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Experimental Study of Hydroxy Gas (HHO) Production with Variation in Current, Voltage and Electrolyte Concentration

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Abstract: In this paper, work has been carried out experimentally for the investigation of the effects of variation incurrent,voltage,temperature,chemicalconcentrationand reaction time on the amount of hydroxy gas produced. Further effects on the overall electrolysis efficiency of advance alkaline water is also studied. The hydroxy gas (HHO) has been produced experimentally by the electrolysis of alkaline water with parallel plate electrode of 316L-grade stainless steel. The electrode has been selected on the basis of corrosion resistance and inertness with respect to electrolyte (KOH). The process used for the production of HHO is conventional as compared to the other production processes because ofreduced energy consumption, less maintenance and low setup cost. From the experimental results, it has been observed that with increase in voltage, temperature and electrolyte concentration of alkaline solution, the production of hydroxy gas has increased about 30 to 40% with reduction in electrical energy consumption.
Keywords- Hydroxy gas, water electrolysis, catalyst, electrode material, constant and regulated DC input.

1. Introduction

Hydroxy gas was invented by Yull Brown in 1977.So it is also called Brown gas. According to Yull Brown [1] the Brown Gas is a combination of hydrogen and oxygen molecule. Whenkeep it in a container without changing the proportions of each of the gasses, they exist together in monatomic state.It can further be separated into two components of Oxygen and Hydrogen. But in such case the atoms are kept in their diatomic state instead of separating to their monatomic state. It is known that O_2 and H_2 must exists as diatomic in order to become stable, but it also exist as HHO (monatomic state - the atomic state of water). The flame of this gas is a mono-electric state instead of separating it to a diatonic flame and it has 3 times more energy potential as a diatomic flame.This is an explosive gas-a new molecular state of implosion. The property of Brown gas flame is not formed as a set of explosion, but as a set of implosion and the implosion technology is used to decay radiation. The hydroxy gas is disintegrated to radioactive products and decreases their toxic decayto "half-life" process from

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millions of years to only seconds. The flame of gas is generally colorlessandis much longer than that visualized actually. In light, it appears as an extremely small flame due to colorless and in dark it will be about 2 feet long.But when emits from a torch it forms a small blue cone. As application the flame temperature of hydroxy gas increases due to interactive combustion property. It has higher energy conversion efficiency than the hydrogen, which is conventionally considered to possess the highest conversion efficiency as fuel. It has no theoretical temperature limit as application in local environment. The temperature of flame in surrounding air contact is measured as 127^{o}C to 137^{o}C. When same flame is applied to brick, the temperature of flame is 1704^{o}C and when applied to tungsten wire the temperature is 6000^{o}C (shown fig.1). There is no other method to produce such a gas. Hydroxy Gas is a new product and it is sufficiently different from a combined molecular hydrogen and oxygen gas mixture (2:1 proportion). The Hydroxy gas revealed a number of properties as:

- This new 'Hydroxy gas' will burn, just like a propane fuel.
- The by product is again -water.
- When burning a substance, hydroxy gas changes state directly from solid to gas without going through the matter change of gas.

As a welding flame, the temperature of the flame varies depends on what it is burning. It will vaporize Tungsten Steal, but will not burn hand.

According to Eagle-Research experiments [2], there would also be a significantly larger volume of gas produced by the electrolyzer, well beyond any reasonable expectation of a 'normal' electrolyzer. The mon-atomic moles would take up twice the volume that the di-atomic moles for the same weight of water electrolyzed.

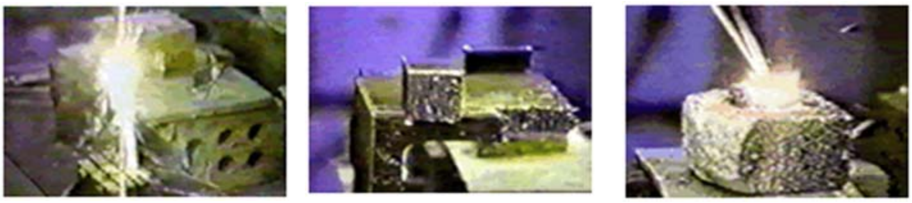

Fig.1. Hydroxy flame cut Tungsten steel (hardest metal on the earth) like butter, but not burn skin [1].

