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The Influence of Various Currents and Voltages on Hydrogen Production by Electrolysis Method

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A B S T R A C T

There are different ways of minimizing the emission of CO_2 resulting from different industrial based of using fossil fuel. Nowadays, the alternative methods for producing energy also are developed. One ways is to use hydrogen as a source of electricity which is generated from mixing hydrogen with oxygen via the electrochemical process. The current work is dealing with the factors that affect the amount of hydrogen production, such as voltage and amperage Two different electrolytes were employed in this work (NaOH & KOH) to evaluate the H_2 production levels. Two ways used for characterizing the stability of electro-catalysts to produce hydrogen via the electrolysis. One is the relationship (I–t curve) which measures the current variation with time under a fixed potential. In this way, the results showed that the changes in H_2 production values at different currents in both NaOH and KOH was observed. The changes may attribute to the conductivity of the electrolysis. The other ways for characterizing hydrogen production via the electrolysis is applied the relationship (E–t curve) to measure the potential change with time at a fixed current. Here, the rate of hydrogen production decreased as voltage increased in both electrolyte mediums. This result explained in terms of overvoltage created over the electrode surface.

تأثيرات فرق الجهد والتيار على انتاج الهيدروجين بطريقة التحليل الكهربائي

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الملخص

هناك طرق مختلفة لتقليل انبعاث ثان اكسيد الكربون الناتج عن مختلف المحركات الصناعية ومحركات الاحتراق والوقود الأحفوري. في الآونة الأخيرة هناك تركيز شديد علي الطرق البديلة لإنتاج الطاقة. إحدى هذه الطرق هي استخدام الهيدروجين كمصدر للكهرباء التي يتم توليدها من خلال خلط الهيدروجين بالأكسجين عبر العملية الكهروكيميائية. يختص هذا البحث بالية إنتاج الهيدروجين من خلال التحليل الكهربائي للماء. وقد ركزت التجارب المعملية على العوامل التي تؤثر على كمية إنتاج الهيدروجين مثل الجهد والتيار. تم استخدام م حفزين مختلفين في هذا العمل هيدروكسيد الصوديوم وهيدروكسيد البوتاسيوم لتقييم مستويات إنتاج الهيدروجين. تم استخدام نموذجين لتوصيف ثبات المحفزات الكهربائية لإنتاج الهيدروجين عبر التحليل الكهربائي. الأول هو إنشاء منحني العلاقة (التيار مع الزمن) الذي يقيس التباين الحالي مع ثبوت الجهد. وبهذه الطريقة، أظهرت النتائج أن التغيرات في قيم إنتاج الهيدروجين عند تيار مختلف في كل من المحفزين كانت واضحة، وقد تنسب التغييرات إلى موصلية التحليل الكهربائي. الطرق الأخرى لتوصيف إنتاج الهيدروجين عبر التحليل الكهربائي يتم فيها تطبيق منحني علاقة (الجهد مع الزمن) لقياس التغير المحتمل في ظل تيار ثابت. هنا، انخفض معدل إنتاج الهيدروجين مع زيادة الجهد في كلا الوسطين. يمكن تفسير هذه النتيجة من حيث الجهد الزائد الناتج على سطح القطب.

الكلمات المفتاحية:
الطاقة
الهيدروجين
الفولاذ الأوستنيتي المقاوم للصدأ
عملية التحليل الالكتروليتي
هيدروكسيد الصوديوم
هيدروكسيد البوتاسيوم

