Generation of electric energy using a PEM fuel cell

Task and equipment

Information for teachers

Additional information

All fuel cells fundamentally consist of two electrodes (cathode and anode) and an electrolyte which separates the two electrodes from each other. The mode of operation corresponds to a reversed electrolysis. Fuel cells are classified according to the type of electrolyte. Their working temperature, efficiency and application area, for example, are hereby given.
The PEM fuel cell (abbreviated as PEMFC, polymer electrolyte membrane fuel cell) requires neither acid nor alkali. The "waste product" of it is simply water. The electrolyte consists of a thin, proton-conducting membrane, the two sides of which are coated with a catalyst material. These sides act as the fuel cell cathode and anode.
The PEM fuel cell highly efficiently generates electric energy from hydrogen and oxygen (or from air). Such cells are in use, for example, as electric drives in cars and to supply power for houses. They can also serve as substitutes for disposable and rechargeable batteries, as hydrogen can be stored in many ways (in pressure tanks or stored as liquid-hydrogen or metal hydride).

Notes on the setup and procedure

The electrolyser and the fuel cell are differentiated by colour marking. The electrolyser is blue.
The maximum permissible values for the electrolyser are 2 V for the voltage and 2 A for the amperage.
Take care that the two openings on each side of the electrolysers are connected with tubing again at the end of the experiment, so that the membrane does not dry out. Refer here to Fig. 1 in Set-up.

Caution:
Do not apply a voltage to the fuel cell, as this would then be damaged beyond repair.
Use exclusively distilled water in experiments with the electrolyser and fuel cell as otherwise they will be damaged beyond repair.

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Task

How can hydrogen be used to drive a small electric motor?

In this experiment, the PEM fuel cell generates electric energy from hydrogen and oxygen, whereby the PEM electrolyser is used to produce the two gases.

Student's Sheet

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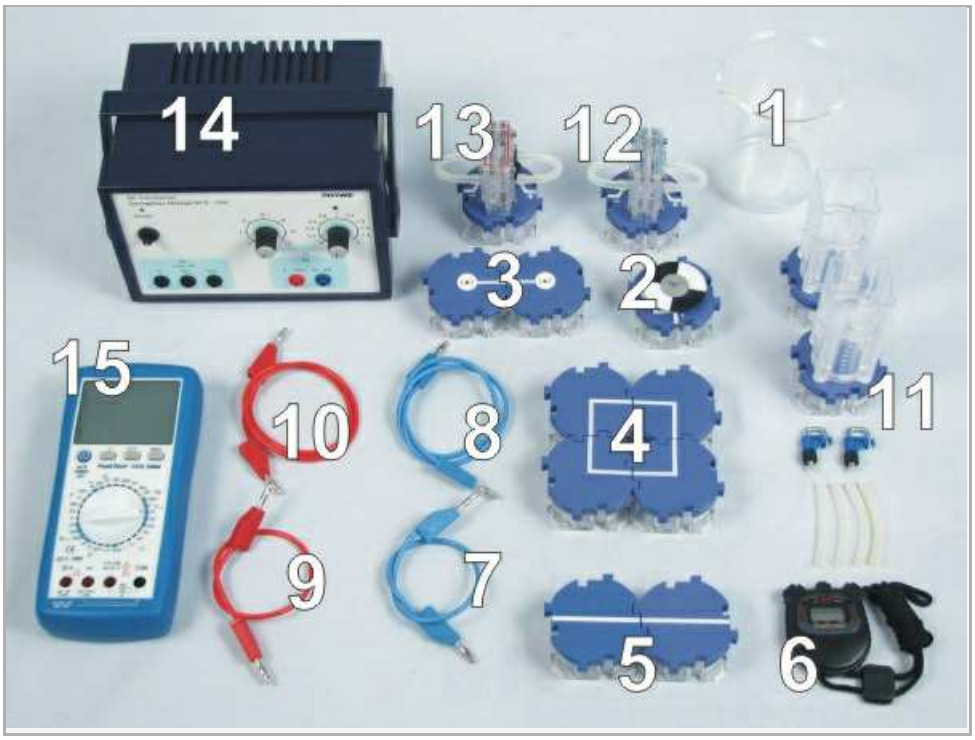
Equipment



Position No.	Material	Order No.	Quantity
1	Glass beaker DURAN®, short, 400 ml	36014-00	1
2	Motor with indicating disc, SB	05660-00	1
3	Junction module, SB	05601-10	2
4	Angled connector module, SB	05601-02	4
5	Straight connector module, SB	05601-01	2
6	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
7	Connecting cord, 32 A, 250 mm, blue	07360-04	1
8	Connecting cord, 32 A, 500 mm, blue	07361-04	1
9	Connecting cord, 32 A, 250 mm, red	07360-01	1
10	Connecting cord, 32 A, 500 mm, red	07361-01	1
11	Gas storage, SB, incl. tubes and plugs	05663-00	2
12	PEM electrolyser, SB	05662-00	1
13	PEM fuel cell for hydrogen/ oxygen operation and	05661-00	1
14	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
15	DMM with NiCr-Ni thermo couple	07122-00	1
Additional material			
	Distilled water		
	Protective glasses		

Set-up and procedure

Set-up



H: 220 / 270
P: 210 / 220

- Oxygen is a colourless, odourless and tasteless fire-promoting gas. It is a fire hazard on contact with combustible materials.
- Hydrogen is a colourless, odourless and tasteless combustible gas which easily forms explosive mixtures with air. All sources of ignition must therefore be removed prior to starting experiments which involve hydrogen.
- Wear protective glasses.