The Hydroxy gas is clean, eco-friendly and naturally recyclable alternate fuel among the gasoline fuel which is produced from renewable energy source. It is also expected to be used as secondary energy in near future. It is having highest gravimetric energy density of all known fuels [3]. It has about 3.8 times more combustion power than the gasoline. When this gas is mixed with gasoline fuel, it reduces harmful gases NO_x, CO, CO_2 and HC from exhaust emission [4].The methods offer renewable and clean production of hydroxy fuel and therefore has attracted increasing research interests in recent years. One of the most promising methods for the production of combination of hydrogen and oxygen gas is water electrolysis using different type of energy sources such as solar, geothermal, hydroelectric and nuclear [5]. Alkaline water electrolysis represents one of the best choices for the splitting of water molecule into gaseous form of hydrogen and oxygen. The electrodes are the main physical part of the electrolytic cell system. In this work two electrodes have been taken same material property, out of them one act as an active electrode where redox reaction will occur resulting in accumulating or consuming materials of electrodes and other electrode is inert which uses its surface for neutralization of ions [6]. The schematic diagram of an electrochemical cell is shown in Fig.2 [A]. In order to achieve a better estimation of power consumption and amount of gas production, importance should be given to the geometry of electrode, where internal resistance should be kept as low as possible in order to keep energy consumption sufficiently small [1]. The parallel plate electrodes are kept at short distance apart in order to reduce the resistance between electrodes in the alkaline solution.Alkaline solutions of water are commonly used in electrolysis and the electrode's main properties to be considered for water electrolysis are: large active surface area, electrochemical stability, good electrical conductivity, low hydrogen over-potential, good electro catalytic activity and high corrosion resistance. Platinum and gold are known as the two best choices to be used as electrodes. However, high prices limit their usage in industrial and commercial electrolyzers. The most common stainless steel electrode material is used for alkaline electrolysis. This popularity is the result of their satisfactory price range, corrosion resistance and chemical stability [7]. The surface of the electrode remains inert and so longer the gas bubbles remain attached to it. The electrical resistance of the electrolyticcell increases with increase in volume fraction of gas bubbles on the inert electrode surface, resulting in the decrease in efficiency of water electrolysis [8].

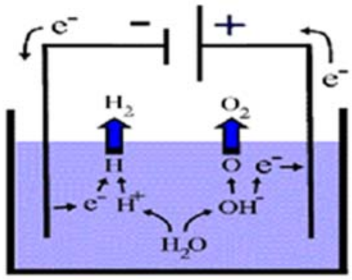

Fig.2Working principle of electrolysis ofalkaline solution [A]

The water splitting reaction is endothermic and therefore it requires energy readily, provided by the flow of electric current in Fig.3 [B]. In case of acidic or basic water, the reactions which occur at the electrode interface are slightly different. In water electrolysis there are no side reactions that could yield undesired byproducts, therefore the net balance is:

H_2O + energy ($2e^-$) $\rightarrow$ $H_2 + ½O_2$ (1)

Oxygen and hydrogen gas can be generated at noble metal electrode by electrolysis of water.

1.1Principle of water electrolysis

By applying electric potential to the electrode, the positive electrode produce hydrogen gas and negative electrode produce oxygen gas. The gases are produced when electron react with the ionic species of water molecule such as (H^+, OH^-).

1.1.1 Hydrogen evolution reaction (HER)

At cathode (- electrode):

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (2)

$2H^+ + 2e^- \rightarrow H_2$ (3)

In alkaline electrolyte (M) HER start with volmer step which involves the binding of atomic hydrogen to the electrode at adsorption site M

$M + H_2O + e^- \rightarrow MH_{ad} + OH^-$ (4)

$M + H^+ + e^- \rightarrow MH_{ad}$ (5)

And is completed with a desorption step which occur by Heyrovsky reaction [9]:

$H_2O + MH_{ad} + e^- \rightarrow M + H_2 + OH^-$ (6)

$MH_{ad} + H^+ + e^- \rightarrow H_2 + M$ (7)

The H-adsorption energy is a good "descriptor" for HER, which guides the identification of the most promising materials. The HER exchange current of electrode is at least two orders of magnitude higher in acids than in alkaline electrolytes, including KOH, possibly because of the shorter SS-H_{ad} distance in alkaline electrolytes suggested by theoretical estimates [10].

