The efficiency of an electrolyser – fuel cell system

Task and equipment

Information for teachers

Additional information

The use of hydrogen and oxygen for energy storage only makes sense when it functions with the lowest possible losses.

The use of hydrogen has the advantage that the energy required to produce it must not be brought by fossil fuels, but can also come from renewable energies. The production of it is then climatically neutral.

At times when the electric energy is not needed in the electric mains, it can be intermediately stored in the form of hydrogen and be converted back to electric energy later.

The use of fossil fuels is not climatically neutral, however. Combustion of them generally liberates CO_2, which is one of the climate-damaging greenhouse gases.

Notes on the setup and procedure

The electrolyser and the fuel cell are differentiated by colour marking. The electrolyser is marked blue, the fuel cell red.
The maximum permissible voltage for the electrolyser is 2 V and the maximum permissible current is 2 A.
Take care that the two openings on each side of the electrolyser are connected with tubing again at the end of the experiment otherwise the membrane will dry out. Refer here to Fig. 1 in Set-up.

Caution:
Use exclusively distilled water in experiments with the electrolyser and fuel cell to avoid them being damaged beyond repair.

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Task

Does it make sense to use hydrogen for electric energy?

In this experiment, an examination is to be made on the efficiency of an electrolyser - fuel cell system and consequently on the total efficiency of the chain from generation to usage of the hydrogen and oxygen.

Equipment

Position No.	Material	Order No.	Quantity
1	Connecting cord, 32 A, 500 mm, red	07361-01	2
2	Connecting cord, 32 A, 500 mm, blue	07361-04	2
3	Connecting cord, 32 A, 250 mm, red	07360-01	2
4	Connecting cord, 32 A, 250 mm, blue	07360-04	1
5	Angled connector module, SB	05601-02	3
6	Junction module, SB	05601-10	4
7	Interrupted connector module, SB	05601-04	1
8	Straight connector module, SB	05601-01	2
9	Glass beaker DURAN®, short, 400 ml	36014-00	1
10	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
11	Gas storage, SB, incl. tubes and plugs	05663-00	2
12	PEM fuel cell for hydrogen/ oxygen operation and	05661-00	1
13	PEM electrolyser, SB	05662-00	1
14	Potentiometer module 250 Ohm, SB	05623-25	1
15	DMM with NiCr-Ni thermo couple	07122-00	2
16	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	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 PEM electrolyser together as shown in Fig. 1.

Fig. 1

Connect both gas storages to the PEM electrolyser, each with two pieces of tubing.

Also fit a piece of tubing to each of the gas storage ends that are still free and clamp each with a pinchcock (Fig. 2).

Fig. 2

Set up the circuit with fuel cell, potentiometer and connecting modules as shown in Fig. 3.

Connect the two circuit elements.

Check the polarity of the individual circuit elements. The left of the fuel cell and the left of the electrolyser must have the same polarity, the right of each also.

Turn the fuel cell round if necessary.

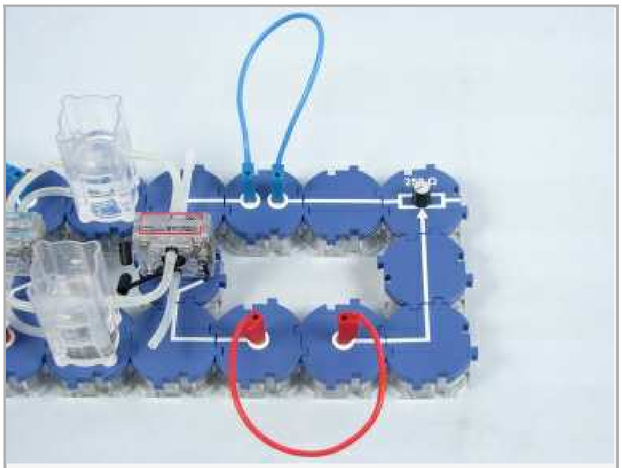

Fig. 3

Have about 150 ml of distilled water filled into your 400 ml glass beaker.

Use this water to fill both gas storages up to their lower mark from above (Fig. 4).

Caution:

Use distilled water only!

Fig. 4

Open the pinchcocks while holding the free end of the tubing up a little, so that water flows down into storage without spillage of water (Fig. 5).

Fig. 5

Remove the pinchcocks and close the free tubing ends at the fuel cell (Fig. 6).

The additional pieces of tubing are needed to prevent any water that emerges from reaching the contacts.

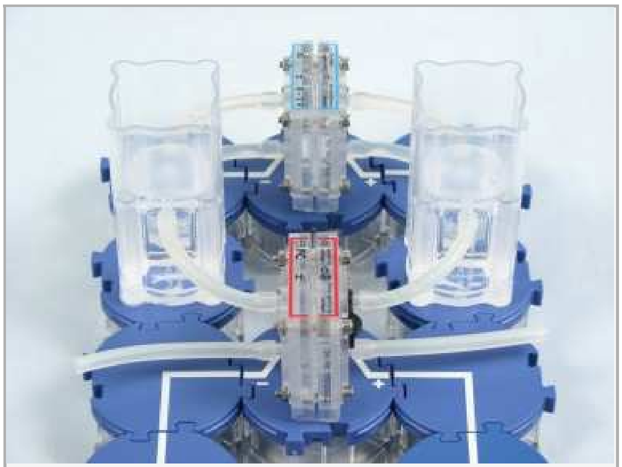

Fig. 6

For the measurement of voltage and current in the electrolyser circuit, connect an ammeter in series with the power supply (Fig. 7) and a voltmeter in parallel with the electrolyser (Fig. 8).

