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Solar thermochemical for hydrogen production

الطاقة الشمسية الكيميائية الحرارية لإنتاج الهيدروجين

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Dedication

To our parents who guided us through our life with their love and care.

To our brothers and sisters, who never stopped giving us all the support and trust that we needed to go on.

To our friends who helped us to accomplish our duties and for being there for us

Wishing them good health and luck in their life
Last but not least this is dedicated for all who helped us even with just a single word

Thank you all

Acknowledgment

We are greatly indebted and ever grateful to our supervisor, Doctor A.A.A.Abuelnour , who inspired us throughout the laborious steps of this project. He helped us with project selection, planning and proposal writing, and supervised our entire work with diligence and enthusiasm.

Special thanks are deserved to the general manager of Solar Energy Enterprise Co, Dr. Saleh Hamadto, and Engineer Yasmeen for giving us permission to carry out our project in their facility, for their kind cooperation, encouragement, support, guidance and wise advices, without which this project would not have been a success.

Abstract

Energy is a basic need of humankind. Modern production of energy is used for applications such as electricity generation, transportation and heat production for heavy industry in the industrialized countries. One of the oldest conversion methods to transform fuel into energy is the combustion. The disadvantage of using fossil fuel in the combustion process is the emission of unwanted pollutants that will consequently create adverse effects on environment and human health. Hydrogen is a suitable option because of its environmental friendly properties and its combustion characteristic is similar to the regular gaseous fossil fuels. An experimental study of produce hydrogen from water in a lab scale using solar thermochemical. This experimental showed the use of solar thermochemical to produce hydrogen from water. Experiments show that the temperature is more than 1000 ° C. This temperature is sufficient to break down oxygen and remove hydrogen from water.

المستخلص

تعتبر الطاقة غرض اساسي لاستمرار الحياة حيث يستخدم الإنتاج الحديث للطاقة في تطبيقات مثل توليد الكهرباء والنقل وإنتاج الحرارة للصناعات الثقيلة في البلدان الصناعية. وتعتبر واحدة من أقدم طرق التحويل هي تحويل الوقود إلى طاقة عن طريق الاحتراق. ومن مضار استخدام الوقود الأحفوري في عملية الاحتراق هو انبعاث الملوثات غير المرغوب فيها التي تترتب عليها آثار ضارة على البيئة وصحة الإنسان. ويعتبر الهيدروجين هو الخيار المناسب كوقود صديق للبيئة وادت الدراسة التجريبية لإنتاج الهيدروجين من الماء باستخدام الطاقة الشمسية الحرارية حيث أظهرت التجارب أن درجة الحرارة أكثر من 1000 درجة مئوية كافية لكسر الأكسجين وإزالة الهيدروجين من الماء.

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List of abbreviation:

Symbol	
CO2	Carbone Dioxide
CO	Carbone Monoxide
H2O	Water
H2	Hydrogen
O2	Oxygen
H	Hour
G	Gram
Kg	Kilogram
KW	Kilowatt
MW	Megawatt
K	Kelvin
C	Celsius
CSP	Concentrated solar power
EGS	Engineered geothermal system
MSW	Municipal solid waste
ATM	Atmospheric pressure
T	Temperature
S	Second
Min	Minute
L	Litter
N_2	Nitrogen

CeO_2	Ceria oxide
Al_2O_3	Aluminum oxide

CHAPTER ONE

1.1 Background

There are many political, economic, and environmental issues concerning the use of fossil fuels. Because of these problems, research into a sustainable, environmentally friendly source of fuel that can be manufactured has become prevalent. The current work focuses on solar-thermal energy storage where the thermal energy from the sun is stored as hydrogen. Hydrogen has received a lot of attention because of its abundance, particularly in water, and that the product of its use is only water. If the hydrogen can be produced with low or zero Co_2 emissions, this would only add to its environmental compatibility. The hydrogen produced can be used in several areas. These areas include petroleum processing, petrochemical production, oil and fat hydrogenation, fertilizer production, metallurgical applications such as the production of nickel, and the electronics industry in the epitaxial growth of polysilicon [1]. However, there is also significant use of hydrogen in fuel cells. Fuel cells can be both mobile and stationary.

Solar thermochemical cycles converting method is based on two-step metal oxide redox reactions offer-promising paths for solar-driven production of H_2 from H_2O. In the first, endothermic solar step, the metal oxide is thermally reduced to the metal or lower valence metal oxide. In the second, exothermic step, the metal lower valence metal oxide is re-oxidized with H_2O to H_2 and the metal oxide back to its initial condition. The latter is recycled to the first step [2].

1.2 Problem statement

Nowadays the world suffer from fossil fuel emissions that effect on human, animals, and all living creature life. Also cause the thermal emission phenomena. There are many method to solve this problem such as a new technology in combustion and renewable energy. Renewable energy as a source of solar energy, wind energy, geothermal energy, hydro energy and hydrogen. Can product hydrogen thermo chemically using solar energy.

1.3 Research objective

1. To design and fabricate solar energy tracking system.
2. To investigate the possibility of collecting H_2 from H_2O.

1.4 significant study

As a result of global warming and energy problems resulting from emissions, it was found that the production of fuel with renewable energies is the best solution.

