Alkaline concentration on graphite hydrogen production

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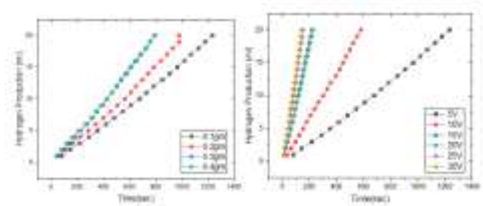
Abstract

We set up the experiment and prepared four electrolytes, each containing 0.10, 0.20, 0.30, and 0.40 g of sodium hydroxide in 400 ml. The experiment was conducted at 5, 10, 15, 20, 25, and 30 V from each of the four different electrolyte concentrations. For each sample, the commutative hydrogen production is notated/measured up to 20 ml, and the time for 20 ml hydrogen production is noted. The results show that at 5 V, the time required to produce 20 ml of hydrogen is longer, whereas at 30 V, the time required is shorter, regardless of concentration. Furthermore, when considering voltage, the time required to produce 20 ml of hydrogen from 0.40 g of electrolyte takes less time than 0.10 g.

The objective of this work is to study the hydrogen production at different concentration of NaOH using graphite electrode. The production increase with increasing the concentration and voltage. Some comparative studies are shown in figure below. The left figure indicate the production of hydrogen with time at 0.10 g NaOH concertation at different voltage while right shows the hydrogen production with time at 5V with different concentration of NaOH. The rate of hydrogen production for other concentration found similar to left figure but production rate is high with increasing the voltage. The rate of hydrogen production for other voltage is found similar to right figure but the production rate of hydrogen is high with increasing voltage.



Keywords: Electrolyte, Hydrogen production, Voltage, Sodium hydroxide

Introduction

The separation of hydrogen and oxygen from water is known as electrolysis. It is very simple and is accomplished by bypassing electricity through some water between electrodes placed in the water. In polar solvents, electrolytes dissolve by dissociating into positive ions known as cations and negative ions known as anions. Anions are drawn to the positive charge on the anode, whereas cations are drawn to the negative charge on the cathode. For faster electrolysis/faster production hydrogen some electrolyte such as acids, bases, and salts are used. Hydrogen can be used as an alternative fuel because it can replace fossil energy while having very little negative environmental impact. In this work, graphite is used as an electrode material because it is made of carbon and is one of the softest materials used in pencils. Graphite has an opaque structure and a hexagonal crystal system that appears as a foliated mass or loose thin sheets. The specific gravity is 2.23. It is non-metallic, conducts electricity, and is an environmentally friendly choice for hydrogen production. When compared to other fuels, the produced hydrogen is 14 times less than air and has a high energy density per kilogram. Hydrogen provides 2 − 3 times the energy of another substance, and electrolysis is the most common environmentally friendly method of producing hydrogen. This method produces higher purity hydrogen than other methods, and hydrogen is being considered as an alternative fuel for the future. There are numerous hydrogen applications underway, but the Fuel Cell application is one of the best technologies for future transportation. Stainless steel is one of the electrodes used to produce hydrogen. Graphite, aluminium, alloys, and so on, but platinum is the best because it resists corrosion better than the others [1]. Furthermore, when 304 stainless steel is used, there is a 20% increase in efficiency compared to platinum, which is approximately 20,000 times more expensive than steel [2]. Numerous studies are being conducted in order to improve energy efficiency and sustainability. There are several methods for producing hydrogen, including electrolytic, photolytic, and thermochemical processes, but electrolytic and photolytic processes are the best because they are environmentally friendly. About 96% of total hydrogen is produced from natural gas, oil, and coal, which pollutes the environment and changes the climate. As a result, photolytic and electrolytic methods are preferred, with electrolysis accounting for approximately 4% of global production. There are several factors/parameters that influence hydrogen production, such as electrode materials, temperature, and electrolytes, and numerous studies are being conducted to increase hydrogen production by varying these parameters. Hydrogen fuel is regarded as the cleanest alternative fuel to meet the world's energy challenge, prompting researchers to seek more cost-effective and environmentally friendly ways to meet rising global energy demand. Hydrogen is an important source of sustainable energy systems, and it has the potential to be a promising alternative energy source for carbon-based fuel. Hydrogen can also be compressed and liquefied by adsorption in compressed H_2 tanks. Water electrolysis is one of the most primitive and capable methods of producing hydrogen. Water is the most abundant natural resource on the planet, and electrolysis produced only pure oxygen as a by product. When compared to hydrogen obtained from other greenhouse gas emitting sources, electrolysis produces hydrogen with a purity of 99.99%. The electrolysis process has lagged behind due to the high cost of the electrolytic system. External power sources account for a larger portion of a cell's cost. One of the most difficult challenges in producing efficient hydrogen is reaching commercial scale. In 2018, it was reported that 79.50% of energy is produced from non-renewable sources, which harms the environment. However, due to the increasing environmental concerns and difficulties in storing battery-based energy, electrolysis with hydrogen based on fuel cell technology is the best option and offers the most opportunities for hydrogen production as well as applications. Urbanization and rising population demand energy, which has been met in the past by the consumption of fossil fuels. The consumption of fossil fuels is increasing, causing environmental problems. As a result, we need alternative, renewable, sustainable, and clean energy sources like hydrogen energy, which is abundant and produces no emissions when consumed. Alternative hydrogen-generation processes include thermochemical processes, direct solar water splitting processes, biological processes, alkaline water electrolysis, and others [3]. Numerous devices based on carbon with oxygen functional groups (OFGs) used as best electron transfer include electrolysers, supercapacitors, batteries, and fuel cells. According to Radinger et al. (2021), charge transfer properties are caused by graphitic defects rather than OFGs [4]. Hydrogen production using solar energy has gained popularity in recent years because it is both a green technology and a cost-effective renewable energy source [5]. Potential loss between electrodes is a major contributor to an electrolytic cell's inefficiency. Researchers are always interested in finding a feasible electrodes combination in terms of cost and efficacy. Recently, Ni, Co, Cu, Pt, Fe, and their alloys, oxides, and bi-metal coatings, among others, have been successfully used as electrode constructing materials. Most of these materials are extremely expensive and necessitate a high level of purity (99.99%). The current study aimed to develop a new suitable efficient electrode combination at the lowest possible cost [6]. The imbalance between electricity generation and consumption creates difficulties in the efficient use of electricity. The constant production of electricity only fulfil the demand, there is massive amounts of surplus electricity during the time. As a result, it is critical to develop an efficient method of storing excess electricity. Because hydrogen is promoted as a green energy carrier, producing hydrogen through water electrolysis is a promising strategy for converting surplus electricity to sustainable clean energy. The development of such technology is dependent on an appropriate redox mediator and corresponding decoupled electrolyser catalyst. However, it is still severely constrained by the electrolyser's with small capacity are used to hydrogen production [7].

