H-TEC EDUCATION

Operating Instructions

E105 - Quattro Electrolyzer

General Safety Precautions

- The electrolyzer module should only be set up and operated by a responsible supervisor.
- WARNING! Not suitable for children under 12 years old.
- Read the Operating Instructions before setting up the electrolyzer module. Follow the instructions provided in this document during use of electrolyzer module and keep them readily available for reference. If the operator is intending to use an electrolyzer module with H-TEC Education fuel cell module, read the Operating Instructions for both modules before starting any type of experiments.
- This equipment should only be used with other H-TEC Education products or accessories (such as H-TEC Education Fuel Cells, H-TEC Education Solar Modules, H-TEC Education battery box, or H-TEC Education plug-in power supply, etc.). It is strongly advised that the operator follow the manufacturer's instructions if he/she decides to use third party hardware such as standard bench-top DC power supply, etc. to ensure that the selected hardware is compatible, and operate the Quattro Electrolyzer module safely.
- Wear protective goggles.
- Equipment and gases should be used and stored out of the reach of small children.
- Plug-in power supplies can be dangerous - they are not toys!
- Disconnect the electrolyzer module from any plugin power supply or the solar module before cleaning.
- Unless instructed to the contrary by the manual, do not reverse or short-circuit the connecting terminals.
- The electrolyzer module must not be operated when empty. Always ensure that they contain sufficient deionized or distilled water. Pay attention to the water level marks on the storage tanks.
- Do not use tap water or any other water source that is ion-rich. Operation of this electrolyzer module with water sources other than deionized or distilled water will permanently damage the electrolyzer module.

General Safety Precautions

- Remove flammable gases, vapors, or liquids from the area surrounding electrolyzers. The catalytic materials used inside the electrolyzer module may cause spontaneous ignition.
- Hydrogen and oxygen may escape from the modules. Operate the electrolyzer module in well-ventilated rooms to ensure that the hydrogen and oxygen gases do not accumulate and form explosive mixtures.
- The electrolyzer module may only be operated in display cases if adequate ventilation is guaranteed under all circumstances. The operator is responsible for ensuring this.
- Remove anything from the vicinity of the electrolyzer module that could ignite the hydrogen gas exiting the cathode side of the electrolyzer (e.g. open flame, materials that can become charged with static electricity, substances with a catalytic action, etc.).
- Remove all substances from the vicinity of the electrolyzer module that could spontaneously ignite in increased oxygen concentration.
- Do not smoke in the vicinity of the electrolyzer module.
- Hoses, plugs, and storage tanks are used for pressure compensation. They must not be permanently fixed or secured with clamps, adhesive, etc. in an obstructive manner that may result in pressure build up inside the electrolyzer module or storage tanks.
- Only use the gas storage tanks associated with or supplied with the electrolyzer module. Never connect alternative gas storage tanks.
- The electrolyzer module should only be operated at room temperature and ambient pressure.
- If the electrolyzer module is to be operated with a solar module, then a minimum separation distances must be observed when using solar modules and artificial lights.
- WARNING! The surface of solar modules can get very hot during extended operation.
- Tell students about any potential dangers and carefully supervise experimentation.
- H-TEC Education accepts no responsibility for injuries or damage sustained in the event that these safety precautions are not followed.

Starting Up

Introduction

This PEM (Proton Exchange Membrane) electrolyzer module uses electricity to break down deionized or distilled water into hydrogen and oxygen gases electrochemically. Breaking down of water molecules to hydrogen and oxygen gases in this manner is also called water electrolysis.

During the electrolysis reaction, water molecules are split into **protons**, **O_2 gas**, and **electrons** at the anode side of the electrolyzer module.

Generated **protons** get transferred to the cathode side by traveling through the membrane due to the electrical gradient between anode and cathode.

Electrons, on the other hand, get transferred to the cathode side through the external electrical connection. Hydrogen gas is generated once the protons interact with the electrons at the cathode side of the electrolyzer module.

