(OH)_{3(S)} + 3H_{2(g)} \quad (1.1)$$

$$3Al_{(s)} + 2H_2O_{(l)} + AlOOH_{(S)} + 3H_{2(g)} \quad (1.2)$$

$$Al_{(s)} + 3H_2O_{(l)} + Al_2O_{3(S)} + 3H_{2(g)} \quad (1.3)$$

4 Martial

It uses commercial aluminum foil in the local market. It is completely divided into several different sizes, respectively: 1cm x 1cm, 1.5cm x 1.5cm, and 2cm x 2cm. each size was cut in to 15 pieces. and hydrochloric acid bottle 500 ml, liquid. Conical flask 250ml was used in the experiment. rectangular basin to be filled with water. A cylinder measuring 500 ml. A thermometer to measure the reaction temperature inside the glass cone and a timer to measure the reaction time.

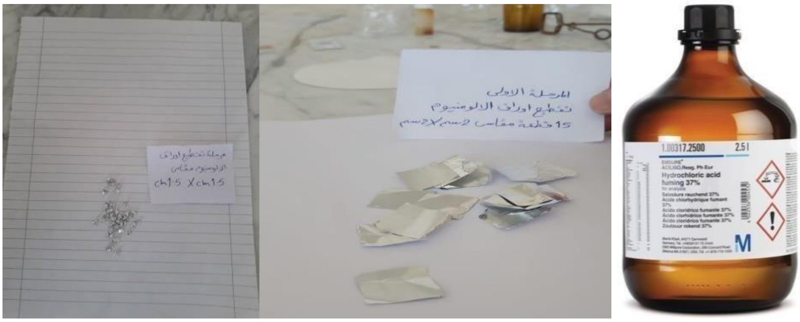

Fig. 1. Aluminum foil and Hydrochloric acid bottle

4.1 Water Displacement Apparatus for Hydrogen Production

The experimental setup is depicted in Figure1. a conical flask was filled with a predetermid volume of hydrochloric acid solution and aluminum foil. a rubber stopper with plastic tubing at the neck was employed to prevent gas leakage and route the gas generated to the measurement cylinder. a measuring cylinder was entirely filled with water, inverted, and plunged into a basin of water. the H2 gas created took up space in the measuring cylinder, reducing the water level. the occupied level in the measuring cylinder was recorded over time. volume and temperature. each test was carried out three times.

Fig.2. Schematic of the experimental Water displacement apparatus

When aluminum metal reacts with dilute hydrochloric acid, aqueous aluminum chloride, AlCl3, and hydrogen gas, H2 are formed. This is the balanced chemical equation that explains the single replacement reaction. keep in mind that this reaction will not occur as soon as the piece of aluminum is added to the hydrochloric acid solution.

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2 \quad (1.4)$$

This is due to an aluminum oxide (Al2O3) layer that prevents the metal from interacting with water. the hydrochloric acid will take some time to react through this protective layer, but once it does, the reaction will proceed quickly, with hydrogen gas beginning to bubble out of solution.

Fig. 3. stypes aluminum reacts with hydrochloric acid

4.1 Why is hydrogen collected by the downward displacement of water?

This method of gas collection is my preferred approach for collecting gases that do not dissolve in water. the scientific principle in this case is the quality of matter known as impenetrability. according to the principle, no two things may occupy the same place at the same time. as hydrogen gas enters the water-filled container, liquid water exits the container. because all of the water has evaporated, you can see that the collecting container is already full of hydrogen gas. the volume of an insoluble solid can also be calculated using water displacement. when a solid is submerged in water, the water level rises because the solid has taken up the area formerly held by the liquid

5 Results and discussion

Temperature distribution and the and hydrogen generation rate

Figure 3 The hydrogen generated through the reaction of aluminum foil with hydrochloric acid of 1 cm x 1 cm, the lowest volume was 101 ml and the temperature was 39°C. while 2 cm x 2 cm was the highest volume of 320 ml and the temperature was 45°C, because of the surface area of the reaction and have 1.5 cm x 1.5 cm was a little high to 270 ml and the temperature was high 44°C where the higher the surface of the reaction with the acid, the greater the amount of hydrogen generated from the reaction.