Hydrogen's high energy and long-term energy carrier motivate people to use it in various technologies. Furthermore, the developed technology based on hydrogen is used to decarbonize and create a healthy environment [8]. According to the literature, pencil graphite electrodes (PGEs) have become increasingly popular in recent years due to their ease of availability, low cost, eco-friendliness, and lack of cleaning time. Graphite electrodes, according to David et al. (2017), are composed of an inorganic or organic matrix and a composite of graphite, clay, and binder [9,10]. The production of hydrogen from alkaline water via electrolysis is simple, but it faces challenges such as lowering energy consumption, costs, maintenance, increasing reliability, durability, and safety, among other things. According to the experimental report [11], graphite is one of the best materials for maximum hydrogen production when compared to other materials. It is reported in [11, 12] that increasing the concentration of NaOH for hydrogen production by electrolysis method. With increasing concentration, the production of hydrogen accelerates. Because hydroxide ions increase conductivity, production is faster [13].

Materials and Methods

The chemical equation for electrolysis is:

$$ennergy\,(electricity) + 2H_2O \rightarrow O_2 + 2H_2 \qquad (1)$$

The splitting of water into proton and hydroxide are shown in equation (2),

$$H_2O \rightarrow H^+ + OH^- \qquad (2)$$

The neutral atom of hydrogen and molecules are formed on the basis of (3) and (4) equation,

$$H^+ + e^- \rightarrow H \qquad (3)$$

$$H + H \rightarrow H_2 \qquad (4)$$

The positively charged hydroxide ion (OH^-) has traveled across the container to the anode as a result of the positive anode. When it reaches the anode, the anode removes the extra electron, and the hydroxide uses the electron from the hydrogen atom to recombine the oxygen and water molecules [14],

$$4OH^- \rightarrow O_2 + 2H_2O + 4e^- \qquad (5)$$

The shape and size of electrodes can increase the effective surface, which improves electrolysis efficiency. When the electrode is placed vertically, the efficiency of water electrolysis increases. The electrode's proposed shape is a solid cylinder 7.50 cm long and 5 cm in diameter. Similarly, the resistance of electron movement between electrode plates is reduced by shortening the distance between electrodes, allowing the electrical resistance to be as low as possible. The rate of hydrogen production is altered by varying the current density and the distance between the electrodes [15]. In our work, the electrode separation distance is (3 ± 0.50) cm. The experiment is carried out in the configuration shown in Fig. 1. 400 ml of distilled water was mixed with 0.10, 0.20, 0.30, and 0.40 g of NaOH for each experiment. The cylindrical electrode is separated by 3 cm (7.50 cm length and 5 cm diameter). Graphite electrodes are used in the electrodes. The electrode is connected to a DC power supply (Input: 0 − 220 VAC, Output:0 − 30 V/5A DC). The applied voltage ranges from 5 − 30 V.