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1. Introduction

In recent years, the energy program is concerned with resources of natural, energy rich materials, such as coal, crude oil, natural gas, and minerals. However, this program is also investigated of less developed sources of energy, including oil shale, and biomass. There are plans to review the energy potential of hydropower, geothermal, solar and wind power technology [1]. Alternative methods for obtaining energy by using technologies that maximum efficiency, high reliability and minimum pollution are strongly studied by many researchers [2,3]. It was reported that, sustainable energy can be obtained based on the concept of fuel cells [3,4,5]. Dealing with a form of renewable energy, hydrogen can be presented as a promoting potential to meet the energy needs of businesses and all stationary infrastructures. Researchers have been studied a transition to a hydrogen economy as the solution for a zero-carbon energy system [6,7,8,9]. According to these reasons, due to hydrogen physical and thermodynamic properties, hydrogen-based technologies could be found in many applications within a decarbonized global energy system. It is expected that hydrogen would have a key role in the energy future. The use of this material was mainly in refineries as an upgrade to lower the Sulphur content of oil-derived fuels or as a commodity in the industrial process [10]. However, the attractive of using hydrogen included storing renewable energy, heating, and as fuel for the transport has been increased. It was reported that [11,12,13]. hydrogen can be burned directly in boilers or used in fuel cells and has higher efficiencies and no fundamental difference compared to the natural gas equivalents. The importance of using hydrogen as a source of electricity (fuel cell) which is generated from mixing hydrogen with oxygen via the electrochemical process has been increased. This plays a signification role in providing a cost-effective solution for reducing carbon emissions. Lot of studies indicated that using hydrogen can helped for reducing CO_2 emission by amounts up to 60-80% compared from the traditional energy sources [14,15,16]. Also, the importance of the electrolysis method lies in the fact that the only source of hydrogen is pure water, while other methods, for example the steam reforming method produce co_2 with hydrogen because they use methane in their production, this causes many problems in environmental like Ozone hole etc. The current work is aimed to learn more on the production of hydrogen and studied factors that effect on the amount of hydrogen production such as voltage and amperage. The experimental procedure will focus on the change of production level as the changes in previous factors. In addition, in this work will give some information upon how to manufacture a hydrogen cell, and investigate and produce the hydrogen. It well known that, hydrogen is the element with very good diffusion potential coefficient [17]. Hydrogen may be found in both gas and liquid state. In metals, the rate of hydrogen solubility is normally high. For example, about $2x10^{12}$ jumps per second at room temperature. H_2 can diffuse in vanadium and exceeds that of heavy interstitials like oxygen and nitrogen at high temperature by 15-20 orders of magnitude [18,19].

2. Experimental Procedures

2.1 Materials

Different engineering materials were employed to set up the experiment. Stainless steel was used to manufacture and set the electrodes. Due to its good corrosion resistance and high surface area, austenitic stainless steel was widely applied in steam-generating plants and nuclear reactors [20,21] and thus, it was selected as electrodes (anode & cathode) in the current electrolysis cell. The water filter case is used to process the reaction within the electrolysis solution. A nylon laboratory was used to close the cups and maintain the solution concentration. Glasses such as conical flasks, sticks and graduated cylinders to measure the hydrogen.

2.2 Electrical devices

There are some electrical devices were used for test measurements, see Figure 1. No.(a) is power supply IRWIN L-T. It has been used to provide a variable voltage and high current to meet need requiring a higher output. No.(b) The Fahrenheit temperature scale was used. No.(c) The electronic balance used for measuring the amount of salt in the experiment. No.(d) The Ammeter device used to measure current. Measured in Amber (A).

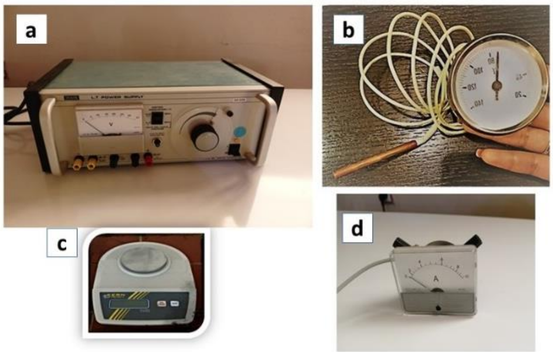


Figure 1: electrical devices used

Digital Multi meter (AC/DC), DT9205A LCD, No.(a) was used, see Figure 2. This device was providing with a resistance capacitance tester with low battery indication / overload indication /Auto power off function. No.(b) The resistance OHMS 4 amps was used. An electrical resistance is the opposition to the movement of electrons as they flow through a circuit, No.b. In addition, X-ray Fluorescence Analyser was employed for estimating all elements and providing a significant improvement in elemental peak resolution and counting statistics.