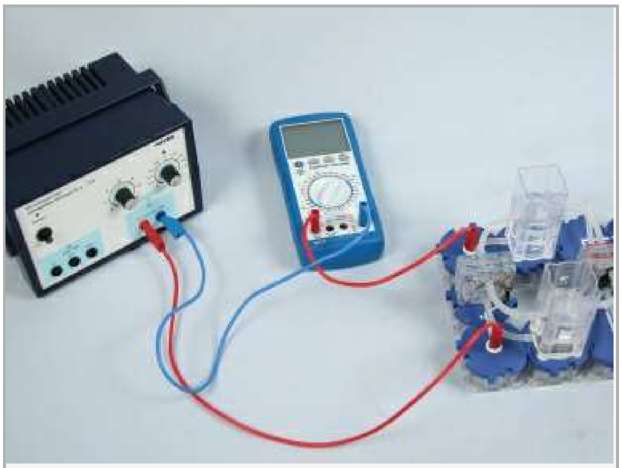

Fig. 7

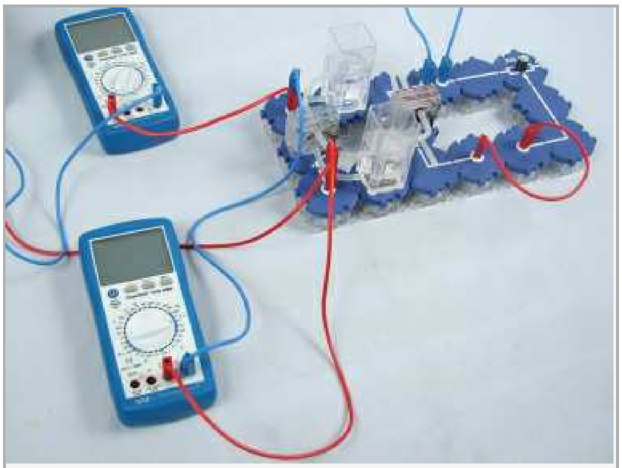

Fig. 8

Set the voltmeter to the 20 V- measurement range and the ammeter to 20 A-.

The power supply is switched off.

Procedure

Set the voltage U at 2 V and turn the current adjusting knob fully clockwise to 2 A.

Switch the power supply on.

Allow the electrolyser to operate for about three minutes so that the air still in the system can escape through the fuel cell.

Remove the tubing from the lower opening of the PEM fuel cell and close it with the stopper so that no further gas can escape (Fig. 10).

Fig. 10

Start the stop watch when the gas volume in the hydrogen gas storage reaches 10 cm^3 and note the amperage and the voltage in Table 1. Note the time taken for the gas volume to reach 25 cm^3 in Table 1.

Switch the power supply off when the gas volume in the hydrogen gas storage reaches about 30 cm^3. Use the pinchcocks to close the pieces of tubing connecting the electrolyser to the hydrogen gas storage (Fig. 11).

Fig. 11

Change the set-up so that you can measure current *I* (Fig. 12) and voltage *U* (Fig. 13) at the fuel cell.

Fig. 12

Fig. 13

Turn the adjusting knob of the potentiometer for resistance to bring the voltage *U* to about 0.35 V.

Wait until the gas volume in the hydrogen gas storage reaches 25 cm^3 and start the stop watch. Determine the fuel cell voltage and current values and enter them in Table 1 until the gas volume is only 10 cm^3.

After ending measurement, close the fuel cell with the previously-removed tubing.

Empty gas storage:

With the power supply turned off, remove the cable and connecting modules. Ensure that the pinchcocks are closed. Now 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. 15).

Fig. 15

Carry out the same procedure with the other gas storage.

Report: The efficiency of an electrolyser – fuel cell system

Result - Table 1

Record your measured values in the table.

Calculate the corresponding electrolyser and fuel cell powers and energies from the measurements in Table 1 and enter them in the table.

E = P · t

E = Energy in Ws

P = Power in W

t = Time in s

Device	*U* in V	*I* in A	*P* in W	*t* in s	*E* in Ws
Elektrolyser	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0
Fuel cell	1 ±0	1 ±0	1 ±0	1 ±0	1 ±0

Evaluation - Question 1

Calculate the η_{total} efficiency of the electrolyser - fuel cell system.

$$\eta total = \frac{E_{fuel\ cell}}{E_{electrolyser}}$$

η_{total} = ...%

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Evaluation - Question 2

The efficiency of the action chain from crude oil via petrol to a normal internal combustion engine is about 20 %. Compare the calculated value for the total efficiency of the electrolyser - fuel cell system to that of crude oil.

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Evaluation - Supplementary problem 1

Because of the consumption of fossil fuels, the raw material price for crude oil will rise in the near future. Which advantage does the use of the electrolyser - fuel cell systems offer?

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