HYDROGEN: 'On Demand' Production of Hydrogen from Ammonia Borane using Ruthenium as a Catalyst Production ready with Safe Storage

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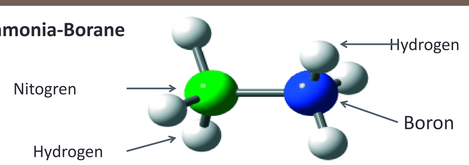
ABSTRACT

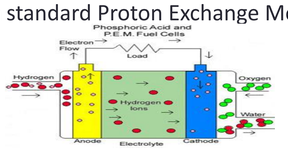
Hydrogen is commonly regarded as the simplest and most abundant element in the universe. The scientific community estimates that 90% of our visible universe is composed of hydrogen. Ammonia Borane is a chemical compound which is approximately 20% hydrogen by weight, having the chemical formula NH_3 BH_3. This colorless solid is a simple boron-nitrogen-hydride compound and has attracted a lot of attention as a source of hydrogen fuel. However, a catalyst is required for the hydrolysis generation of hydrogen (H) gas from the NH_3BH_3. The highest active catalyst being examined for testing is Ruthenium (Ru). When extracting H_2 from the readily available source such as freshwater (H_2O), an energy source from an electrical charge is required, whether it be generated from a turbine or collected from solar support. This process is called "on board" and tends to logistically create space and weight issues for the mode of transportation. Ru, when used as a catalyst generates H_2 (gas) at room temperatures from NH_3BH_3. The purpose of this investigation is to effectively produce H_2 gas from NH_3BH_3 at room temperatures with out additional energy input. In turn, eliminating the need for additional electrical input for extracting/producing H and freeing-up gravimetric mass and volumetric space. Furthermore, safety, decrease the need for hydrogen storage and design an 'On Demand' server for delivery of hydrogen requirements.

BACKGROUND

Ammonia-Borane



Ammonia–borane (AB, NH_3BH_3) contains 19.6 weight % H, and is one of the materials currently being examined as a possible H_2 source for use in fuel cells to power automobiles. Challenges for this technology must be investigated and considered, especially when looking at the transportation sector and the target storage requirements of the U.S. Department of Energy. The development of both transition-metals and acid catalysts which promote H_2 release from AB under mild conditions in conjuction with a standard Proton Exchange Membrane (PEM) hydrogen cell.



OBJECTIVES

- Differentiate between Physical Process and Chemical Process of creating and using Hydrogen as an energy source.
- Determine the significance of using Ruthenium as a catalyst.
- Using 'Inquiry Based' science strategies, design a possible solution for improving 'on-board' technology for Hydrogen produced fuel source.

INQUIRY SCIENCE

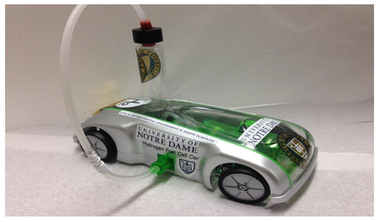
Using a hydrogen car science kit (H-Racer 2.0 from Horizon), develop a possible solution to eliminate the need for 'on demand' electrical charge required for H_2 production.

Possible Soluition#1:

Affix two vials on the outer shell of the H-Racer. Vial #1 is to extract H2 from the NH_3BH_3 with the aid of the Ru catalyst. Vial #2 contains H_2SO_4 (Sulfuric Acid) - scrubs any impurities from the H_2 before entering the fuel cell and potentially contaminating the H cell.

Possible Solution #2:

Affix one vial on the outer shell of the H-Racer. H2 will be produced and collected inside the vial. The H2 will then go directly into the H-Racer without any scrubbing of impurities. Longevity of the PEM is unknown and will need to be tested in future studies.



MATERIALS

Hydrogen Science Kits from Horizon:

H-Racer 2.0, i-H2GO w/Smart Phone Controls, and Solar Hydrogen Education Kit

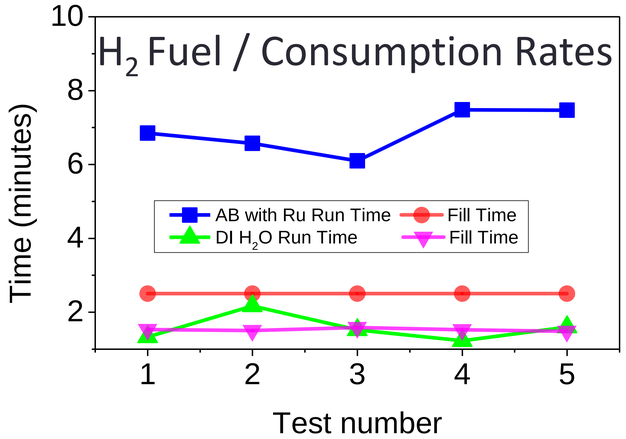
Teflon Tape	Pipette
Scissors	Cell Phone
Glue	Distilled Water
AA Batteries	1/8 Clear Rubber Tubing
10 ml and 20 ml vials	Timing Device

RESULTS

What is a fuel cell?

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution–much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, namely water.



$$Ru^{3+} + NH_3BH_3 \longrightarrow \text{Ru Nanoparticles}$$

$$NH_3BH_3 + 2H_2O \xrightarrow{Ru} 3H_2 + NH_4BO_2$$

CONCLUSIONS

- Ammonia-borane is a non-hazardous solution that carries a high solubility when mixed in DI H_2O. Upon mixing Ru as a catalyst the 'Run Time' of the prototype vehicle is 4.87 times greater than of the electrolysis demonstration. Issues that need to be addressed include and not limited to: added weight percentage to the prototype, surface friction, longevity of the PEM, life span of the catalyst due to loss of surface area, improvements for prototype gearing and ratios, and hydrogen pressure flow and rates.
- Challenges addressed during this 'Inquiry' exercise included: production of H_2 too fast, over load on prototype suspension and gearing, moisture inside the exchange tubing, leaking connections, ratio of AB solution and Ru measurements, and design/build engineering logistics.
- The optimum solution/catalyst production is 15mg NH_3BH_3 with 2.5ml DI H_2O mixed with 0.1mg of Ru (0.1ml of 1,000 ppm Ru) Safety is achieved with 'On Demand' supply.