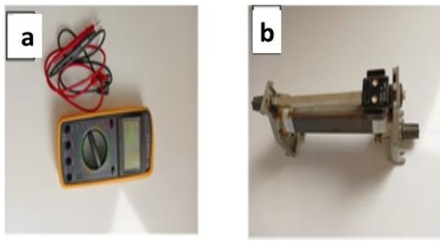


Figure 2: Digital Multi meter (AC/DC) and OHMS 4 Amps used

2.3 Preparation of hydrogen cell

2.3.1 Electrolysis preparation

It was clear that electrolysis does not manufacture electric charges and it is the "splitting' of compounds by electricity. For example, water decomposes into oxygen and hydrogen by electric current [22]. Electrolysis begins when the electric circuit is completed and ends abruptly when the electric circuit is broken [23]. Number of steps was used to prepare the electrolysis media for both KOH and NaOH solution. Different concentration used to evaluate their effect on the rate of hydrogen production. Sensitive balance is used to measure the weights of the chemical salts in the experiment. Also, filter paper or semi-permeable paper is used to separate the fine solids in a liquid during a filtration process. Glass tube used for mixing the salt powder within the solution for achieving a good homogenous electrolyte media. For preparing 5,10, 15 g/l , KOH powder salt was rinsed in 1000 ml tap water. The solution was doped in water until the homogenous solution reached. The concerted solution was used as the electrolysis medium to conduct the test. The same procedure was applied for all concentration rang in both KOH and NaOH.

2.3.2 Cell Preparation

Within the electrolyte cell, it used an electrolyte composed of an aqueous solution of potassium hydroxide (KOH) and sodium hydroxide (NaOH). Through the process, the oxygen ions migrate the electrolytic material, leaving hydrogen gas dissolved in the water stream. The hydrogen gas is readily extracted from the water stream directed into a separating chamber [24]. To setup and operating the cell, L-T power supply model was used to maintain, and generate regulated DC voltage. The reading was recorded for each experiment according to the required affecting parameter, see Figure 3.

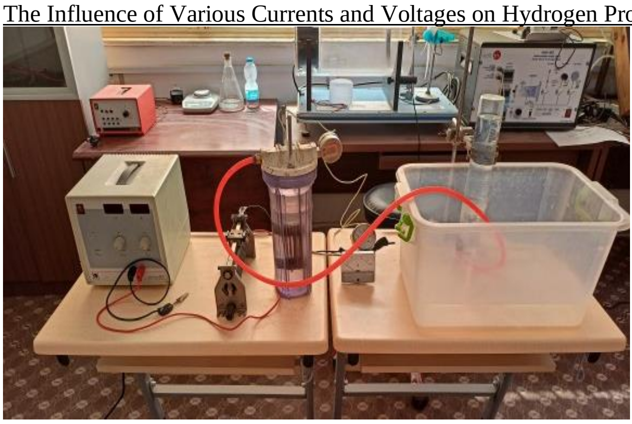


Figure 3: set up the used hydrogen cell

In addition, the electrodes are made of stainless steel 316, as shown in Figure 4. The two electrodes are flat plate shape, each of them is 24cm height and 5cm width. The thicknesses of each plate is 1.5 mm and the gap between the two plates is 2 mm. The flat plates electrodes are separated by a non-electrical conducting material which is resistive Teflon. The electrodes are immersed in water where the process of splitting water into hydrogen and oxygen occurs when electrical current generated by the power supply.

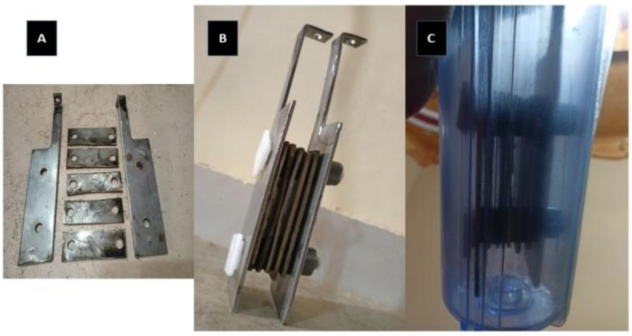


Figure 4: the electrodes of the cell

3. Measurement of Hydrogen

It well known that hydrogen gas is the lightest and most common chemical element in the universe. Normally, hydrogen is a tasteless and colorless gas, which makes it very difficult to measure. In the currently work, we used the displacement of water from graduated measuring cylinder or graduated test tube placed inside a water bath to measure and collect the hydrogen production, see Figure 3.

3.1 Effects of applied current on H_2 production

Three different applied current was selected in the current work to study their effects on the rate of hydrogen production at different electrolyte concentrations. The power supplied was employed in these experiment. Due to the key features on the device which allow us to change the selected current required for each test at constant voltage, power supply was the right device for this work.

3.2 Effects of operation voltage on H_2 production

The influence of an applied voltage on the hydrogen production can be studied over stainless steel electrode at room temperature of 25 °C with different concentrations of KOH and NaOH solutions. The applied voltage was varied from (10,15 and 20V). the same power supply was applied to control the voltage at constant current.

