Experiment 11 – Introducing the Hydrogen Fuel Cell: Reversing the electrolytic process

Preliminary discussion

Fuel cells are highly efficient electrochemical electricity generators. The principle of the fuel cell is much simpler than that of conventional power generation, since it converts the energy storage directly into electrical energy. The basic principle behind the fuel cell is the direct generation of electricity using a fuel (e.g. hydrogen) and an oxidant (oxygen) in an array electrochemical process.

A fuel cell consists of two electrodes and the electrolyte. The anode is supplied with the fuel and the cathode with the oxidant. The electrolyte is in between and connects the two electrodes. The fuel is "oxidized" at the anode and electrons are released. The electrons released during this process flow via the attached external circuit to the cathode. Here the oxidant is "reduced" by absorbing electrons. The flow of electrons through the external circuit can be used to perform useful work. The charge transfer within a fuel cell is achieved by the movement of the ions through the electrolyte.

This reduction and oxidisation process is commonly abbreviated as a "redox" process. Reduction is the gain of electrons, whereas oxidisation is the loss of electrons.

Hence, like a battery, a fuel cell supplies energy from an electrochemical process. The essential difference is however, that the fuel cell cannot be discharged so long as fuel is being continuously supplied, usually from storage. Unlike a conventional power system which converts chemical energy from say, coal, into heat energy and then mechanical energy, into electrical energy, the fuel cell system converts the available chemical energy directly into electrical energy and some heat.

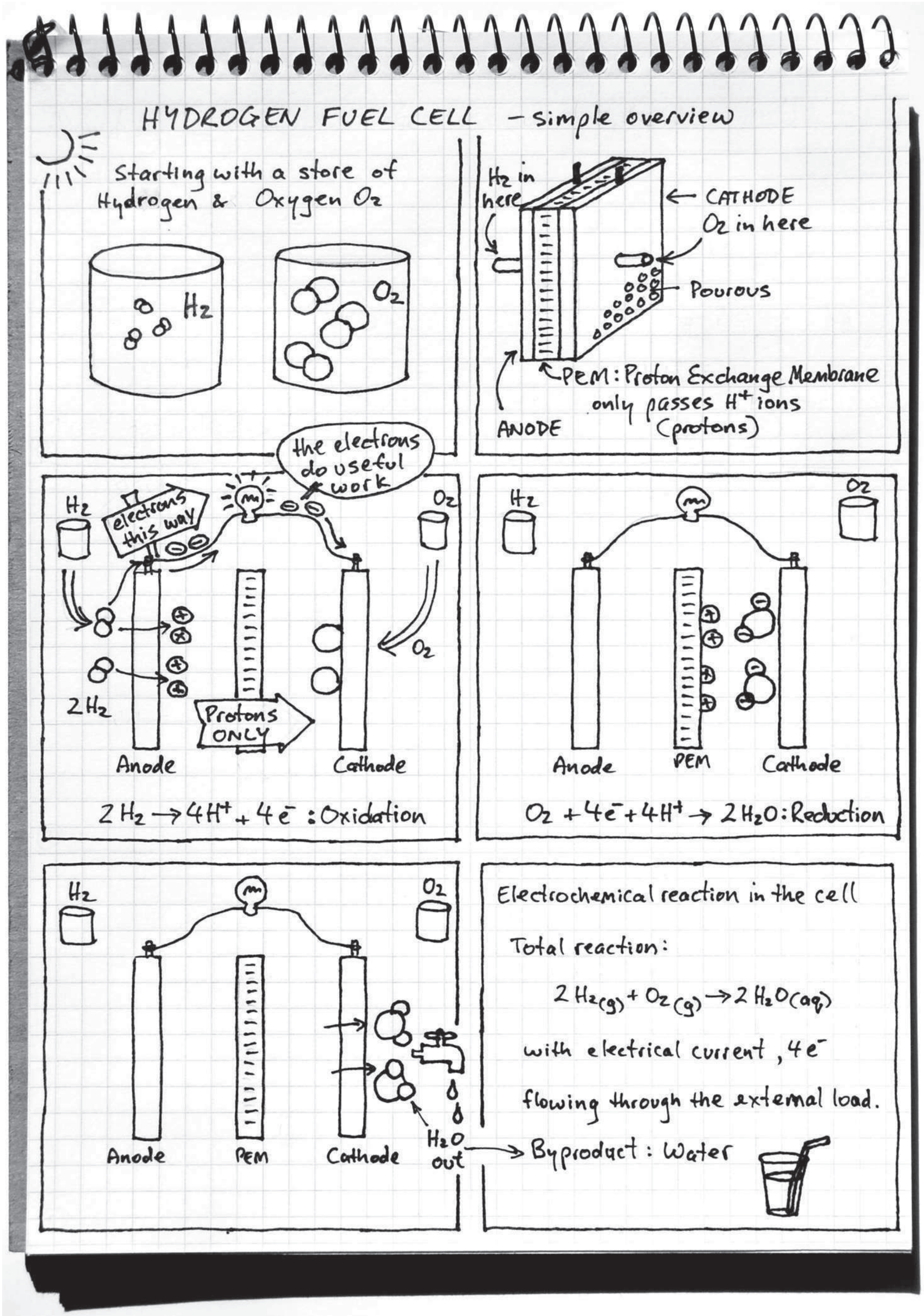

Figure 1: overview of fuel cell operation

The experiment
In this experiment we investigate how hydrogen and oxygen , the constituent parts of water can be recombined to form water again as well as a release of usable electrical energy. We examine how much electricity is generated in this process and get a hands-on appreciation of the work done by the catalytic converter in the fuel cell. As well we confirm the theoretical expectations of how much of each gas will be consumed and use these findings to confirm various scientific principles.