CHAPTER TWO

Literature review

2.1 Introduction

Today's world suffers from an increasing dependence on fossil fuels, either for electricity production, transportation or reagent for the chemical industry. A technological revolution in hydrogen and electricity production is important to support the future needs and lead the world towards a better future. For that, technological and economic barriers have to be broken. Concentrated solar power (CSP) has been proving to be a valid means to start this revolution and produce electricity and hydrogen from completely renewable sources water and the sun. Although solid steps should be taken to solve the current limitations and increase the technical and economic viability of these projects, there are conditions to begin this revolution using factual bridges from the current fossil technologies to renewable technologies [3].

2.2 Renewable energy

Electricity generation from renewable sources of energy is an important element in the Government's development of a low-carbon economy. There are ambitious renewable energy targets in place and a significant increase in generation from large-scale renewable energy infrastructure is necessary to meet the 15% renewable energy target [4].

2.2.1 Solar energy

Solar energy is the energy that sustains life on earth for all plants, animals and people. It provides a compelling solution for society to meet their needs for clean and abundant sources of energy in the future. Energy has played a key role in bringing about our modern civilization. In the era of modern civilization, energy demands are likely to increase for power generation for industrial and domestic usage. Solar energy is the most important source of renewable energy in the globe. The greatest advantage of solar energy comparing with other forms of energy is that it is clean and can be supplied without environmental pollution. Over the past century, fossil fuels provided most of our energy, because it was much cheaper and more convenient than energy from alternative energy sources, and until recently, environmental pollution has been of little concern. The limited reserves of fossil fuels cause a situation in which the price of fuels will accelerate as the reserves are decreasing [5].

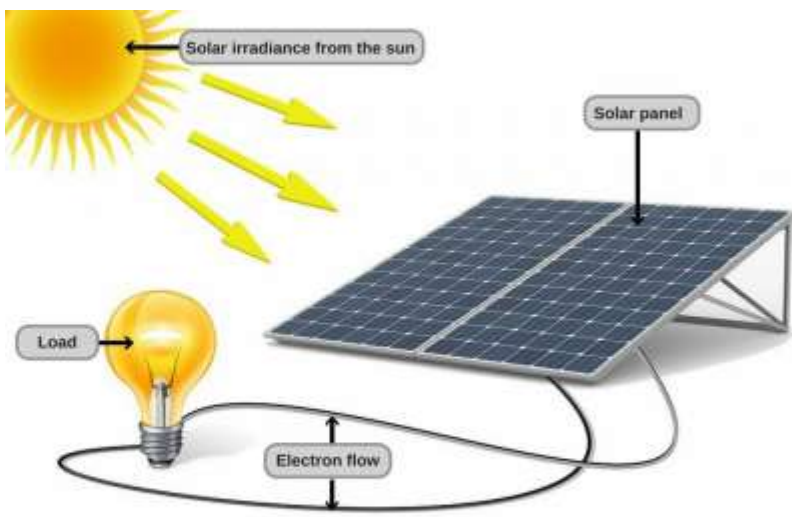


Figure 2. 1 show solar cell energy [5]

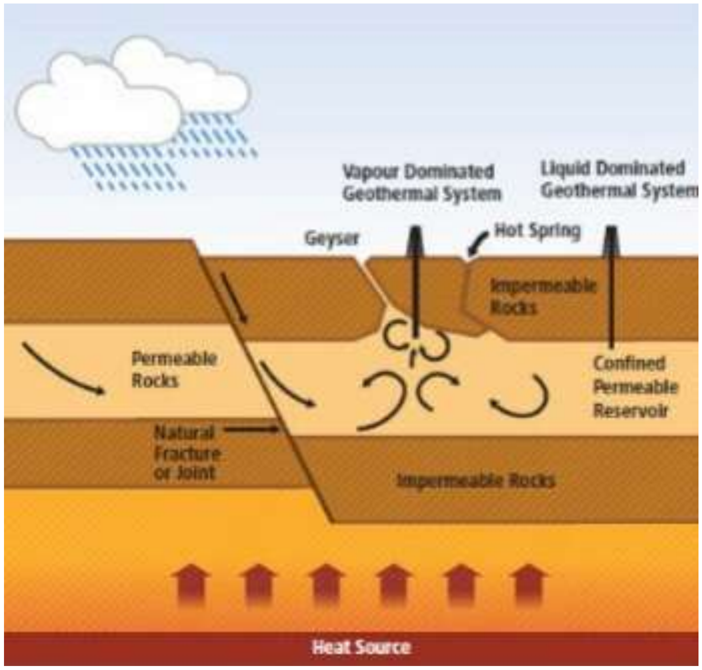
2.2.2 Wind energy

Wind mills and horizontal-axis and vertical-axis turbines are used to convert the kinetic energy of the wind into electricity. The electricity produced by wind energy can be supplied to the grid. The technology is beneficial for locations where wind velocity is high. The wind energy start from the sun when the sun heat certain zone from the earth air absorbed other of heat after that air raise above because low density of hot air and hot air molecular have faster motion than cold air that help to replace the air and make air current to moving the mills [6].