In the industry, electrolyzers are used for various applications. If the intended application is hydrogen gas generation to be stored for a later use, then only the hydrogen gas generated at the cathode is stored and the oxygen gas is usually vented out. If the intended application is for the oxygen gas generated at the anode side such as oxygen concentrator for home therapy use, then the user would consume the oxygen gas at the anode via an oxygen mask and bring ambient air to the cathode side and recombine the protons with oxygen molecules (present in the ambient air) and generate water for a later use (the water generated at the cathode can be recycled back to the anode for further oxygen generation).

Overview

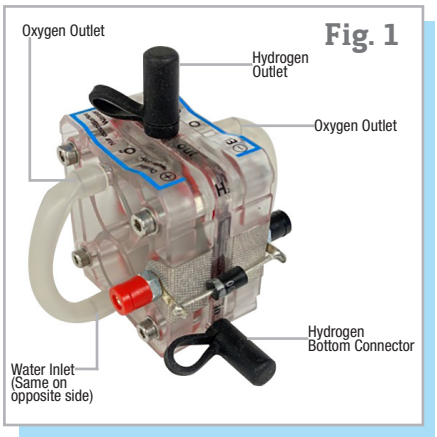

Fig. 1

Set Up

Fig. 2

1. Use four silicone tubes to connect the top and bottom connectors of the electrolyzer module to the corresponding connectors on the electrolyzer side of the gas storage tanks (Fig. 2).

Note:
If using the H-TEC Education Storage 30 the sides have been labeled “Electrolyzer” and “Fuel Cell / Reversible Fuel Cell”. The silicone tubing should be connected on the Electrolyzer side of the storage tanks.

Note:
If using the H-TEC Education Storage 30, ensure the black caps are open on the “Fuel Cell /Reversible Fuel Cell” side of the storage tanks.

2. Open the cap on the electrolyzer’s Hydrogen Outlet and connect a silicone tube (Fig. 3). Ensure that electrolyzer’s Hydrogen bottom connector is plugged with the cap that is attached to that port.

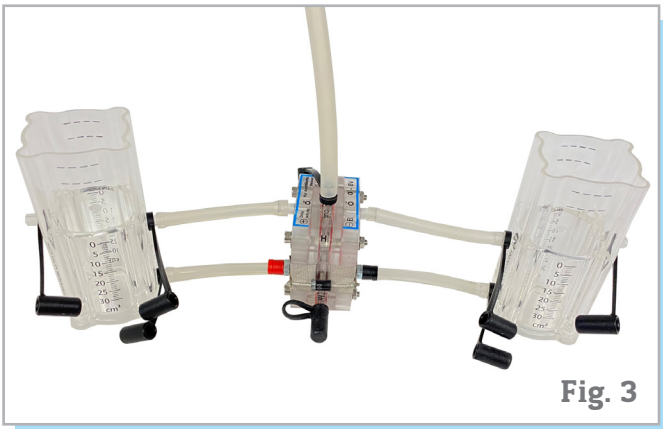

Fig. 3

3. Fill the storage tanks with deionized or distilled water ($\sigma < 2$ µS/cm) until water is coming out of the top connectors of the electrolyzer and travels into the tubing leading to the storage tanks.

Note:
The Quattro Electrolyzer requires both storage tanks to be filled with deionized or distilled water. ***Do not operate the Quattro Electrolyzer with only one storage tanks filled with water. Running one side of the electrolyzer dry will permanently damage the module.***

4. Attach another gas storage tank, or fuel cell module to the silicone tubing connected to the Hydrogen Outlet.

5. If you are intending to use the Oxygen that is generated by the Quattro Electrolyzer, connect silicone tubing to the Fuel Cell/Reversible Fuel Cell side of the storage tanks. You can join the two Oxygen outputs with a T- or Y-connector in order to combine the oxygen streams into a single output.

Note:
Do not pressurize any H-TEC Education modules. Any pressurization can create module failures or physical damages to the operator depending on the severity of the pressurization.