4. Result and discussions

4.1 Effects of applied current at different concentration

4.1.1 Effects of applied current (10v and 5g/l).

In this part, the experimental result was concluded for (NaOH and KOH) by selecting (10v and 5g/l) for each current (2,3,4A) at different operatory time. Typical methods have been used for characterizing the stability of electro-catalysts to produce hydrogen via the electrolysis [25]. One is making the relationship (I–t curve) which measures the current variation with time under a fixed potential. Figure 5 shows the changes in H_2 production values at different current in both NaOH and KOH. The changes can be attributed to the conductivity of the electrolysis. In addition, it noted that after 3 min (180 s) of time reaction at constant 4A, the production of H_2 gas was higher than that in 2A and 3A. This may attribute to the rate of electrical charge conducted by the electrolyte, because of high current flow (in Amps) was operated. Generally, the result indicated that as a current increase the rate of H2 production increased into both electrolysis mediums. The improvement in H_2 production in KOH in all different currents compared with that in NaOH was noted. Electrons are transferred per time. Therefore, the reaction for producing hydrogen on the surface of the electrode accelerated as time increased.

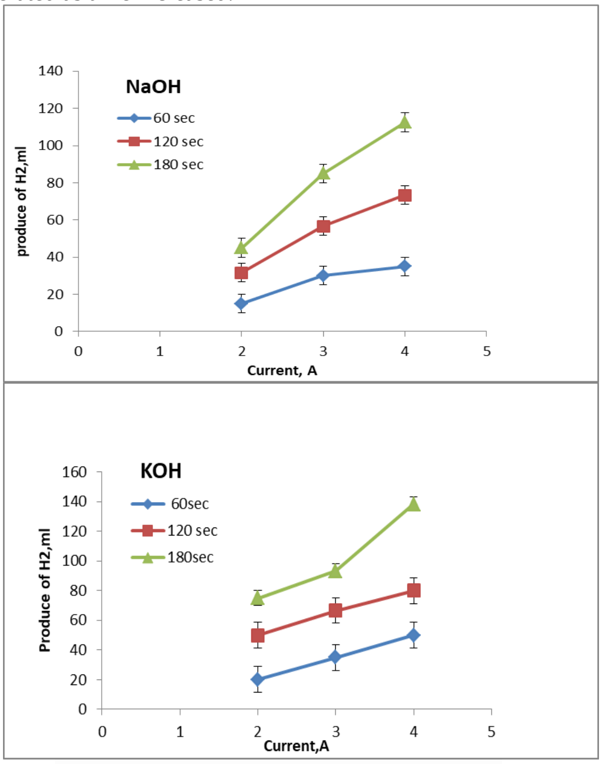
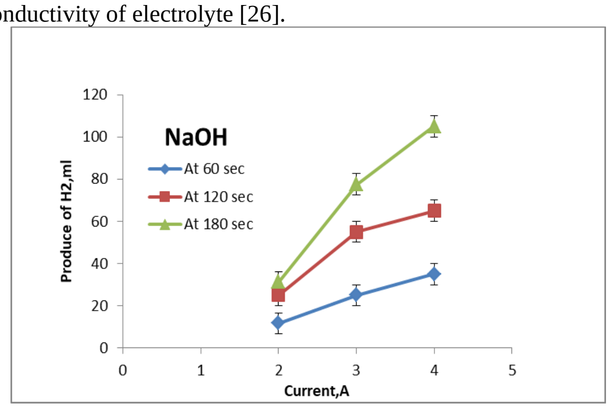


Figure 5: the changes in H_2 production values at different current (10v and 5g/l)

4.1.2 Effect of applied current (10v and 10g/l)

The changes in hydrogen production for (NaOH and KOH) by selecting (10v and 10g/l) at different applied current (2,3,4A) was evaluated as shown in Figure 6, the rate of H_2 production increases as the applied current increase in all different time for both KOH and NaOH. The result showing that a little improvement in H_2 production at low time (60 sec) in NaOH medium compared with that in KOH medium. This behaviour may be attributed to the nature of NaOH, which is shown better the electrolysis process in the beginning of cell operation. The increase in the concentration of electrolyte from 5g/l to 10g/l showed a little change in H_2 production in both solutions. This behaviour can be attributed to the changes in solubility and conductivity of electrolyte [26].