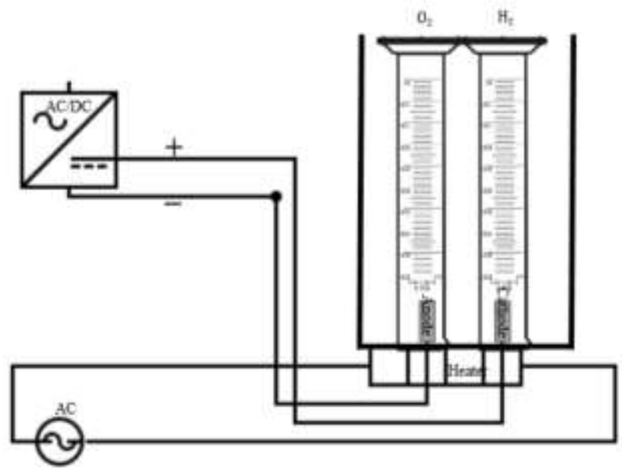


Fig. 1 Experimental setup for hydrogen production and measurement.

Results and Discussions

Production of hydrogen at the different voltage at a different constant concentration of NaOH

When a high concentration of alkaline is used, the reaction rate is generally faster [13]. Fig. 2(a) depicts the commutative hydrogen production with time for a 20 ml hydrogen production. The electrolyte sample is prepared by dissolving 0.10 g of NaOH in 400 ml of distilled water, and measurements are taken at 5, 10, 20, 25, and 30 V. At each voltage, the time for the commutative volume of hydrogen 20ml is measured. It has been discovered that producing 20 ml of hydrogen at 5 V takes a long time (approximately 1,200 s), whereas producing it at 30 V takes less time (about 75 s). Fig. 2(b) depicts the commutative hydrogen production with time for a 20 ml hydrogen production. The electrolyte sample is prepared by dissolving 0.20 g of NaOH in 400 ml of distilled water, and measurements are taken at 5, 10, 20, 25, and 30 V. At each voltage, the time for the commutative volume of hydrogen 20 ml is measured. It has been discovered that producing 20 ml of hydrogen at 5 V takes a long time (approximately 980 s), whereas producing it at 30 V takes less time (about 50 s).

Fig. 2(c) depicts the commutative hydrogen production with time for a 20 ml hydrogen production. The electrolyte sample is prepared by dissolving 0.30 g of NaOH in 400 ml of distilled water, and measurements are taken at 5, 10, 20, 25, and 30 V. At each voltage, the time for the commutative volume of hydrogen 20 ml is measured. It has been discovered that producing 20 ml of hydrogen at 5 V takes a long time (approximately 800sec), whereas producing it at 30 V takes less time (about 25 s). Fig. 2(d) depicts the

