Recent Advances in Hydrogen Production

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1. INTRODUCTION

Hydrogen power has long been heralded as the renewable energy source of the future because of its cost effectiveness and low environmental impact. Unfortunately, Hydrogen gas (H_2) is not readily found in nature, and if generated by fossil fuels or nuclear power, it is falls outside the sphere renewable energy. In addition, the present methods by which H_2 is produced require separate energy source to create that fuel. Recently, tremendous strides have been taken in generating H_2 from renewable and sustainable sources, without environmental degradation. For these scientists, finding an efficient and renewable method by which the H_2 producing Organism can be supplied energy has become a priority.

Hydrogen gas (H_2) can be used for cooking, water heating, space heating, electricity generation, welding and cutting, and the synthesis and purification of other Chemical materials. When hydrogen is made from water and renewable energy resources such as PV, wind, or micro hydro, we refer to the produced gas as "solar-hydrogen." Solar-hydrogen is a sustainable carbon-free gas. It can release heat when burned with air or oxygen, or produce electricity when combined electrochemically with oxygen in a fuel cell. When solar-hydrogen is made or burned, there is no carbon monoxide, carbon dioxide "greenhouse gas," or hydrocarbon pollutants produced.

The first element of the periodic table, which is also the most abundant element in the universe, may be the panacea to solving world's energy crisis as well as the environmental and ecological issues arising from carbonaceous emissions. In this article we introduce hydrogen as a commercially viable fuel and some emerging technologies that make use of this clean fuel.

There is a large and growing demand for hydrogen in the United States and the rest of the world, with the bulk of the hydrogen being produced by steam reforming of methane with carbon dioxide as a byproduct. Hydrogen and electricity are expected to dominate the world energy system in the long term. As the world transitions to a hydrogen economy, hydrogen will be used increasingly by the transportation, residential, industrial, and commercial sectors of the energy market. Eventually, the demand for natural gas may outpace its production. There may also be strong environmental and economic incentives in the future to produce hydrogen without generating carbon dioxide as a byproduct.

2. WHY HYDROGEN

Hydrogen can be used as a fuel replacing gasoline in the automobiles. This means, the size and look of automobiles is unlikely to change with the use of hydrogen as fuel. Hydrogen burns clean inside fuel cells and the only resulting emission is water. Hydrogen is considered the ultimate fuel of the future as it has beneficial effects on global warming, environment and ecology. There are cost benefits of using hydrogen as fuel, by reduction in the requirements of pollution control. There are health's benefits of using hydrogen as fuel – emissions from hydrocarbon combustion are often believed to be carcinogenic.

Hydrogen (H_2) has long been hailed as the fuel of the future. One of the main utilizations of hydrogen as a fuel is for fuel cells to generate electricity. At present over 90% of available hydrogen is produced by catalytic steam reforming and partial oxidation of methane (CH_4) as well as steam reforming of carbon monoxide (CO), CH_4 and CO are produced from fossil fuels, particularly coal and natural gas. These processes are however unsustainable, in addition they release considerable amounts of carbon dioxide (CO_2).

There are further difficulties associated with H_2 and these include its storage and transportation. H_2 is the least dense of all molecules requiring compression and refrigeration for practical applications; both are energy intensive processes. These difficulties have motivated the findings of other processes for H_2 production.

Ethanol as an energy carrier is easily transported using the existing fuel infrastructure and conversion to H_2 immediately prior to the use in a fuel cell constitutes a practical and efficient means of energy production. Furthermore ethanol is produced from biomass with little energy input and steam reforming alleviates the necessity of the energy intensive distillation in the separation of water from crude ethanol.

Ethanol steam reforming (ESR) may provide a viable step in the search for efficient sustainable energy production in a transitional period. In addition the process can produce H_2 onboard of stationary or moving devices thus avoiding compression on refrigeration processes. However, the technology is still in the research and development stage.

Fuel cells have emerged as one of the most promising technologies for meeting future global energy needs. The full environmental benefit of generating power from hydrogen fuel cells is achieved when the hydrogen fuel is produced from renewable sources such as solar power and biomass. Indeed, the production of hydrogen from renewable biomass-derived resources is a major challenge as global energy generation moves towards a “hydrogen society”. In this presentation, we show that it is possible to generate hydrogen by catalytic reforming of oxygenated hydrocarbons in liquid water at temperatures near 500ºK.

These reforming reactions lead to high selectivities for the production of hydrogen over Pt-based catalysts from oxygenated hydrocarbon reactants having a C: O stoichiometry equal to 1:1. For example, glucose can be converted to hydrogen and gaseous alkanes over platinum-based catalysts, with hydrogen selectivities of 50 %. Higher selectivities of hydrogen can be achieved from S orbital and glycerol, and nearly 100 % selectivity for hydrogen production can be achieved for aqueous-phase reforming of ethylene glycol and methanol.