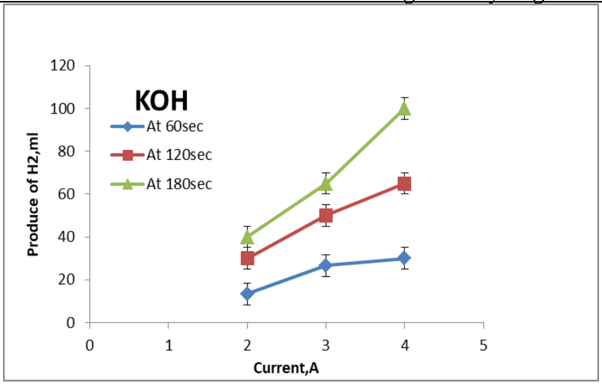


Figure 6: the changes in H_2 production values at different current (10v and 10g/l)

4.1.3 Effect of applied current (10v and 15 g/l)

Figure 7 represent the changes in H_2 values in terms of different time at the higher concentration of solution (10v and 15 g/l). It can be seen that as a current increase the rate of H_2 production increase in all different operation times. A little improvement in the experimental result in KOH medium compared with that in NaOH. Generally, energy required to electrolysis process has direct effect on production of H_2. More operation time lead to increase H_2 production, and this can be explained as the electrolysis process enhanced as a time increase. The result indicated that there is not clear effects on H_2 production as the electrolyte concentration increase from 10g\l to 15g\l.

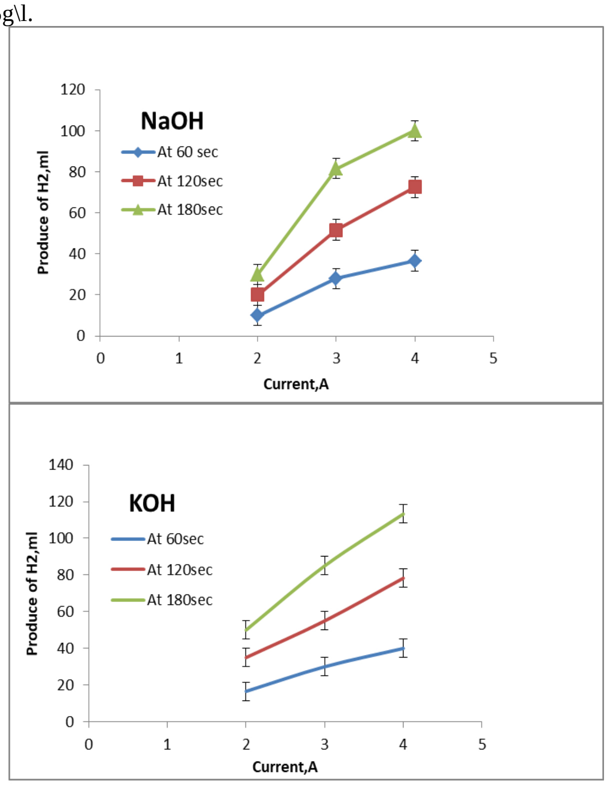


Figure 7: The changes in H_2 production values at different current (10v and 15g/l)

4.2 Effects of operation voltage at different concentrations

The other ways for characterizing hydrogen production via the electrolysis is applied the relationship (E–t curve) to measure the potential change with time at a fixed current. The experiment was conducted in just two different concentrations (5g/l & 10g/l) for both solutions.

4.2.1 Effects of operation voltage (4A and 5g/l)

It was clear that the experimental result for hydrogen producing in KOH was higher than that in NaOH in all different voltage, see Figure 8. from the results, it noted that after 3 min (180 s) of time reaction at constant 4A and 5g/l, the production of H_2 gas in both solutions (NaOH and KOH) was the higher value. However, the influences of applied voltage were changed. In both electrolyte mediums, the rate of hydrogen production decreased as voltage increased. This result may be explained in terms of overvoltage created over the electrode surface. Choi at. el [27] revealed that as the magnitude of the applied voltage increased, the magnitude of the lost overvoltage also increased with time. Moreover, the behaviour may be related to the departure of large bubbles from the electrodes. The large potential fluctuations appear after a certain time, which may proportional to the applied voltage.