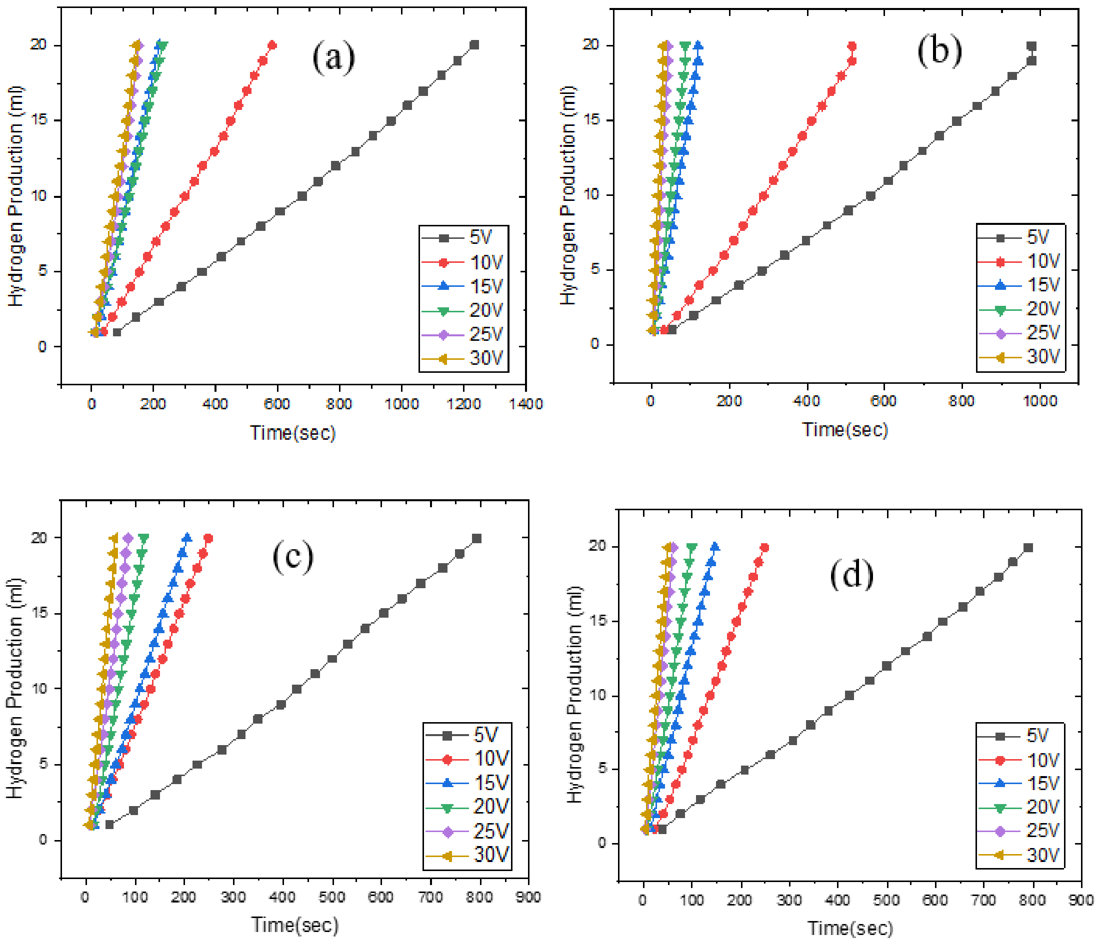


Fig. 2 Production of Hydrogen at different voltage with NaOH concentration (a) 0.10 g, (b) 0.20 g, (c) 0.30 g, and (d) 0.40 g

commutative hydrogen production with time for a 20 ml hydrogen production. The electrolyte sample is prepared by dissolving 0.30 g of NaOH in 400 ml of distilled water, and measurements are taken at 5, 10, 20, 25, and 30 V. At each voltage, the time for the commutative volume of hydrogen 20 ml is measured. It has been discovered that producing 20 ml of hydrogen at 5 V takes a long time (approximately 790 s), whereas producing it at 30 V takes less time (about 25 s).

Comparison of hydrogen production at different voltage and concentration

Fig. 3(a) depicts a comparison of hydrogen production at different NaOH concentrations of 0.10, 0.20, 0.30, and 0.40 g. The experiment with different concertation of NaOH at 5 V demonstrates that commutative hydrogen production increases with time and concentration. The production of 20 ml of hydrogen with a concentration of 0.40 g of NaOH in 400 ml takes less time (250 s), whereas 0.10 g takes more time (580 s).

Fig. 3(b) depicts a comparison of hydrogen production at different NaOH concentrations of 0.10, 0.20, 0.30, and 0.40 g. The experiment with different concertation of NaOH at 10 V demonstrates that commutative hydrogen production increases with time and concentration. The production of 20 ml of hydrogen with a concentration of 0.40 g of NaOH in 400 ml takes less time (245 s), whereas 0.10 g takes more time (570 s). Fig. 3(c) depicts a comparison of hydrogen production at different NaOH concentrations of 0.10, 0.20, 0.30, and 0.40 g. The experiment with different concertation of NaOH at 15 V demonstrates that commutative hydrogen production increases with time and concentration. The production of 20ml of hydrogen with a concentration of 0.40 g of NaOH in 400 ml takes less time (122 s), whereas 0.10 g takes more time (220 s). Fig. 3(d) depicts a comparison of