Operation

This PEM electrolyzer uses electricity to break down distilled water into hydrogen and oxygen. All H-TEC Education electrolyzer modules require the use of a DC power supply (e.g. H-TEC Education Solar Modules, H-TEC Education Power Supply, H-TEC Education Battery Box, or a DC Lab Power Supply) for their operation.

Electrolyzers can be operated in the constant voltage or constant current mode. Though, it is always suggested to operate an electrolyzer in the constant current mode in order to easily estimate the quantity of generated hydrogen or oxygen gases (1A of electricity would generate 28 mL/min of hydrogen gas and 14 ml/min oxygen gas for this product).

Note:
Do not connect an AC power supply to the Quattro Electrolyzer module. This will permanently damage the module.

Caution!
Note the maximum DC Voltage and Current allowed for the Quattro Electrolyzer: **0 - 8V and 0- 1.8 A**. DO NOT OPERATE THE ELECTROLYZER AT HIGHER VOLTAGE OR CURRENT THAN SPECIFIED. This will result in permanent damage.

1. Connect a DC power source to the Quattro Electrolyzer. When doing so ensure correct polarity (red = "+", black = "-") and observe the maximum permissible voltage.

2. The current breaks down the water into hydrogen and oxygen in a ratio of 2:1. The oxygen gases collect in the gas storage tanks and displaces the water there into the compensation tanks for Quattro Electrolyzer. Hydrogen gas does not go to storage tanks.

Creating an IV Curve (Using Lab Power Supply)

Note:
Use constant current mode.

1. Ensure that the DC power supply is turned on and the current and voltage values are set to zero.

2. Set the voltage value to 8V as the maximum value on the DC power supply. Then, put the DC power supply in the constant current mode.

Note:
Ensure that the current value is still set to 0 Amps.

3. Enable the power supply to provide electrical current to the electrolyzer module. Slowly increase the electrical current value during your test. Record your findings on Page 11. Plot the points to view the IV Curve (Fig. 4).

An example of current set points as follows in order to get a full IV curve: 0.00 A, 0.05 A, 0.10 A, 0.15 A, 0.20 A, 0.25 A, 0.30 A, 0.35 A, 0.40 A, 0.45 A, 0.50 A, 0.60 A, 0.70 A, 0.80 A, 0.90 A, 1.00 A, 1.20 A, 1.40 A, 1.60 A, and 1.80 A. Hold the electrolyzer module at each current set point for a few minutes and then record the electrolysis voltage.

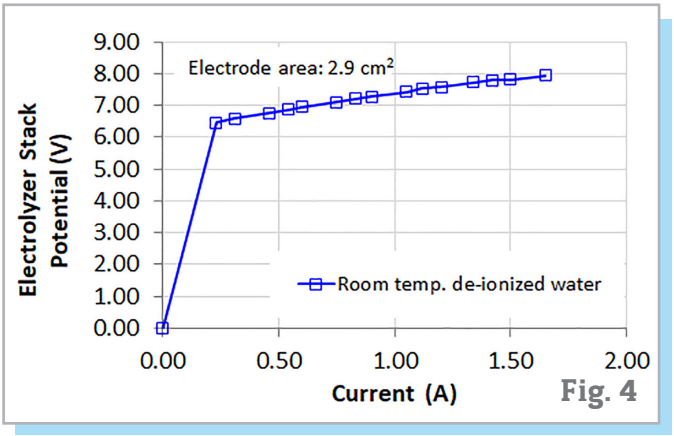

Fig. 4

Note:

The Quattro Electrolyzer module is designed to work with room temperature deionized or distilled water ($\sigma < 2$ µS/cm or 16-18 MΩ). This module can also be used with slightly warmed water as long as the water temperature is less than 45° Celsius. Depending on the temperature of the water, the observed voltage will vary.