1.1.2 Oxygen evolution reaction (OER)

At anode (+ electrode):

$2OH^- \rightarrow ½ O_2 + H_2O + 2e^-$ (8)

$H_2O \rightarrow ½ O_2 + 2e^- + 2H^+$ (9)

This reaction may occur through various path ways and adsorbed intermediates (O*, HO*, HOO*) which makes the identification of a "descriptor" somehow more difficult. Man et al. [11] believe that a suitable descriptor for the OER is the difference between the calculated free energy of reaction ΔG° of the second and the first electron abstraction step ($\Delta G_{O*^{\circ}} - \Delta G_{HO*^{\circ}}$); this quantity describes correctly experimental trends from the literature but is of course model-dependent.The reverse of the OER reactions (8,9) is the oxygen reduction reaction (ORR) where molecular oxygen is reduced to water. ORR involves the same intermediates as the OER and is most conveniently carried out in an alkaline environment [12]where catalysts are available which are more active and stable than in acid.

2. Experimental

2.1 Size of the electrodes

The projected area of the electrode's face can be changed by changing the geometry of the electrode keeping samesurface area. The production of hydrogen and oxygen depends on the movement of ions in the electrolytic solution. The shape of electrodes may increase the effective surface, whichimproves the efficiency of electrolysis [1]. The formation of hydrogen and oxygen bubbles depend on the effective surface of electrode. The largegas-bubbles movement is the result of larger amounts of bubble accumulated from the active electrode surface. The efficiency of water electrolysis becomes high when the electrodes are placed in a vertical position. Latteris caused by reduced ohmic resistance due to the "optimum bubble departure rate" [13]. The impact of perforated electrode with a specific porosity on the cellovervoltage and the frequencyof bubble detachment are high.

2.2 Space between the electrodes

The resistance of the movement of electrons in between the electrode plates is reduced by reducing the distance between electrodes, so that the electrical resistance could be obtained minimum. Nagai et al. [14] carried out a number of experiments to determine the optimum space between electrodes. They examined the effects of the void fracture between electrodes which is caused by the formation of gas bubbles. These experiments were conducted at an ambient temperature and pressure with Ni-Cr-Fe alloy electrodes in a 0.03 mole potassium hydroxide aqueous solution. They varied the current density and the distance between the electrodes. The author concluded that with the reduction in distance between electrodes, increases the value of the void fracture and leads to a less efficient process. LeRoy et al. [15] also reported the same effect.

2.3 Procedure

The experimentation is carried out in the set-up shown in Fig. 3. It is consisting of a compartments (ID and height of the compartment were 8 cm and 28 cm, respectively). Theelectrolyzer containing 2.15 liter distilled water. In the electrolyzertwonarrow rectangular electrode of size (15.5 cm × 5 cm × 0.1cm) is placed. The electrodes are made-up of stainless steel (SS) of 316-L grade. The SS electrodeis chosen as its material composition relatively inert property in alkaline solution compared to other metals.The distance between the two electrodes was kept constant at a value of 2 cm. DC power supply is connected to a bridge rectifier through a Multi regulated power supply (Input: 0 - 220/ 230 V AC, Output: 0 - 30 V/2A DC). The applied voltage is varying from 3V to 10V.

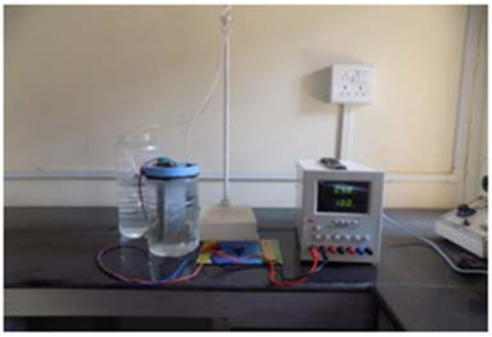

Fig.3. experimental set-up of electrolyzer connected with multiple power supply.

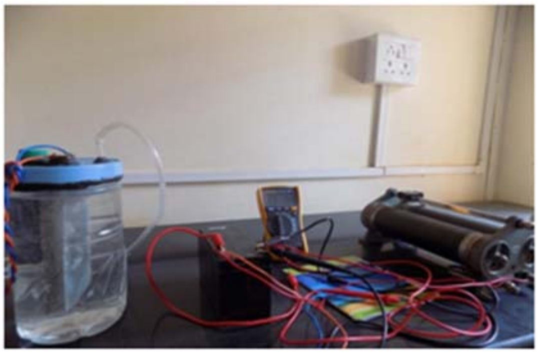

Fig.4. Electrolyzer connected to 10V battery and Rheostat in parallel. The digitalmultimeter connected in series to

The gases obtained from the anode and the cathode limbs are collected together in another tank by downward displacement of water from the measuring bottle. The volume of hydrogen produced was twice the amount of oxygen produced. The production rate of hydroxy gas is calculated by half liter water displaced from bottle in how much specific time. The process is carried out at ambient temperature and pressure.

