Hydrogen Fuel Cell Car PRE Questionnaire

Student's name____________________________________ Student ID____________________________

TO BE COMPLETED AND TURNED IN TO TA BEFORE STARTING THE EXPERIMENT

1. Typical units for measuring gas volume are meters cubed or m^3. Please convert 100 cm^3 into m^3.

   a. 100 cm^3 = 0.0001 m^3
   b. 100 cm^3 = 0.01 m^3
   c. 100 cm^3 = 1 m^3
   d. 100 cm^3 = 100 m^3
   e. 100 cm^3 = 10000 m^3

2. What is the difference between distilled water and tap water?
   a. distilled water is colorless when compared to tap water
   b. distilled water has no weight when compared to tap water
   c. distilled water has no smell when compared to tap water
   d. distilled water has no impurities when compared to tap water

3. What is the kinetic energy of 1kg object that is moving 5 m/sec?
   a. 0
   b. 1/5 J
   c. 2.5 J
   d. 5 J
   e. 10 J

4. Which gas has the simplest structure and the lightest when compared to other gasses?
   a. Hydrogen
   b. Helium
   c. Oxygen
   d. Nitrogen
   e. Neon

5. What happens during electrolysis?
   a. Chemical compounds are decomposed using electrical current.
   b. Chemical compounds are compressed using electrical current.
   c. Chemical compounds gain specific color.
   c. Chemical compounds are mixed together.

University of California at Santa Cruz,
Jack Baskin School of Engineering
EE-80J: Renewable Energy Sources

Hydrogen Fuel Cell Car Laboratory Experiment

Oxana Pantchenko and Prof. Ali Shakouri

Student's name______________________ Student ID________________________ Grade _____ / _____

ABSTRACT
In this experiment, students will obtain knowledge about fuel cells, energy conversion, hydrogen fuel cells as a power source and their advantages and disadvantages. The students will also learn about HyRunner Module and how its movement is powered by hydrogen.

INTRODUCTION

Diminishing resources, more severe environmental impacts and the ever increasing demand for energy force our population is to reconsider the structure of our energy supply system. Automobile industry and oil companies increasingly invest in hydrogen technology because it offers solutions to some of these concerns. This fascinating technology combines a large energy supply with minimal impact on our natural resources. The goal of this lab is for the students to become familiar with the terms and obtain knowledge on the subject.

EXPERIMENTAL PROCEDURE

CAUTION

In the fuel cell hydrogen (H_2) and oxygen (O_2) react with each other. These gases represent a source of danger if handles improperly. In order to avoid any risks each students must follow General Safety Precautions.

GENERAL SAFETY PRECAUTIONS:

- Read the instructions before setting up the HyRunner. Follow them during use and keep them readily available.
- Wear protective goggles
- Unless specified otherwise, do not short circuit or reverse the polarity of the terminals.
- Do not operate the system empty. Always ensure that is contains sufficient water. Observe the water level markings.
- Do not smoke.
- Only operate the system at the room temperature and ambient pressure.

LIST OF MATERIALS

- Ruler
- Protective goggles
- HyRunner car
- Power source
- Distilled water

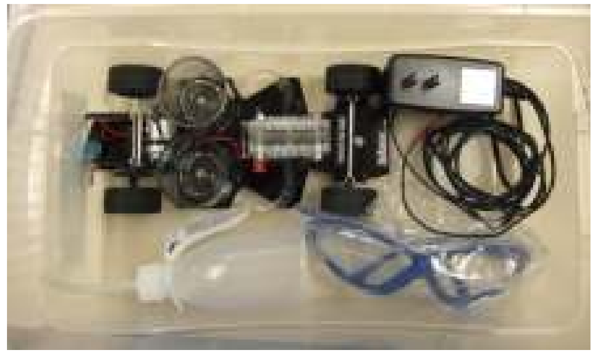

Figure 2 Supply box of materials. Make sure your box has all the listed components. Is something is missing, contact your TA as soon as possible.