Figure 2. 2 propeller type [6]

2.2.3 Geothermal energy

Geothermal energy is heat from within the earth. We can use the steam and hot water produced inside the earth to generate electricity. Geothermal energy is a renewable energy source because the water is replenished by rainfall and the heat is continuously produced inside the earth. Climate change is not expected to have any major impacts on the effectiveness of geothermal energy utilization, but the widespread deployment of geothermal energy could play a meaningful role in mitigating climate change. In electricity applications, the commercialization and use of engineered (or enhanced) geothermal systems (EGS) may play a central role in establishing the size of the contribution of geothermal energy to long-term emissions reductions. The natural replenishment of heat from earth processes and modern reservoir management techniques enable the sustainable use of geothermal energy as a low-emission, renewable resource [7].



2.2.4 Hydro energy

Figure 2. 3 geothermal energy [7]

Hydroelectric must be one of the oldest methods of producing power which that generate electricity where the motion of running water (kinetic energy) is converted into electricity [8].

2.2.5 Biomass

Biomass is a term used to describe all organic matter produced by photosynthesis, existing on the earth's surface. They include all water- and land-based vegetation and trees, and all waste biomass such as municipal solid waste (MSW), municipal bio solids (sewage), and animal wastes (manures), forestry and agricultural residues, and certain types of industrial wastes. The world's energy markets have relied heavily on the fossil fuels. Biomass is the only other naturally occurring energy-containing carbon resource that is large enough in quantity to be used as a substitute for fossil fuels [9, 10].

2.2.6 Biofuel

Biofuel is renewable energy source that can produce predominantly from domestic biomass feedstock or as a by-product from industrial processing of agricultural or food products or from the recovery and reprocessing of products such as cooking and vegetable oil. Bioethanol and biodiesel are the most widely recognized biofuel source for the transport sector. Biofuel does not contain petroleum but it can be blended in any proportion with petroleum fuel to create a biofuel blend. It can be used in conventional heating equipment or diesel engines with no major modification [10, 11].

2.2.7 Hydrogen:-

Hydrogen is the simplest element. An atom of hydrogen consists of only one proton and one electron. It's also the most plentiful element in the universe. Despite its simplicity and abundance, hydrogen doesn't occur naturally as a gas on the Earth it's always combined with other elements. Water, for example, is a combination of hydrogen and oxygen (H_2O) [12].

2.3 Hydrogen energy

Hydrogen is a high quality energy carrier, which can be used with a high efficiency and zero or near zero emission at the point of use. It has been technically demonstrated that hydrogen can be used for transportation, heating, and power generation and could replace current fuels in all their present uses. Hydrogen can be produced using a variety of starting materials, derived from both renewable and nonrenewable sources, through many different process routes. The hydrogen produced can be used in several areas. These areas Include petroleum processing, petrochemical production, oil and fat hydrogenation, Fertilizer production, metallurgical applications such as the production of nickel, and the electronics industry. A solar-hydrogen system can provide the means of a totally emissions-free method of producing hydrogen [13].

2.3.1 Methods of Hydrogen production

Hydrogen was first identified by the English scientist Cavendish in 1776 when dissolving metals in dilute acids. Since the discovery, a number of chemical Transformations were used to produce hydrogen in the laboratory and for small-scale usage. These included, among others, the electrolysis of water, the reaction of zinc with hydrochloric acid, the reaction of sodium with water, and the dissolution of aluminum or silicon in caustic alkali sodium hydroxide solutions. However, by far the greatest amount of hydrogen produced for industrial purposes is produced by the steam reforming of natural gas (methane) [11].

2.3.1.1 Electrolysis

Electrolysis employ electricity to dissociation water to hydrogen and oxygen, electrolysis is a mature technology based on a fundamentally simple process and does not involve moving parts, this method is very efficient to producing the hydrogen fuel, but the power required to supply electrolysis is significant than hydrogen produced so that is more expensive to use .following some of electrolysis paths to producing hydrogen [12].

2.3.1.2 Thermolysis

Water can be split thermally by high temperature source around 2000-3000 k, the degree of dissociation is a function of temperature. The product is a mixture of gases at extremely high temperature. The main problem is connection with this method are related to materials required for extremely high temperature, recombination of the reaction product, and separation of hydrogen from the mixture [12].

2.3.1.3 Photolysis

Extraction of hydrogen from water by utilizing sunlight as energy source can be accomplished by employing photo biological system, photochemical assemblies, or photo electrochemical cells [14].

2.3.1.4 Solar electrolysis cell

This path depend on silicon cell electricity generation to supply the electrolyzer, is a two-step process. The first step is the conversion of solar to electrical energy by means of silicon solar cells, and the second step is electrolyze the water into hydrogen and oxygen, but this path have high cost [15].

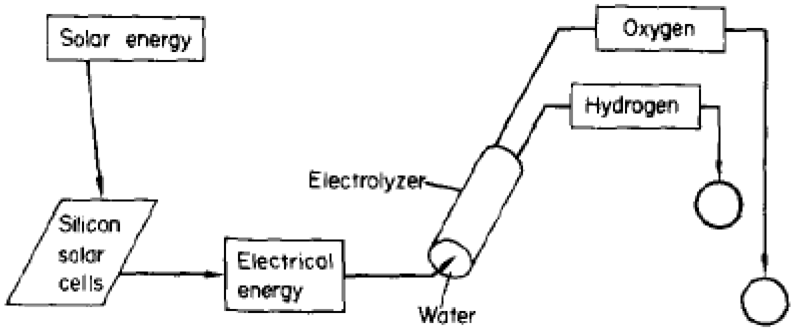


Figure 2. 4 producing hydrogen from solar energy using silicon solar cells [19].