It should take you about 40 minutes to complete this experiment.

Pre-requisites:
You should have completed the introductory chapters 1 ,2,8,9,& 10 so that you're familiar with the equipment setup and capabilities.

Equipment

- PC with LabVIEW 8.5 (or higher)
- NI ELVIS 1, 2 or 2+ and USB cable to suit
- EMONA HELEx experimental add-in module
- Assorted patch leads
- Electrolyzer
- Distilled water
- Dismantlable PEM fuel cell

Procedure

Part A – Setting up the NI ELVIS/HELEx apparatus

1. Turn off the NI ELVIS unit **and** its Prototyping Board switch.

2. Plug the HELEx board into the base board, then the base board into the NI ELVIS unit. Lock it into place with the knurled knob on the HELEx board.

Note: This may already have been done for you.

3. Connect the NI ELVIS to the PC using the USB cable.

4. Turn on the PC (if not on already) and wait for it to fully boot up (so that it's ready to connect to external USB devices).

5. Turn on the NI ELVIS unit but not the Prototyping Board switch yet. You should observe the USB light turn on (top right corner of ELVIS unit).The PC may make a sound to indicate that the ELVIS unit has been detected if the speakers are activated.

6. Turn on the NI ELVIS Prototyping Board switch to power the HELEx board. Check that all three power LEDs are on. If not call the instructor for assistance.

7. Launch the HELEx Main VI.

8. If you're asked to select a device number, enter the number that corresponds with the NI ELVIS that you're using and restart the HELEx VI if necessary.

9. Set the HELEx module's PC CONTROL/MANUAL mode switch to the MANUAL position.

10. You're now ready to work with the NI ELVIS/HELEx bundle.

Note: To stop the HELEx VI when you've finished the experiment, it's preferable to use the STOP button on the HELEx SFP itself rather than the LabVIEW window STOP button at the top of the window. This will allow the program to conduct an orderly shutdown and close the various DAQmx channels it has opened.

Ask the instructor to check your work before continuing.

Safe operating guidelines to be followed at all times

Intended use:

This equipment is only to be used as directed in this Lab manual and User Manual and for experiments under the supervision of teaching staff.

All users must carefully read the User Manual to become familiar with the operation of this equipment before using this equipment and keep this information available with the equipment at all times.

This equipment may not be used with any other components other than what is supplied with the EMONA HELEx kit and is provided for teaching and demonstration purposes only.

This equipment may only be operated in accordance with local statutory regulations.

DOs – SAFE PRACTICES:

Always read and precisely follow the operating instructions. Ask your instructor if unsure at any time. The instructor is responsible for maintaining correct supervision at all times.
Always wear safety glasses when near the equipment in operation.
Always place the equipment safely at correct distances and with sufficient clear, flat and stable room around it.
Always work in well ventilated spaces with adequate clearance above and around the equipment.
Always fill or empty the electrolyser away from other equipment and over a sink.
Always work in a typical indoor environment of between 10 – 35 C

DONTs - WARNINGS:

Never have any sources of ignition near the equipment.
Never touch the lamp or solar cell when in operation or immediately after until confirming that it has cooled down sufficiently.
Never apply external components or equipment to the HELEx kit such as external power supplies or other apparatus or any signals other than those provided on the HELEx board itself.
Never allow hydrogen or oxygen to accumulate in quantities of more than 20 ml.
Never leave the equipment operating unattended.
Never use any liquid other than steam-distilled water with the electrolyser unit.
Never place the operating lamp closer than 30 cm from any surface.

DANGERS:

Hydrogen and oxygen are **highly flammable and explosive gases**. There is danger of explosion.

The lamp and solar cell will heat up to **high temperatures** and there is danger of skin burns if touched.

The lamp will cause surfaces to **overheat and burn** if placed closer than 30 cm whilst operating.

Avoid spilling the distilled water on any of the HELEx kit, especially the board itself and the NI ELVIS unit and power supply block, to avoid electrical hazards.

Avoid using the equipment if it shows any signs of damage or malfunction. Contact EMONA immediately for repair or replacement after referring to the User Manual for confirmation of correct specifications. There are no user-repairable parts in this kit.