LABORATORY PROCEDURE:

1) Gather all needed materials described in the list of materials section. Be sure to use DISTILLED WATER because it FREE of IMPURITIES that could cause problems inside the HyRunner.
2) Remove black closing cap from the inlet socket on the fuel cell's oxygen side.
3) Connect the hose of the water bottle to the inlet socket of the cell.
4) Holding the bottle upside down and vertical, squeeze it to fill the gas tank up to the 'A' mark with water introduced via the fuel cell.
5) Release the pressure on the bottle. When the water level has fallen to 'B' mark, pinch the hose between thumb and forefinger until the water stops dropping.
6) Pull the water bottle hose off the fuel cell. Replace the black cap on the inlet socket.
7) Remove black closing cap from the inlet socket on the fuel cell's hydrogen side.
8) Connect the hose of the water bottle to the inlet socket of the cell.
9) Holding the bottle upside down and vertical, squeeze it to fill the gas tank up to the 'A' mark with water introduced via the fuel cell.
10) Release the pressure on the bottle. When the water level has fallen to 'B' mark, pinch the hose between thumb and forefinger until the water stops dropping.
11) Pull the water bottle hose off the fuel cell. Replace the black cap on the inlet socket.

12) The car is now filled with distilled water.

13) BE SURE THAT THE SWITCH IS SET TO OFF POSITION.

14) Connect the power source to the fuel cell of the car. Positive to positive (RED) and negative to negative (BLACK) electrodes. The charging time is approximately **2 minutes.**

    When electric current is applied, the process of ELECTROLYSIS is occurring. In this process, distilled water will be split or decomposed into its components, hydrogen and oxygen. These gases are then accumulated in the gas storage tanks.

15) Disconnect the power supply leads as soon as 15 cm^3 of hydrogen has been stored in the hydrogen tank.
16) Place the HyRunner on the empty pathway.
17) Move the switch into 'ON' position.
18) Let the car run. At the end of the pathway, reverse the direction by lifting HyRunner and rotating it 180 degrees.
19) Measure the total time the car is running for?

    Total time= ___________ minutes.

20) It has been previously calculated that such HyRunner cars would run for approximately 8 minutes, if your car ran for less than 8 min, explain one reason why it happened so.

21) Where are the energy loses in this experiment?

22) Measure the total distance that the car traveled.

    Total distance=________ __________meters

23) Calculate car's speed.

    Car's speed=______________________m/s

24) Calculate kinetic energy. Kinetic Energy = ½ m V^2 where m is the mass of the vehicle and V is it's speed. Mass is measured in kg and V is in m/s.

    KE=____J

25) Be sure to show your TA that your car is running.
26) Explain how the energy is converted in HyRunner car.

MAITENANCE

- Drain the water from the storage tanks after operation to avoid possible discoloration of the graduations.
- Replace the caps to ensure that a small amount of water remains in the cell.
- Wipe the base plate dry to avoid any water stains.

ADDITIONAL QUESTIONS

The following data was collected from the same PEM electrolyzer that is used your fuel cell car when it was connected to the power source. A PEM electrolyzer produces hydrogen and oxygen continuously if the applied DC voltage exceeds a certain value. The time, voltage and current values have been recorded in this table for various volumes (in 5 cm^3 increments) of hydrogen gas produced. Calculate the power for each time increment.

Table 1

$Volume_{H2}$ [cm^3]	t[s]	V [volts]	I [Amps]	P [Watts]; P = I x V
0	0	1.9	1.73	
5	23	1.9	1.73	
10	47	1.9	1.73	
15	68	1.9	1.73	
20	92	1.9	1.73	

Plot the produced volume of H_2 as a function of time on a graph.