2.3.1.5 Solar electrolysis – vapor power cycle

This path use vapor power cycle to generate electricity power the concept is neither new nor radical. The first step in the process is solar energy collection using concentrating collectors. The efficiency of a collector is defined as the ratio of the increase in the enthalpy of the steam. The second step in the process is the vapor power cycle. For a source temperature of 550°C and a heat rejection temperature of 27°C, but this path have high initial capital cost [20].

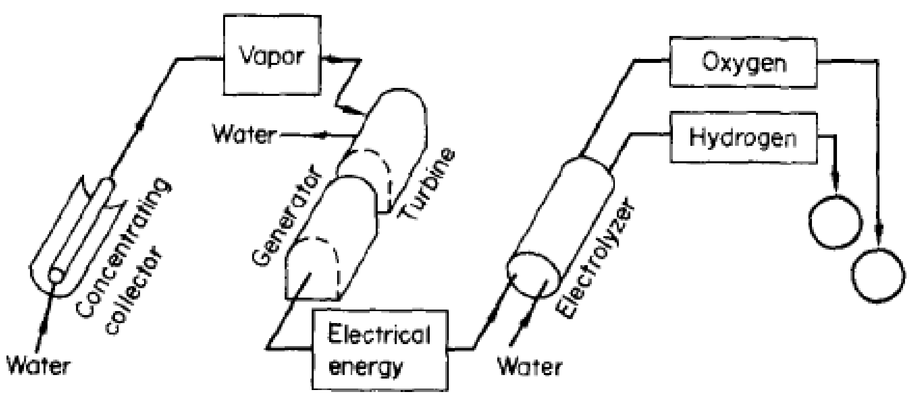


Figure 2. 5 producing hydrogen from solar energy using a vapor power cycle [20]

2.3.1.6 Thermochemical

Production of hydrogen employing thermochemical cycles involves chemical splitting of water at temperatures lower than those needed for themolysis, through a series cyclical chemical reactions ultimately release hydrogen. Some of the more thoroughly investigated thermochemical process cycles include the following [16, 17] sulfuric acid-iodine cycle, hybrid sulfuric acid cycle, calcium bromide-iron oxide and iron-chloride cycle. Depending on the temperatures at which these process are accruing, relatively high efficiencies are achievable.

2.3.2 Applications of hydrogen

Nearly all of the hydrogen consumed in the world is used by industry for refining petroleum, treating metals, producing fertilizer, and processing foods.

2.3.2.1 Steam generation by hydrogen and hydrogen combustion

Hydrogen fuel cells produce electricity by combining hydrogen and oxygen atoms. This combination results in an electrical current. A fuel cell is two to three times more efficient than an internal combustion engine running on gasoline. A compact hydrogen/oxygen steam generator has been commercially developed by the German Aerospace Research establishment. The generator consists of the ignition, combustion, and evaporation chambers. In the ignition chamber, a combustible mixture of hydrogen and oxygen at a low oxidant/fuel ratio is ignited by means of a spark plug. The rest of the oxygen is added in the combustion chamber to adjust the oxidant/fuel ratio exactly to the stoichiometric one [12].

2.3.2.2 Hydrogen use in vehicles

The interest in hydrogen as an alternative transportation fuel is based on hydrogen's ability to power fuel cells in zero-emission electric vehicles, its potential for domestic production, and the fuel cell vehicle's potential for high efficiency [15].

2.3.2.3 Catalytic combustion of hydrogen

Hydrogen and oxygen in the presence of a suitable catalyst may be combined at temperatures significantly lower than flame combustion (from ambient to 500c). This principle can be used to design catalytic burners and heaters. Catalytic burners require considerably more surface area than conventional flame burners. Therefore, the catalyst is typically controlled by controlling the hydrogen flow rate. The reaction takes place in a reaction zone of the porous catalytic sintered metal cylinders or plates in which hydrogen and oxygen are mixed by diffusion from opposite sides. A combustible mixture is formed only in reaction zone and assisted with a catalyst (platinum) to burn at low temperatures. The only product of catalytic combustion of hydrogen is water vapor [15].

2.3.2.4 Fuel cell

Hydrogen can be combined with oxygen without combustion in an electrochemical reaction (reversed electrolysis) and produce direct-current electricity. The device where such as reaction take place is called a fuel cell [12].

2.4 Hydrogen storage

Hydrogen producing is need to be stored in order to overcoming daily and seasonal discrepancies between energy source availability and demand, there are several form of storage discussed in following [12]

2.4.1 Gaseous hydrogen storage

Depending on storage size and application, several types of hydrogen storage systems may be available. This includes stationary large storage systems and stationary small storage systems at the distribution, or final user level; mobile storage systems for transport and distribution including both large-capacity devices (such as a liquid hydrogen tanker) and small systems (such as fuel gaseous or liquid hydrogen truck) and vehicle tanks to store hydrogen used as fuel for road vehicles [24].

2.4.2 Metal hydride storage

Hydrogen can form metal hydrides. During that process hydrogen molecules are split and hydrogen atoms are inserted in space inside the lattice of the metal or alloy. This creates effective storage comparable to the density of liquid hydrogen. However, when the mass of the metal or alloy is taken into account, then the metal hydride gravimetric storage density becomes comparable to storage of pressurized hydrogen. The best achievable gravimetric storage density is about 0.07kg of H_2/kg of metal, for high temperature hydride such as MgH_2 [12].