Table 1. Hydrogen yields (%) for aluminum foil with HCl

	1cm x1cm	**1.5cm x 1.5cm**	**2cm x 2cm**
Volume (ml)	101	270	320
Temperatures (°C)	39	44	45

5.1 Development of hydrogen through time

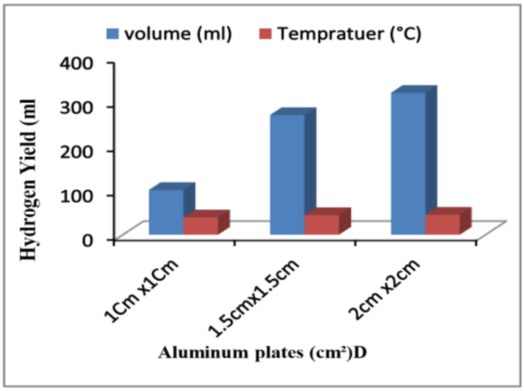

Fig.4. Temperature profile and hydrogen generation rate

Table 3 shows the time course curves for hydrogen evolution under different reaction conditions for the three aluminum surfaces evaluated. according to the foregoing data, a bigger hydrogen volume is formed in the different volume aluminum of time with reaction acid concentration (and hence, the reaction rate is higher. the volume was 320 ml and the reaction time was 37 seconds at the largest surface of aluminum 2 cm X 2 cm. While the hydrogen produced from the reaction at 1.5 cm x 1.5 cm was 270 ml and the reaction time was 30 seconds while 1cm x 1cm was 101 ml and the reaction time was less. where, we note that the larger the surface of the reaction, the longer the time to finish the reaction

Table 2. Hydrogen yields (%) for aluminum foil react HCl with time

	1cm x1cm	**1.5cmx1.5cm**	**2cm x2cm**
Volume (ml)	101	270	320
Time (s)	27	30	37

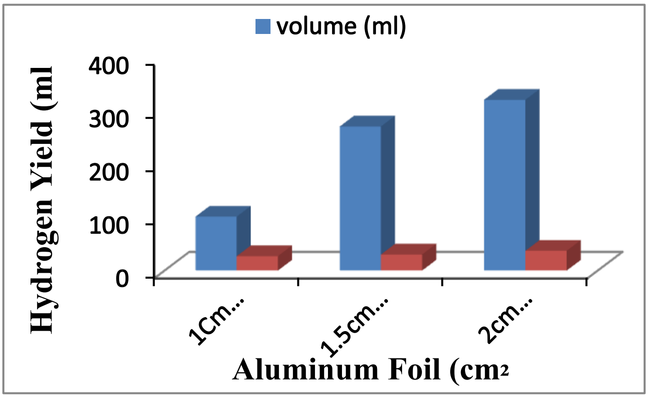

Fig. 5. Evolution of hydrogen from aluminum foils with time

5.2 Production of hydrogen

The rate of hydrogen creation (ml) is also shown in figure 5. the hydrogen generation rate produced with a peak at 2cm x 2cm of 320 ml and a high maximum rate at 1.5cm x 1.5 cm of 270 ml and 101 ml, respectively. based on the findings, it is conceivable to infer that aluminum is a promising alternative for producing high-purity hydrogen.

Table 3. Hydrogen yields (%)

Aluminum plates (cm^2 Area	Volume
1Cm x1Cm	101.667
1.5cmx1.5cm	270
2cm x2cm	320

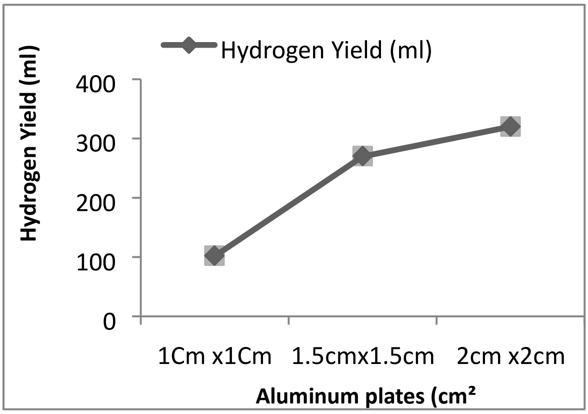

Fig. 6. The hydrogen generation rate (ml)