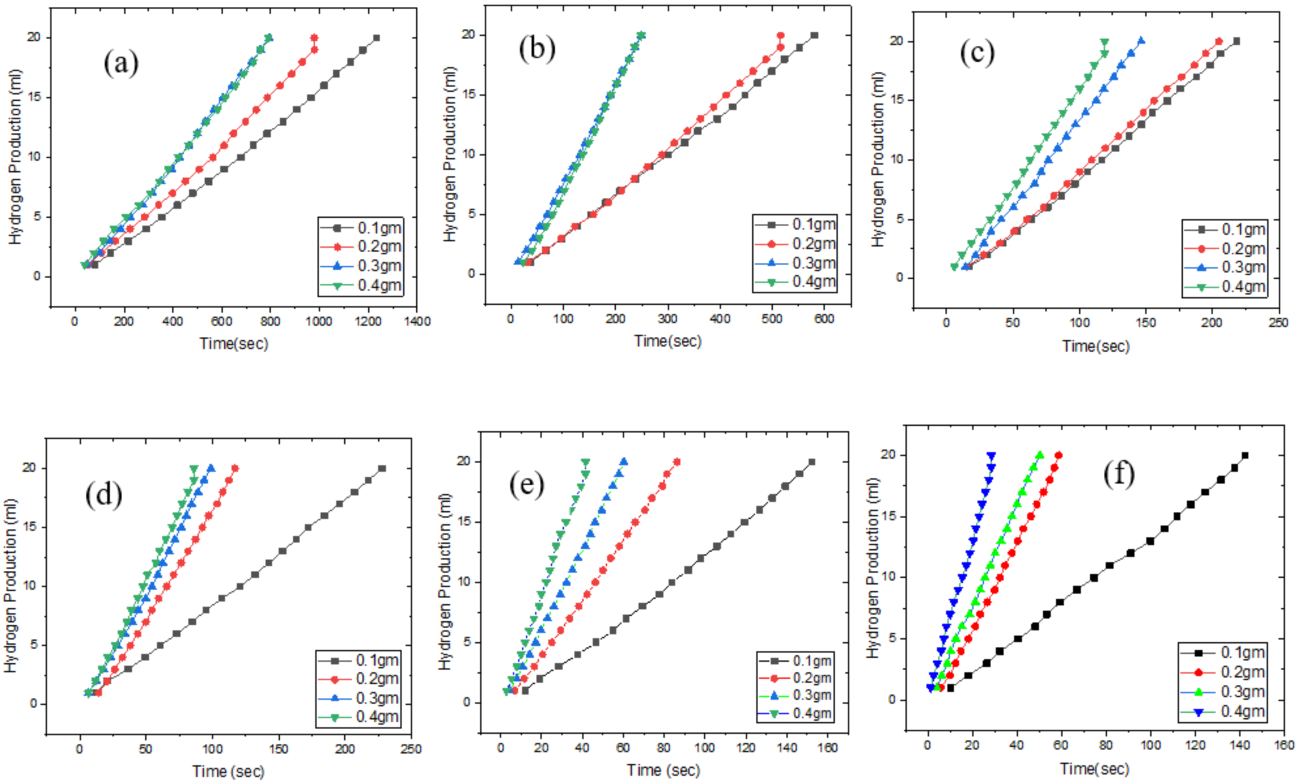


Fig. 3 Hydrogen production with time at different concentrations of NaOH (a) at 5 V (b) at 10 V, (c) 15 V, (d) 20 V, (e) 25 V and (f) 30V.

hydrogen production at different NaOH concentrations of 0.10, 0.20, 0.30, and 0.40 g. The experiment with different concertation of NaOH at 20 V demonstrates that commutative hydrogen production increases with time and concentration. The production of 20 ml of hydrogen with a concentration of 0.40 g of NaOH in 400 ml takes less time (75 s), whereas 0.10 g takes more time (225 s).

Fig. 3(e) depicts a comparison of hydrogen production at different NaOH concentrations of 0.10, 0.20, 0.30, and 0.40 g. The experiment with different concertation of NaOH at 25 V demonstrates that commutative hydrogen production increases with time and concentration. The production of 20 ml of hydrogen with a concentration of 0.40 g of NaOH in 400 ml takes less time (32 s), whereas 0.10 g takes more time (154 s). Fig. 3(f) depicts a comparison of hydrogen production at different NaOH concentrations of 0.10, 0.20, 0.30, and 0.40 g. The experiment with different concertation of NaOH at 30 V demonstrates that commutative hydrogen production increases with time and concentration. The production of 20 ml of hydrogen with a concentration of 0.40 g of NaOH in 400 ml takes less time (26 s), whereas 0.10 g takes more time (140 s).

Conclusion

The experiment, conducted at various voltages and NaOH concentrations, demonstrates that for 20 ml commutative hydrogen production. When the experiment is performed at low voltage, it takes longer than when the experiment is performed at high voltage. Furthermore, when the experiment is performed at different concentrations of NaOH, the time required to produce20 ml hydrogen is reduced when the experiment is performed on high concertation NaOH, whereas the time required for the same volume is increased.

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