2.4.3 Liquid hydrogen storage

Liquid hydrogen favorable characteristics include its high heating value per unit mass and large cooling capacity due to its high specific heat. Liquid hydrogen has some important uses such as in the space program, in high-energy nuclear physics, and in bubble chambers. The transport of hydrogen is vastly more economical when it is in liquid form even though cryogenic refrigeration and special Dewar vessel are required. Although liquid hydrogen can provide a lot of advantages, its uses are restricted in part because liquefying hydrogen by existing conventional methods consumes a large amount of energy (around 30% of its heating value) [25].

2.5 Hydrogen properties

The table below show hydrogen properties [12].

Melting point	**−259.16°C, −434.49°F, 13.99 K**
Boiling point	**−252.879°C, −423.182°F, 20.271 K**
Density (g cm^{-3})	**0.000082**
Relative atomic mass	**1.008**
Key isotopes	**^{1}H, ^{2}H**
CAS number	**133-74-0**

2.6 Solar concentrator system

Solar energy systems have become a viable as source of renewable energy over the past two or three decades and are now widely used for a variety of industrial and domestic applications. Such systems which based on a solar collector, designed to collect the sun's energy and to convert it into either electrical power or thermal energy. The literature contains many studies regarding the use of solar system in main applications include generating electricity [27, 28], cooking [29, 30], irrigation and water heating [31, 32], and other applications such as light fixtures, window covering systems, and so forth [33, 34]. There are many type of solar concentrator system that can reach very high concentration ratio.

2.6.1 Solar dish systems

Power output of the solar dish system is important source of power; this power depends on many factors in the design the dish. One of these factors is the reflector material of the concentrator [35]. The main application of the solar dishes is to generate electrical power using Sterling engines ranging from kW to MW [27].

2.6.2 Solar tower systems

In solar tower systems numerous large, flat, sun-tracking mirrors, known as heliostats, focus sunlight onto a receiver at the top of a tall tower [36]. A heat-transfer fluid heated in the receiver is used to generate steam and then converted to electrical energy using steam turbine [37].

2.6.3 Fresnel lens system

It is a Piece of plastic in order to create annular rings of a flat body. Each ring is slightly thinner than the next and focuses the light toward the center. The Fresnel lens property were studied in references [38, 39]. This solar concentrator expected to acquire a higher thermal efficiency at high temperature level than those non concentrating collectors and can be used for solar thermal power generation or solar cooling.

2.7 current study of hydrogen as a fuel

Solar cell for generating of electrical the first step the conversion of solar to electrical energy by means of silicon solar cells. The efficiency of this conversion has a theoretical maximum of 24 percent. Actual achieved efficiencies are in the neighborhood of 11 per cent. The second step was electrolysis the efficiencies vary from 57 to 70 per cent, while efficiencies in the neighborhood of 80 percent. Dis advantage of this method the cost of solar cell is high. [26] Vapor power cycle. The first step was solar energy collection using concentrating collectors. The efficiency of a collector was 70 percent. The second step in the process was vapor power cycle. For a source temperature of 550°C and a heat rejection temperature of 27°C, efficiency of the second step of is 41.2 per cent. The electrolysis step has an efficiency of 75 per cent, giving the overall process an efficiency of 21.4 per cent. In this method the capital cost of equipment is four or five times of using fossil fuel [26].

Solar syngas production from H2O and CO2 is experimentally investigated using a two-step thermochemical cycle based on cerium oxide redox reactions. A solar cavity-receiver containing porous ceria felt is directly exposed to concentrated thermal radiation at a mean solar concentration ratio of 2865 suns. In the first endothermic step at 1800 K, ceria is thermally reduced to an oxygen deficient state. In the second exothermic step at 1100 K, syngas is produced by re-oxidizing ceria with a gas mixture of H2O and CO2.

The syngas composition is experimentally determined as a function of the molar co-feeding ratio H_2O: CO_2 in the range of 0.8 to 7.7, yielding syngas with H_2: CO molar ratios from 0.25 to 2.34. Ten consecutive H_2O/CO_2-splitting cycles performed over an 8 hour solar experimental run are presented [40].

CHAPTER THREE

Methodology

3.1 Introduction

This chapter showing equipment used for hydrogen extraction experience. These devices are calibrated and adjusted accordingly, then the experiment of solar thermochemical reaction to produce fuel from carried out using the combined solar system and the cavity reactor, and the data finally collected.