Part B – Purging the system of air

11. Connect the experimental equipment as shown in the figure below.

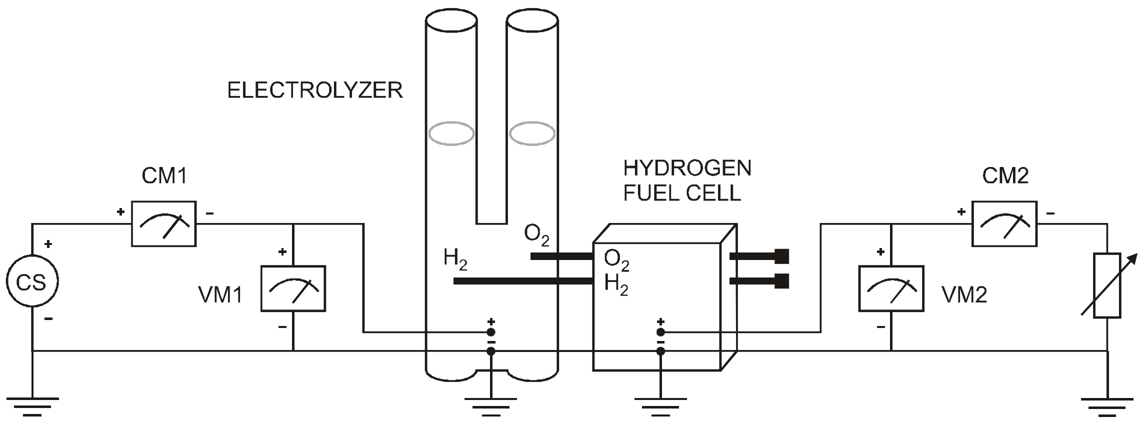

Figure 2: Current driven electrolyzer connected to the fuel cell, with measuring instruments

12. Set the load manually to OPEN CIRCUIT.

13. Fill both sides of the electrolyzer up to the 0 ml mark.

14. Turn on the current flow to the electrolyzer at the CURRENT SOURCE ON switch.

Note: You should see a constant release of gases in the electrolyzer.

15. Continue to release gases at this rate for 3 minutes, while leaving the fuel cell tubes unplugged.

Note 1: Use the TIMER on the HELEx SFP for this purpose.

Note 2: This activity purges the electrolyzer and fuel cell's connecting tubes of air by displacing it with O_2 and H_2 respectively.

16. Set the load manually to 4 Ohm and confirm that current and voltage are being generated.

Note: You should obtain readings other than 0 mA and 0V on CM1 and VM1.

17. Set the load back to OPEN CIRCUIT.

18. After 3 more minutes, turn the current to OFF to temporarily stop the electrolysis.

19. Insert the stoppers into the ends of the fuel cell outlet tubes at points A & B.

Ask the instructor to check
your work before continuing.

Part C - Building up storage of H_2 & O_2

20. Stop and reset the TIMER.

21. Turn the current source back ON and restart the TIMER.

Note 1: Check to make sure that gas is again being released in the electrolyzer.

Note 2: These gases are now being stored in the storage compartments of the electrolyzer. You'll be able to see this over time.

22. Keep the electrolyzer running until 10 ml of H_2 is created. Take these few minutes to read Part D in preparation.

Note: Don't let the electrolyzer create more than 10 ml of H_2.

23. Turn the current source to OFF when exactly 10 ml of H_2 is created and note the time taken in the table below.

Table 1: Time to produce 10ml of hydrogen

Vol H_2 (ml)	time (sec)

Question 1
Is the volume of O_2 created as expected? Explain your answer.

Ask the instructor to check
your work before continuing.

Part D - Consumption by the fuel cell

24. Stop and reset the TIMER to 0.

25. Read **both** of the next **two** steps before doing them so that you're prepared for the measurements that you need to take.

26. Set the load manually to 32 Ohm and restart the TIMER.

Note: The fuel cell will now commence consuming H_2 and O_2 at a higher rate in order to supply the load at its output. Remember, previous to this step the fuel cell had no load (that is, it was OPEN CIRCUIT).

27. Note the power being consumed by this load in Table 2 .

Table 2: load, VM2 and CM2

load (ohm)	VM2 (V)	CM2 (Vl)

28. Using the TIMER on the HELEx SFP, record the levels of H_2 and O_2 every time they reach a marked calibration line on the storage chambers. Also record the elapsed time when this happens.

Note: You can expect to be recording information at least every 0.5 or 1 ml marker level.

Table 3: time (s); O_2 (ml); and H_2 (ml)

time (s)	O_2 (ml)	H_2 (ml)

Ask the instructor to check your work before continuing.

29. When either the O_2 or the H_2 reach the 0 ml point, stop the fuel cell by setting the manual load to OPEN.

Question 2

Which one should reach the 0 ml mark first? Explain your answer

30. Select the "Expt 11" tab on the HELEx SFP.

31. Enter your measured values into the on-screen table and view the rate of consumption of each gas vs. time as a plot on-screen.

32. Take a screenshot or printout of these results for your report.

Note: Use the built-in LabVIEW function "export simplified image" to capture the graph. Right click on the graph to select this option.

Question 3
What can you say about the rate of consumption of each gas ?

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Question 4
Do you think the rate of consumption would change for a different load? Explain your answer.

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Ask the instructor to check
your work before continuing.

LabVIEW programming task

Write a program to display the ratios of H_2 to O_2, against an ideal ratio line of 2:1 to better evaluate the relationship between the volumes and rates of change of the different gases.