5.3 How to apply hydrogen produced from aluminum and hydrochloric acid in real-world scenarios

In a small energy conversion plant, hydrogen produced on-site from the reaction of aluminum and hydrochloric acid is combined with carbon dioxide captured from the atmosphere to produce methanol, which is used as a fuel for hybrid cars

On a space station, the reaction of aluminum with hydrochloric acid is used as part of an emergency system to produce hydrogen that can be used in fuel cells to provide electricity in the event of a main system failure.

At a desalination facility in a remote coastal area, hydrogen produced from the reaction of aluminum with hydrochloric acid is used as fuel to heat saltwater into steam in a distillation process, providing clean drinking water for local residents.

In a small chemical plant, the hydrogen produced from the reaction of aluminum and hydrochloric acid is used in a hydrogenation reaction to produce ammonia, which is then used in the manufacture of agricultural fertilizers.

At the Automotive Research Center, hydrogen is produced from aluminum and hydrochloric acid in experiments to test the efficiency of new fuel cells in hydrogen-powered cars.

During an expedition in a mountainous area, the hydrogen produced on site is used to power small measuring devices or analyzers while studying geological layers and soil.

At a flight test center, hydrogen produced from the reaction of aluminum and hydrochloric acid is used to power a small hydrogen fuel cell drone, helping to test the aircraft's energy efficiency.

At a technology research institute, a team of scientists is developing new technologies for storing hydrogen safely and efficiently, and is using hydrogen produced from the reaction of aluminum and hydrochloric acid to test their prototypes.

5.4 Comparison of the efficiency and cost-effectiveness of this method with other hydrogen production

methods. Cost-effectiveness: Natural gas reforming is cheaper but not sustainable. electrolysis can be expensive, but with renewable energy it becomes more competitive and sustainable. aluminum reaction with hydrochloric acid is relatively expensive and not suitable for large-scale production
Efficiency: Electrolysis and natural gas reforming are more efficient than aluminum reaction with hydrochloric acid Environmental impact: electrolysis with renewable energy is more environmentally sustainable, while aluminum reaction is less sustainable due to the chemical waste and environmental impact of aluminum extraction
Ease of application: Aluminum reaction is suitable for emergency situations and remote locations, while electrolysis and natural gas reforming require more complex infrastructure these factors suggest that aluminum reaction with hydrochloric acid may be a temporary solution in some specific scenarios, but it is not the optimal method for large-scale hydrogen production

6 Conclusion

Given the facts provided, it is plausible to infer that aluminum is a viable option for producing high-purity hydrogen. the temperature and concentration of alkalis and acids that function as catalysts have a major influence on reaction rates. Furthermore, under some conditions, high yields near stoichiometric predictions are attained. connecting such a system to a fuel cell or similar device capable of burning hydrogen to create electricity, particularly for portable and medium-sized electric equipment, may readily control the rate of aluminum consumption. the primary goal of this initiative is to reduce energy use and greenhouse gas emissions. regardless of the high energy required to produce aluminum, some studies have shown that the energetic and energetic efficiency to generate hydrogen overcomes the losses of aluminum production. Hydrogen is used in a variety of applications, including methanol production, water desalination, powering space stations, and producing ammonia for fertilizers. It is also used in testing new fuel cells in cars and drones, as well as in field applications such as geological exploration. finally, it is used in research to develop hydrogen storage technologies. these applications demonstrate the versatility and value of hydrogen as a fuel and energy in many areas.

7 Future works that related to this study

i The production of hydrogen of the reaction of aluminum with water in the presence of NaOH and KOH.

ii The size of the aluminum clippings used will change based on different temperature levels than those used in this paper."

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