Energy Efficiency

The energy efficiency n $_{energy}$ is the ratio of energy out vs. energy in. The usable energy or the energy out is the chemical energy stored in the produced hydrogen, while the input energy is the electrical energy dissipated by the electrolyzer.

$$\eta_{energy} = \frac{E_{useable}}{E_{input}} = \frac{E_{hydrogen}}{E_{electric}} = \frac{V_{H2} \times H_h}{V \times I \times t}$$

where,

H_h : Calorific value of hydrogen (also called "higher heating value") = 12.745 x 10^6 J/m^3
V_{H2}: produced volume of hydrogen in m^3
V: Voltage in volts
I: Current in Amps
t: time in seconds

Calculate the energy efficiency of the electrolyzer at t=92 seconds. (See Table 1) Be sure to use proper volume units, m^3.

$$\eta_{energy} =$$

A relationship between the current and the theoretical volume of gas produced can be obtained using Faraday's second law and the equation of state for an ideal gas. The Faraday efficiency of the fuel cell is obtained from the ratio of the calculated theoretical volume of gas to the volume actually consumed.

Faraday's second law states,

$$Q = I \times t = n \times z \times F$$

The equation of state for an ideal gas states,

$$p \times V = n \times R \times T$$

Combining the two formulas, the volume of gas can be calculated as follows,

$$V = \frac{R \times I \times T \times t}{F \times p \times z}$$

where,
V: theoretically produced volume gas in m^3
R: Universal gas constant = 8.314 J/mol x K
p: Ambient pressure in Pa (1 Pa = 1 N/m^2)
F: Faraday's constant = 96485 C/mol (1 C = 1 As)
T: Ambient temperature in K
I: Current in Amps
t: time in seconds
z: number of electrons to release one molecule

z (H_2) = 2 i.e. 2 mols of electrons are required to release 1 mol of hydrogen.
z(O_2) = 4

If an electrolyzer stack (several electrolyzers electrically connected in series) is used for this experiment, take into consideration that the current flows through each cell, i.e. each single electrolyzer produces a gas volume. These volumes add together to give the stack gas volume. Calculate the volume at t=92 sec.

$$V_{\text{Calculated}} = \frac{R \times I \times T \times t}{F \times p \times z}$$

$V_{\text{Calculated}}$ =_____________________________________-____cm^3

The Faraday efficiency is obtained from the following equation,

$$\eta_{Faraday} = \frac{V_{H2}(Produced)}{V_{H2}(calculated)} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

The volume of hydrogen produced in the experiment at t=92 sec is…

.

$V_{H2\ \text{produced}}$ =______________________________________cm^3

The Faraday efficiency is therefore,

$$\eta_{Faraday} = \frac{V_{H2}(Produced)}{V_{H2}(calculated)} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Disclaimer:
This laboratory experiment procedure may contain parts of various *PASCO Accessory Manuals* which are copyrighted and reserve all their rights. The permission for reproduction is granted to non-profit education institutions for reproduction of any part of *Accessory Manual* providing the reproductions are used only for their laboratories and are not sold for profit.

Hydrogen Fuel Cell Car POST Questionnaire

Student's name_______________________________________ Student ID______________________________

TO BE COMPLETED AND RETURNED TO TA AFTER COMPLETING THE EXPERIMENT

1. Typical units for measuring gas volume are meters cubed or m^3. Please convert 100 cm^3 into m^3.

    a. 100 cm^3 = 0.0001 m^3
    b. 100 cm^3 = 0.01 m^3
    c. 100 cm^3 = 1 m^3
    d. 100 cm^3 = 100 m^3
    e. 100 cm^3 = 10000 m^3

2. What is the difference between distilled water and tap water?
    a. distilled water is colorless when compared to tap water
    b. distilled water has no weight when compared to tap water
    c. distilled water has no smell when compared to tap water
    d. distilled water has no impurities when compared to tap water

3. What is the kinetic energy of 1kg object that is moving 5 m/sec?
    a. 0
    b. 1/5 J
    c. 2.5 J
    d. 5 J
    e. 10 J

4. Which gas has the simplest structure and the lightest when compared to other gasses?
    a. Hydrogen
    b. Helium
    c. Oxygen
    d. Nitrogen
    e. Neon

5. What happens during electrolysis?
    a. Chemical compounds are decomposed using electrical current.
    b. Chemical compounds are compressed using electrical current.
    c. Chemical compounds gain specific color.
    c. Chemical compounds are mixed together.