This aqueous-phase reforming process (i) generates hydrogen without the need to volatilize water, which represents a major energy saving compared to conventional, vapor-phase, steam-reforming processes, (ii) occurs at temperatures where the water-gas shift reaction is favorable, making it possible to generate hydrogen with low amounts of CO in a single chemical reactor, (iii) utilizes safe transportable non-flammable feed stocks, (iv) can utilize renewable biomass derived feed stocks, and (v) takes place at low temperatures which minimize undesirable decomposition reactions typically encountered when carbohydrates are heated to elevated temperatures.

3. BACKGROUND

The world currently consumes about 45 million metric tons of hydrogen per year, with the United States consuming about one-fourth of this quantity. To put this in perspective, the hydrogen consumed in the U.S. per year would generate 50 GW (t)-yr if it were burned. Nearly all of this hydrogen is consumed by the industrial sector, primarily the chemical and refining industries. With a growing economy, the demand for hydrogen will increase further, especially if the U.S. and other countries shift their energy usage toward a hydrogen economy, with hydrogen consumed directly as an energy commodity by the transportation, residential, and commercial sectors.

With recent advances in fuel cells and hydrogen combustion engines, the framework for a hydrogen economy is already being established. An important issue that must be addressed is the source of hydrogen to meet this expected increase in demand. Presently, the bulk of hydrogen is produced by steam reforming of natural gas (methane). The overall process produces 4 moles of hydrogen for each mole of methane, with carbon dioxide as a byproduct. Alternatives to natural gas as a source of hydrogen are needed for the following reasons:

(1) Natural gas consumption is outpacing production in the U.S., which will require importing significant quantities of natural gas in order to fill the projected shortfalls. This increase in demand may result in significantly higher prices for natural gas.

(2) Steam reforming of natural gas is not environmentally friendly because it produces the carbon dioxide.

4. HYDROGEN GAS

As a Renewable Resource

Generating energy via Hydrogen will be the cost effective and efficient renewable energy source of the future. Of all the renewable sources, it has the potential to have the lowest environmental impacts, while producing the most energy. Although Hydrogen is the most abundant element in the universe (more than 75-90% of all atoms), very little H_2 exists in nature. Of course, H_2 plays a vital role in powering the universe through stellar hydrogen fusion, like our Sun.

As a Gas Molecule

H_2 is a molecule of the element Hydrogen. Hydrogen is the first element on the periodic table, and thus, has the lowest molecular weight. A typical H_2 molecule consists of a single covalent bond. Two atoms of Hydrogen combine to form a Hydrogen molecule. The most widely accepted theory assumes that each atom has one orbit, which overlap when combined. Each Hydrogen atom has one valence electron to share. Since this bond consists of the sharing of electrons it is called a covalent bond. Hydrogen is an exception to 8-electron valence shell balance required by all other elements, except Helium. Therefore, the driving force behind creating a stable H_2 molecule is to fill the valence shell with two electrons.

Hydrogen has a number of properties that make it particularly well suited to use as a tracer gas. It has a very low viscosity and the background concentration of hydrogen in ambient air is relatively low. As demand for environmental protection becomes more of a priority, researchers, companies and government incentives build to look at alternate fuels, and resources as methods of both reducing our dependency on fossil fuels and improve our environment at the same time. Recently the president of the United States has expounded on the needs to look at alternative fuels and directly mentioned hydrogen as one of those fuels whose time has come.

5. COMPOSITION

Hydrogen is the simplest and most common element in the universe. It has the highest energy content per unit of weight---52,000 British Thermal Unit (BTU) per pound (or 120.7 KJ/gm) of any known fuel. Moreover, when cooled to a liquid state, this low weight fuel takes up 1/700 as much space as it does in its gaseous state. This is one reason hydrogen is used as fuel for rocket population, which requires fuel that is low-weight, compact, and has a high energy content.

In a free state and under normal conditions, hydrogen is a colorless, odorless, and tasteless gas. The basic hydrogen (H_2) molecule exits as two atoms bound together by shared electrons. Each atom is composed of one proton and one orbiting electron. Since hydrogen is about 1/14 as dense as air, it usually exits in combination with other elements, such as oxygen in water, carbon in methane, and in trace elements as organic compounds.

Because it is so chemically active, it rarely stands alone as an element. When burned (or combined) with pure oxygen, the only by products are heat and water. When burned (or combined) with air, which is about 68% nitrogen, some oxides of nitrogen (Nitrogen Oxides or NO_x) are formed. Even then, burning hydrogen produces less air pollutants relative to fossil fuels.

6. PROPERTIES

- Colorless, odorless, non-toxic gas
- Most abundant element in the universe
- Smallest molecule of all elements
- Low volumetric density
- Energy input required for “extraction”
- Hydrogen occurs almost exclusively locked in other compounds

7. PROPERTIES REGARDING SAFETY

- Colorless, odorless, non-toxic gas
- Easily flammable
- Burns with no visible flame in day light
- Flame radiates less than other fuels
- Hydrogen burns without creating harmful soot
- Hydrogen needs more fuel in the air to detonate
- High burning velocity means likely to explode in confined spaces
- Low volumetric density (lighter than air) means H_2 cloud will rise and disperse quickly.