The use of warmed water will reduce the electrolysis voltage. On the other hand, use of cooler water will increase the electrolysis voltage. With cooler water, such as 10° Celsius, an increase in the electrolysis voltage would be observed due to slower reaction kinetics compared to room temperature deionized water (which is usually around 24° Celsius), hence, 1.8 A of current will not be achieved because the stack voltage will reach to 8 V before the current reaches to 1.8 A. With warmed water, since the reaction kinetics are higher, a reduction will be observed in the electrolysis voltage.

Always run the electrolyzer with distilled or deionized water and do not allow it to freeze. Allowing the water to freeze inside the electrolyzer module will cause permanent damage.

Emptying the Storage Tanks

Remove the hoses from the oxygen collection ports of the storage tanks and hold the storage tanks over a collecting tray until they are completely empty.

Technical data

H_2 Production:	46 mL/min @ 1.65 A
O_2 Production:	23 mL/min @ 1.65 A
Standard operating current:	1.65 A
Standard operating voltage:	8 VDC
Maximum operating current:	1.8 A
Maximum operating voltage:	8.1 VDC
Electrode area:	2.9 cm^2
Guide value for distilled water:	<2 µS/cm
Permitted operating pressure:	0 - 20 mbar

Troubleshooting

The electrolyzer does not produce hydrogen when the DC power supply is connected:

Possible Cause:

- The DC power supply is not turned on or not enabled.

Solution:

- Ensure that the DC power supply is turned on or enabled. Follow the instructions provided in the manufacturer's user manual for the power supply.

Possible Cause:

- The electrical connections are not made correctly (correct polarity) between the power supply and electrolyzer module.

Solution:

- The electrolyzer module is being (or has been) operated in the reverse polarity. The cells inside the module are permanently damaged.

The electrolyzer was working in a previous test and now it does not produce hydrogen when the DC power supply is connected or it is operating at a lower performance after a previous operation:

Possible Cause:

- The electrolyzer module was accidentally operated with low water or operated dry towards the end of the previous run.

Solution:

- Ensure that there is plenty of water at the bottom section of the storage tanks throughout the entire experiment. Allow the electrolyzer to fully hydrate for a few hours and then try to re-create the full IV curve.

The electrolyzer does not produce hydrogen when the solar module is connected:

Possible Cause:

- The light intensity is insufficient.

Solution:

- Check the power specifications of the light source. You must have sufficient sunlight or a halogen lamp with focused light. Energy saving lamps, fluorescent tubes, etc. are not suitable for the operation of solar modules.

Possible Cause:

- The voltage output from the solar module is not sufficiently high (0 to 8 V).

Solution:

- Use the appropriate solar module that provides electrical energy with the following voltage and current characteristics: 0 to 8 V for the voltage and 0 to 1.8 A for the current. The minimum voltage for electrolysis for the stack is 5.6 V.

Maintenance

The electrolyzers we provide in our sets are maintenance-free. The following points should be observed, though:

- Use freshly distilled water for each operation.
- After operation, remove the water from the gas storage tanks.

Disposal

Do not dispose of fuel cells and electrolyzers as general household waste.

⚠ WARNING

Fire hazard from catalytic substances
The catalysts for the electrodes of fuel cells and electrolyzers promote burning when they come into contact with flammable substances.
Avoid contact with hydrogen, alcohol fumes or other organic fumes.
Ensure correct disposal.

According to European regulations, used electric and electronic devices may no longer be disposed of as unsorted household waste. The symbol of the crossed-out wheelie bin indicates the requirement for separate disposal.

Your local waste management company can provide you with additional information about disposal options.

Notes: IV Curve (Using Lab Power Supply)

Current I/A	Voltage U/V	Power P/W
0.00		
0.05		
0.10		
0.15		
0.20		
0.25		
0.30		
0.35		
0.40		
0.45		
0.50		
0.60		
0.70		
0.80		
0.90		
1.00		
1.10		
1.20		
1.30		
1.40		
1.50		
1.60		
1.70		
1.80		

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