Setup

Plug the two junction modules, the two gas storages and the blue-marked electrolyser together as shown in Fig. 1.

Fig. 1

Connect both gas storages to the PEM electrolyser, each with two pieces of tubing.
Now connect a piece of tubing to the free end of each gas storage and use pinchcocks to close the pieces of tubing (Fig. 2).

Fig. 2

Set up the circuit for the fuel cell, motor and connecting modules as shown in Fig. 3.
Pay attention to polarity. Connect the positive side of the motor to the positive side of the fuel cell.

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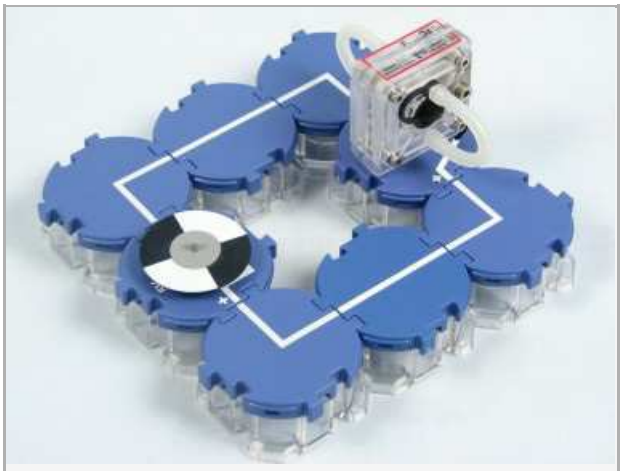

Fig. 3

Connect the two components as shown in Fig. 4.
Check the polarity of each component. The fuel cell, electrolyser and motor must have the same polarity on the left side, and the same polarity on the right side.
Turn the motor and the fuel cell round if necessary.

Fig. 4

Have about 150 ml of distilled water filled into your 400 ml glass beaker.
Use this water to fill each of the gas storages up to the lower mark from above (Fig. 5).

Caution:
Use only distilled water.

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Fig. 5

Open the pinchcocks while holding the free end of the tubing up high, so that water flows down into storage without spillage of water (Fig. 6).

Fig. 6

Remove the pinchcocks and connect the free tubing ends to the fuel cell (Fig. 7).
The two additional pieces of tubing are intended to prevent any emerging water from reaching the contacts.

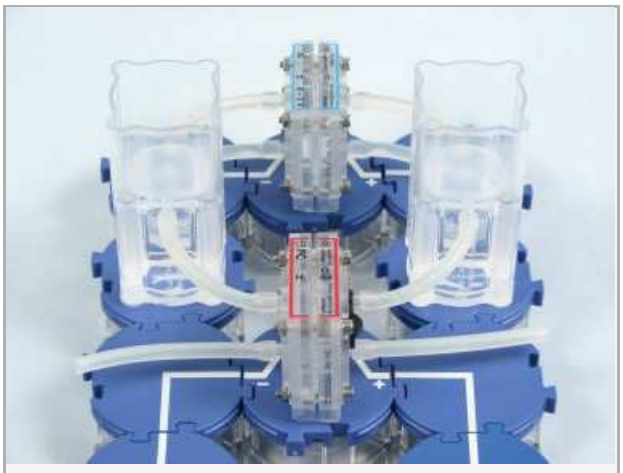

Fig. 7

Connect the junction modules to the direct voltage output of the power supply, with polarity according to that of the PEM electrolyser (Fig. 8).

Fig. 8

Switch a voltmeter in parallel to the power supply.
The power supply is in the switched-off condition (Fig. 9).

Fig. 9

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Procedure

Turn the power supply adjusting knob for voltage fully to the left, then the knob for the current to the right to 2 A. Switch the power supply on.
Set the voltmeter measurement range to 20 V-, then the power supply voltage to 2 V. Start the stop watch (Fig. 10).

Caution:
Higher voltages could damage the PEM electrolyser beyond repair.

Fig. 10

Note how long it takes for the motor to start under Result - Observations 1.

After one minute, turn the power supply adjusting knob for voltage fully to the left again and switch the power supply off.
Note how long the motor continues to run under Result - Observations 2.

When the motor is at a standstill, remove it and re-connect it again after about 10 seconds.
Note what you have observed under Result - Observations 3.

Note what can be seen in the fuel cell after the experiment under Result - Observations 4.

Emptying gas storage:
With the power supply switched off, remove the cable and the connecting modules. First ensure that the pinchcocks are closed, then grip the two gas storages, one in each hand. Do not remove the electrolyser. Lift up one gas storage above the beaker and tip the contents out over one corner into the beaker (Fig. 11).

Fig. 11

Cary out the same procedure with the other gas storage.

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Report: Generation of electric energy using a PEM fuel cell

Result - Observations 1

How long did it take for the motor to start?

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Result - Observations 2

How long did the motor keep running after the power supply was switched off?

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Result - Observations 3

What happened when you disconnected and re-connected the motor?

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Result - Observations 4

What did you see in the fuel cell?

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Evaluation - Question 1

Why did the motor not start right away?

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Evaluation - Question 2

What is produced in the fuel cell?

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Evaluation - Question 3

Why does the motor continue to run when the power supply is switched off and why does it slow down after some time?

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Evaluation - Question 4

Why does the motor run again briefly when it is disconnected and re-connected?

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Evaluation - Question 5

Compare the experimental set-up with that for a rechargeable battery. What is similar and what not?

Evaluation - Supplementary problem 1

How does a PEM fuel cell function?