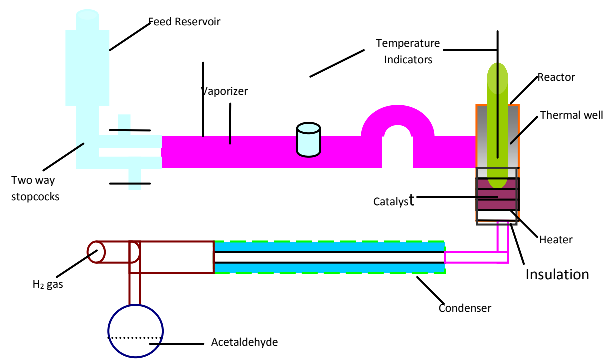
Methods of Production

Hydrogen production is commonly produced by extraction from hydrocarbon fossil fuels via a chemical path. Hydrogen may also be extracted from water via biological production in an algae bioreactor, or using electricity (by electrolysis), chemicals (by chemical reduction) or heat (by thermolysis); these methods are less developed for bulk generation in comparison to chemical paths derived from hydrocarbons. The discovery and development of less expensive methods of bulk production of hydrogen will accelerate the establishment of a hydrogen economy.

- Electrolysis of water
- Nuclear, renewable, conventional electricity
- Reforming
- Catalysis
- Natural gas, coal, oil, diesel, biomass
- Photoelectrical, Photo biological, thermal dissociation

Obstacles to a H_2 Production

There are two obstacles to a hydrogen-economy.



- It takes a lot of volume (or energy) to store hydrogen – Usually five times or so the volume, at reasonable pressures, needed to store an equivalent amount of energy with gasoline.
- There is no hydrogen infrastructure: Making the transition to a hydrogen economy might mean having to scrap the fossil fuels infrastructure that has already developed. One company that has made progress on refueling equipment is Stuart Energy.

Using synthetic fuels and low carbon storage tanks might surmount both of these problems. For example, it is possible, using a catalyst, to make fuels such as methanol, *ethanol* or any carbon based fuel and that yields to get separate as alcohols / aldehydes.

Thermal Degradation: Catalyst activity loss due to thermal damage us often a serious problem in supported metal catalysts (Pt-Al_2O_3, Ni-Al_2O_3 etc) and oxide catalysts with large surface areas (SiO_2-Al_2O_3, Al_2O_3, Zeolites, iron-molybdate etc).

The major thermal damages to the catalysts are:

1) Loss pf metal surface area due to crystalline growth.
2) Loss of support surface area duet to pore collapse and
3) Transformation of the catalytic phase into a non-catalytic phase.

Experimental Setup

The process figure is shown below.

In the process the feed (Ethanol) is given at the Feed Reservoir and that can be comes to enter into vaporizer with the help of a two way feed stock, so here the liquidus form of feed is get converts into the gaseous form and then it enters into the fixed bed reactor.

Fixed Bed Reactor

In any catalytic process we must use the process in a fluidized bed with some height if it may change or not depending upon the process but in our process bed is fixed and it is placed at the starting of the process and it can be changed or moved in the height of the bed depends upon the durability of the catalyst. Hence as copper catalyst is moderately good enough durable so that our process reactor knows also as fixed bed reactor.

The fixed bed reactor compounded (combined) with that of thermal well and vaporizer. The thermal well is having the thermocouple which is connected to the pyrometer which gives the temperature with in the reactor and also the reactor is wounded by a heating tape to generate the desired temperature varying with a dimmer start and it covers by an insulation to avoid heat losses.

Potential uses for hydrogen

When properly stored, hydrogen as a fuel burns in either a gaseous or liquid state. Motor vehicles and furnaces can be converted to use hydrogen as a fuel. Hydrogen has actually been used in the transportation, industrial, and residential sectors in the United States for many years. Currently, industries use large quantities of hydrogen for refining petroleum, and for producing ammonia and methanol. The space shuttle uses hydrogen as fuel for its rockets.

Burning of H_2 creates less air pollution than gasoline or diesel. Hydrogen also has a higher flame speed, wider flammability limits, higher detonation temperature, burns hotter, and takes less energy to ignite than gasoline. This means that hydrogen burns faster, but carries the danger of pre-ignition and flashback. While hydrogen has its advantages as a vehicle fuel it still has a long way to go before it can be used to substitute for gasoline. This is mainly due to the investment required top develop a hydrogen production and distribution infrastructure.

8. CONCLUSION

Energy supplies in the 21st century will be challenged as fossil fuel reserves decline, human consumption increases, and greenhouse gasses accumulate to further damage the atmosphere. These challenges will be met by innovative solutions to enable the hydrogen economy; to replace petrochemical fuels with hydrogen for use in fuel cells and internal combustion engines. One of the most difficult challenges is to produce hydrogen at a cost competitive with current fuel pricing (fossil fuel or natural gas)

Acetaldehyde is the byproduct in the above process and is a colorless liquid with a pungent, fruity odor. It is primarily used as a chemical intermediate, principally for the production of acetic acid, pyridine and pyridine bases, peracetic acid, pentaeythritol, butylene glycol, and chloral. Acetaldehyde is a volatile and flammable liquid that is miscible in water, alcohol, ether, benzene, gasoline, and other common organic solvents.

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