3.Result and discussion

3.1 Effect of applied voltage

The production of hydroxy is influenced by the applied voltage. The hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) can be studied over flat plate stainless steel electrode at the room temperature of 25^{o} C with a 0.1 mole concentration of KOH. The applied voltage is varied from 3V to 10 V and the resultant graph as shown in Fig.6. It shows that, the rate of production of hydrogen gas gradually increases with increase in applied voltage. The plausible reason is the uniform charge density increases on the surface of the flat plate electrode. The fig.7 shows the production rate also depend on current. At constant voltage, as current increases gas production rate is also increase.

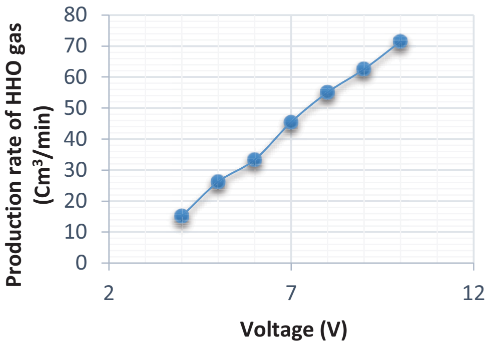

Fig.5. Effect of production rate of hydroxy gas with variation of applied voltage in 0.1 mole electrolyte concentration of solution (at ambient temperature and pressure).

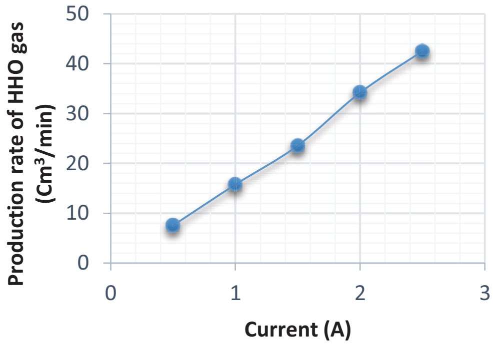

Fig.6. Effect of production rate of hydroxy gas at constant voltage with current variation in 0.1 mole electrolyte concentration (at ambient temperature and pressure).

3.2 Effect of time on production of gas

It is very necessary to analysis the continuous production of hydroxy gas for flat plate electrode with the continuous increase electrolysis time. At the starting of electrolysis, theProduction rate of hydroxy gas is gradually increase and become maximum within 15 min.After that it fluctuate very small variation in gas generation rate. The obtained results are illustrated in Fig.8. From the figure, it is observed that initially the hydroxy gas production is reached to maximum 51cc/min and thereby it attains the stable state. During the gas production about 90 minutes the electrode remains stable state without any fouling formation on active surface of electrode throughout operation. The overall performance of the stainless steel electrode has shown an acceptable level of stability under present experimental conditions.

3.3Effect of electrolyte concentration

At constant voltage of 10V battery and 2A current is adjusted byRheostat connected parallel to the system. A digital multimeter is connected in series to the electrolyzer at a constant current. As concentration of electrolyte is increased from 0.10 to 2.0 M in distilled water (shown in Fig. 5) the catalyst increases theionicconductivityof distilled water. In pure water no electron travels from active electrode surface to the inert electrode surface.Due to increase the conductivity of pure water the resistance of overall electrolyzer system is reduce. Thus reduce effect of the overvoltage value on theelectrolyzer [16]. The concentration level of acidic and alkali solutions is limited in practice due to the highly corrosive behavior of electrodes. The graph shows (Fig.9) that the hydroxyl gas production gradually increases with increase in electrolytic concentration. In another word, the increase in hydrogen evolution and oxygen evolution in increased electrolytic concentration is due to a greater number of effective ionic collisions per unit time.

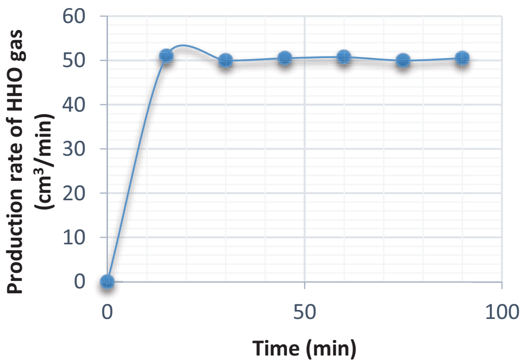

Fig.7. Effect of production rate of hydroxy gas w.r.t. time, with 0.1 mole concentration of electrolyte at constant voltage and constant current