3.2 Flow chart

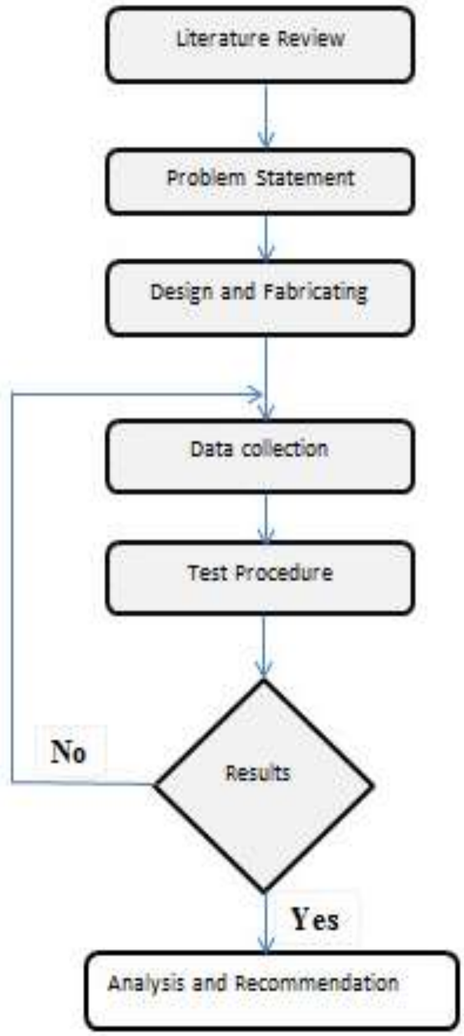


Figure 3. 1 low chart

3.3 Design & Fabricate

The design and testing of this equipment is carried out by computerized design programs in which the structure of the aluminum rack as shown in figure 3.1 is designed and the reactor designed for the purpose of oxidation and reduction process with appropriate dimensions to control the design. The holder supports a hydraulic device that stabilizes and moves the rack on two levels to obtain direct sunlight attaching to the assembled lens.

Figure 3. 2 Frame created by SolidWorks

3.4 Track system

Track system made from iron and steel aluminums who measures system stability and easily in motion as shown in figure (3.2). The base of the system made of casual iron placed inside the earth and installed by template steel to give cohesion largest suspension. Upper part made of article aluminums which features properties high lightness weight, easily movement, durability and other properties. Designed this structure using Program computer based on test dimensions appropriate and measure durability in appropriate circumstances hardest possible. There in this system hydraulic device placed as supports basic work on carry system in two dimensions.

Figure 3. 2 track system

3.4.1 Fresnel lens

A Fresnel lens is a flat, thin piece of plastic (As shown in figure (3.3b)) on which has been molded a series of small, concentric stepped zones. They extend from center to outer margin. Each groove is a minute refracting facet capable of bending light. Its transmittance (ability to pass light) is greatly increased over that of a conventional lens of the same focal length. It can also be used to build overhead projectors and camera obscures. Most important its advantages that her estimated on arrival temperatures very high (even 2000 ° c) in short time. Figure (3.3a) shown parameter of Fresnel lens.

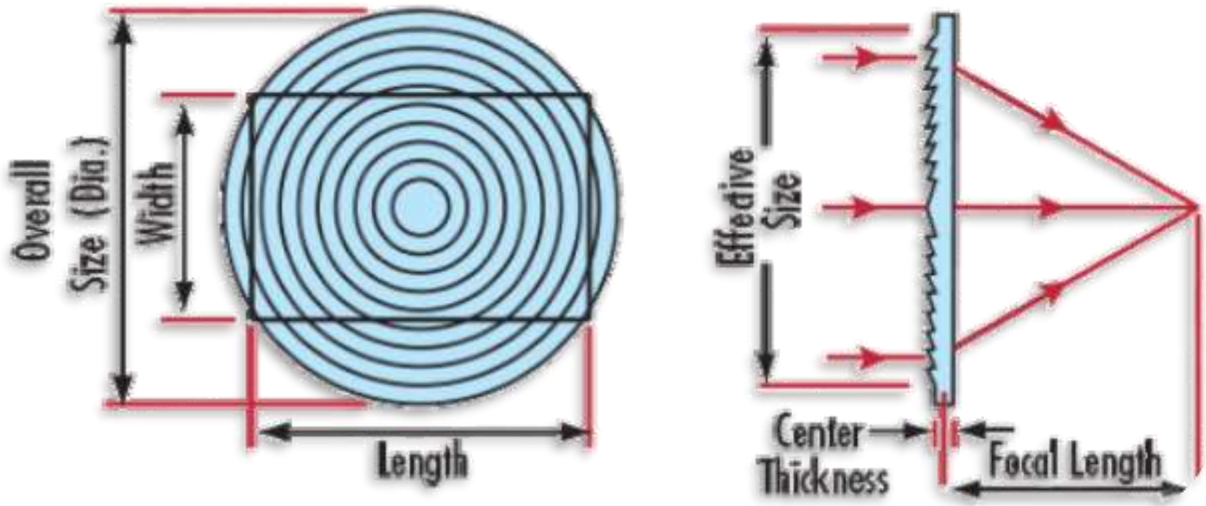


Figure 3. 3 Parameter of Fresnel lens

Figure 3. 4 Fresnel lens

3.4.2 Reactor

An aerosol reactor was tested for the thermal reduction of ceria as part of a solar thermochemical redox cycle for producing H2 from H_2O. The design is based on the downward aerosol flow of ceria particles, counter to an argon sweep gas, which are rapidly heated and thermally reduced (As shown in figure (3.4)). This reactor concept inherently results in separation of the reduced ceria and evolved O2 (g), operates isothermally throughout the day, and decouples the reduction and oxidation steps in both space and time for potential 24-h syngas generation.

Figure 3. 5 show 3D model of the reactor which was created by SolidWorks

3.5 Boiler

The boiler used to prepare the water vapor required for the oxidation process by heating water to temperature greater than the latent temperature.

3.6 Quenching

Used to control the temperature inside the reactor and outlet of gas production.