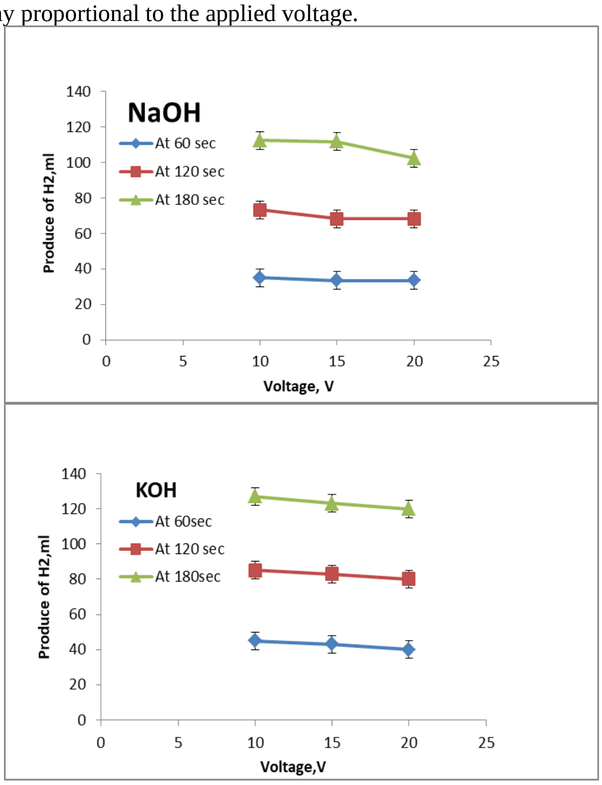
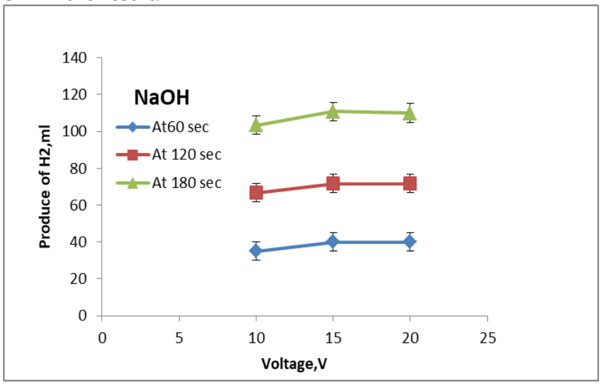


Figure 8: The changes in H_2 production values at different voltages (4A and 5g/l)

4.2.2 Effect of voltage (4A and 10 g/l)

The obtained results show that in figure (9), there is a little increase in H_2 production as the increase in applied voltage in both electrolysis media, see Figure 9. In KOH, it can be noted that there are clear changed in H_2 production at (20v) in all different times compared with that of NaOH. Also, the results showed that the change in H_2 production remaining constant when the applied voltage was (15 and 20v) in NaOH. Similar behaviour to the applied amperage in the previous part Figure (5). The durations (time) to produce a volume of hydrogen at different voltages during the experiments indicated the increased the amount of gas production. Changing the voltage applied (potential difference) would cause migration of ion coming from dissociation of NaOH or KOH in water. The migrations of ion would make reduction-oxidation reaction whereby in cathode water reduced to hydrogen H^+ and in anode ion OH^- will be oxidized to be oxygen [28]. So, due to the conductivity, this behaviour explained the changes in H_2 production by using KOH was higher than that of NaOH in the result.



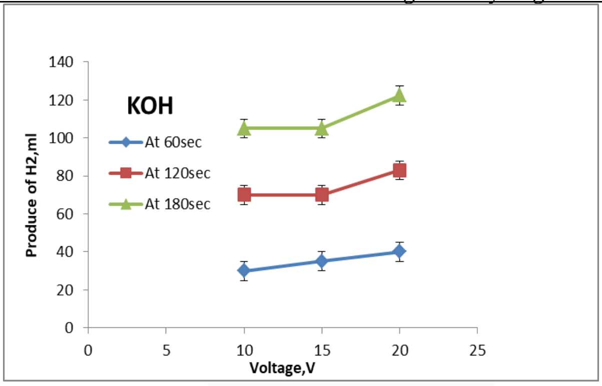


Figure 9: The changes in H_2 production at different voltages (4A and 10g/l)

5. Conclusions

Production of hydrogen was evaluated with the aim of providing further information related to electrolysis process. The factors that affect the amount of hydrogen production, such as voltage and amperage at different concentration and electrolysis type (KOH & NaOH) were discussed. The following conclusions can be reported as. At constant voltage (10v) for both electrolytes there is increase in H_2 production as changes in current, in KOH. However, more H_2 production in KOH was noted compare to NaOH. Generally, the result indicated that as a current increase the rate of H_2 production increased into both electrolysis mediums and the best used current in this study is 4A. In 5g/l, the production of H_2 at different voltages and constant current at 4A is decreased in both (NaOH and KOH) electrolyte mediums. However, in10g/l, H_2 values was stable at 15v and 20v in NaOH. But, it was increased in both 15 and 20v into KOH medium

6. Acknowledgement

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