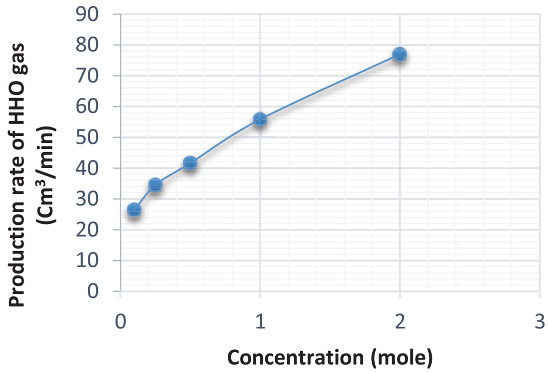

Fig.8. Effect of production rate of hydroxy gas with variation of electrolyte concentration at constant voltage and constant current.

3.4Effect of temperature

In most cases, such as room temperature water electrolysis, the electric input is larger than the enthalpy change of the reaction, so some energy is released as waste heat. High temperature electrolysis is more efficient economically than traditional room-temperature electrolysis because some of the energy is supplied as heat, which is cheaper than electricity, so that the electrolysis reaction becomes more efficient at higher temperatures [17]. It is most effective variables on the electric power demand of an electrolytic cell. Electrolysis process increases the hydroxy gas production rate asthe temperature increased.In this experiment, the electrolyte temperature has gradually increased from 300K to 360 K (Fig. 10). The result clearly shows, that when there is an increase in temperature the hydroxy gas production increases linearly [18]. Due to the thermodynamic characteristics of a water molecule, the potential required to split water molecule into the gaseous form is known to reduce as the temperature increases. The ionic conductivity and surface reaction of an electrolyte is directly proportional to the temperature [19]. In addition, the high temperature accelerates the reaction kinetics, reducing the energy loss due to electrode polarization, thus increasing the overall system efficiency.

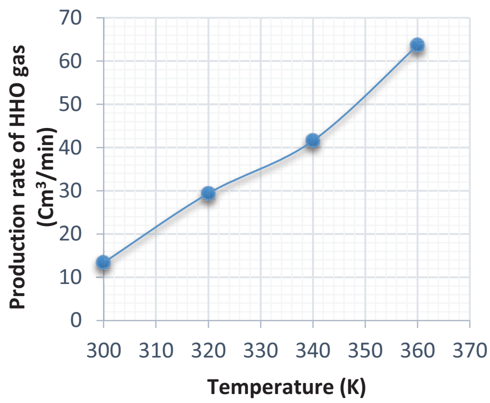

Fig.9.Effect of variation of temperature on production of gas at constant voltage and current with 0.1mole concentration (KOH).

3.5. Thermodynamic study of water electrolysis

The analysis of the rate of alkaline water electrolysis is studied on flat plate electrode.According to Hyperphysic, there is 237 KJ energy required to create 1 Mol of H_2 and 1/2 mole of O_2.All values are based on SATP-Condition (Standard Ambient Temperature Condition) that is 298K which is about 25°C.

Now, from literature the correct calculation of the gas volumina of 1 mole hydrogen and oxygen at 25 Celsius is;

1 Mole of hydrogen volume = 22.4 Ltr.

1Mole of oxygen volume =11.2 Ltr.

1 Liter of water can make 1860 Liters of HHO gas. That is, 1000 Milliliters of water can make 1860 Liters of HHO, or 1,860,000 Milliliters. Thus, 1 Milliliter of water can make 1.86 Liters of HHO, or 1860 Milliliters.

According to Faraday law 250KJ energy is required per mole of water. This is generally 250 KJ per 1.5 liters of hydroxygas i.e. 1mole of H_2 and 0.5 mole of O_2 from 1 mole of water or 18 grams.The ratio 1,860:1 refers to the fact that when the gas is electrically sparked, it immediately returns to water. If the amount of gas sparked, and thus imploded could fill 1,860 units, then the amount of water produced by its implosion would then only fill one unit. The resulting space instantly becomes filled with a very high and particularly clean vacuum.

4. Conclusions

It is observed in the present experimental work that as voltage increases through regulated DC power supply, consequently current also increase and it follows ohms law. But increase in current at constant voltage, results higher power consumption. The optimal result is obtained at 1A current and 5V potential with 1 mole electrolytic concentration. The hydroxy gas production rate is increased by 30% to 40% with a reduction of electrical energy consumption about 35% (at ambient temperature and pressure). The production rate is also increased 10% to15% more when temperature of alkaline solution increased from 25°C to 40°C with same parameters.

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