3.6.1 Nitrogen

Nitrogen is one of the best types of refrigerants to accelerate the reaction without any side effect by converting the temperature from (1450 ° C) to (600-450 ° C) in very short time. As shown in figure (3.10).

Figure 3. 6 N_2 cylinder

3.6.2 Condenser

The condenser intensifies the gas out of the reactor`s content by exposing its external surface to cold water that extracts the heat from the outside seam.

3.7 Storage Containers

Is a tight flask made of glass has a large space in the center and taped in one of the parties (is locked by a valve) either the other party has a cover made of plastic solid Geri gas permeable through it.

Figure 3. 7 storage battle

3.8 Temperature Measurement

A Thermocouple is a sensor made from two dissimilar metals. When these two metals are fused together at one end they create a junction. When the junction experiences changes in temperature, a very small voltage is created (see millivolt chart) which corresponds to a temperature reading. These different thermocouples can measure and monitor temperature within a wide range of environments.

3.8.1 Type-K thermocouple

Type-K is the most common general purpose thermocouple as shown in figure (3.8). Type K probes are reliable, inexpensive and has a wide temperature range. This is the most versatile sensor type and can hold continuously high temperatures. It has two junction made from chrome (+) and alum (-).

Temperature Range:-

- Thermocouple grade wire, -328 to 2,300°F (-200 to 1260°C)
- Extension grade wire, 32 to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- Standard: +/- 2.2°C or +/- .75%
- Special Limits of Error: +/- 1.1°C or 0.4%

Figure 3. 8 Thermocouple

3.8.2 Temperature Collector

A device that works on the processing of small electric frequencies coming from the sensor and works to read by a graphic screen showing temperature in the percentage and has a control button at the maximum temperature required. As shown in figure (3.9).

Figure 3. 9 Collector temperature

3.9 Pressure measurement

Used to control pressure in reactor and make it stable.

3.9.1 Vacuum pump

Vacuum mean empty space (as shown in figure (3.11)), when the pressure lowers than atmospheric, in an enclosed area. A condition in which the quantity of atmospheric gas present is reduced to the degree that, for the process involved its effect can be considered negligible. They used to control a chemical reaction, great force and flow (Vacuum pick-up, Vacuum cleaner).

Figure 3. 10 Vacuum

3.9.2 Gauge

A valve that controls the pressure coming from the cylinders as shown in figure (3.12)

Figure 3. 11 Pressure Gauge

3.10 chemical materials

Chemical materials used as catalysts and they assistance the reaction process.

3.10.1 Ceria

Ceria is reduced at elevated temperatures, generally above 1673 K. The amount of oxygen released is dictated by the change in its initial nonstoichiometric to its nonstoichiometric after thermal reduction, which is highly dependent on the reduction temperature (T) and oxygen partial pressure (pO2). As shown in figure (3.5).

Figure 3. 12 Ceria Oxide

3.10.2 Aluminum oxide AL_2O_3 ceramic foam

Aluminum oxide is one of the most cost effective and used material in the family of engineering ceramics. High oxidizing and reducing atmospheres over a temperature range of 1700 ° c to 2000 ° c. As shown in figure (3.6).

Figure 3. 13 Aluminum oxide

CHAPTER FOUR

Results and discussion

4.1 introduction

This chapter display the results obtained after many experiments that used to disassemble a water particles, the effect of the cycling, and the average of high temperature that taken from many experimental and the effect of temperature on cerium oxide.

4.2 experimental results and discussion

Design and fabricate of tracking system was done as shown in figure 4.1below

Figure 4. 1 tracking system

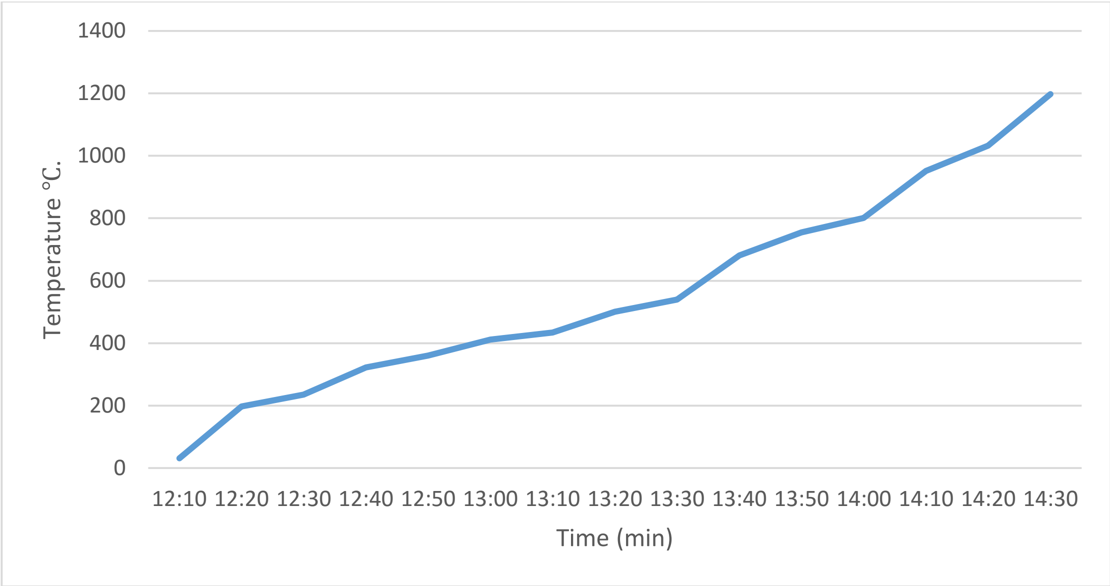


Figure 4. 2 temperature with time (during September)

Figure 4.2a show in X axis the time by (min) and in Y axis the temperature by°C.

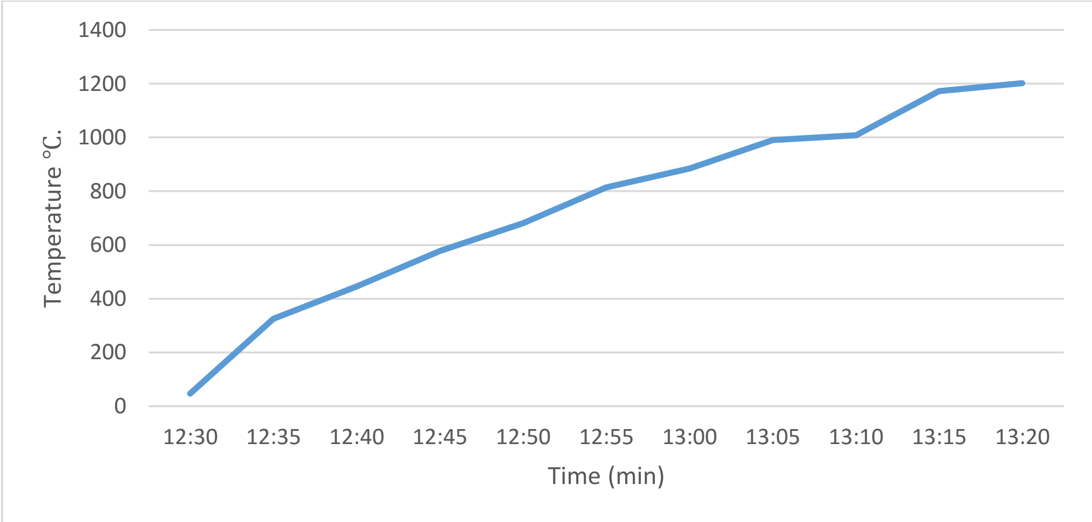


Figure 4. 3 temperature with time (during October)

Figure 4.2b show in X axis the time by (min) and in Y axis the temperature by°C.

From the figures 4.2a and b observed that a temperatures are increase with the time as result of sun passes on reactor.

As a shown the temperature reached to 1200℃ that is sufficient to Dissociation the oxygen from cerium oxide. On September temperature reached to 1200℃ in 2 hours and 20 minutes and On October the temperature reached to 1200℃ in 45 minutes because September is autumn reason in Sudan. All of this result agree with previous study [40].

4.3 Visual inspection

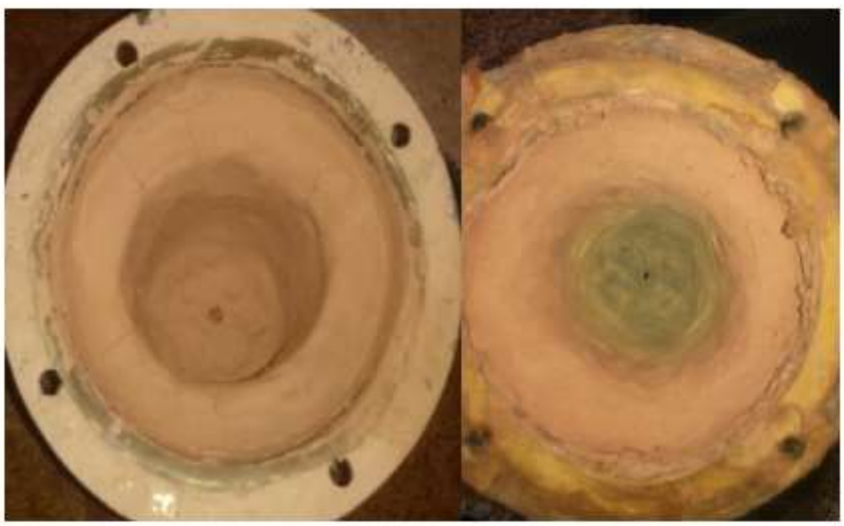


Figure 4. 4 sample of cerium oxide before 2 cycles and after 2 cycles

From a figure observed that colors of cerium oxide is differ after receiving sun radiation. That different in colors as a results of high temperature. Difference in colors explain in below table.

All this result agree with previous research [41].

Material	Color
CeO_2	Grey-yellow-green
CeO	Green -black

Table 4.1 [41]

As shown in above figure the temperature is reached more than 1000℃ and that is sufficient to dissociation oxygen and break down hydrogen from water. All this result agree with previous studies [42. 43].

CHAPTER FIVE

Conclusion and Recommendations

5.1 Conclusion

The design and fabricate of tracking system was done. And the temperature reached more than 1000℃ that mean all oxygen dissociation from H_2O.

5.2 Recommendations

1. From the problem of fossil fuel used the hydrogen as sustainable energy. By using the same steps can combine hydrogen with monoxide to produce hydrocarbon.

2. Find suitable device to analysis the result of production fuel.

3. Prefer to make the experimental in summer due to the hot weather.

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