Faradic efficiency and energetic efficiency of a PEM electrolyser

Task and equipment

Information for teachers

Additional information

The efficiency of an electrolyser is an indicator of the efficiency of energy conversion. A differentiation is made here between energetic and faradic efficiencies.

When a new technology is developed, it is important that it can be economically utilized. If the efficiency is low, then there is no sense in bringing it to market.

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 electrolyser 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.
The amounts of gas and water in the gas storages can vary according to the filling accuracy. Make sure that the gas storages are completely filled with water.

Caution:
Use exclusively distilled water in experiments involving the electrolyser otherwise it will be damaged beyond repair.

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Task

How efficient is gas production in an electrolyser?

Different efficiencies of the electrolyser are examined in this experiment.

Equipment

Position No.	Material	Order No.	Quantity
1	Connecting cord, 32 A, 500 mm, red	07361-01	2
2	Connecting cord, 32 A, 250 mm, blue	07360-04	2
3	Connecting cord, 32 A, 500 mm, blue	07361-04	1
4	Junction module, SB	05601-10	2
5	Glass beaker DURAN®, short, 400 ml	36014-00	1
6	Digital stop watch, 24 h, 1/100 s & 1 s	24025-00	1
7	Lab thermometer,-10..+100 °C	38056-00	1
8	Gas storage, SB, incl. tubes and plugs	05663-00	2
9	PEM electrolyser, SB	05662-00	1
10	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
11	DMM with NiCr-Ni thermo couple	07122-00	2
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 PM electrolyser together as shown in Fig. 1.

Fig. 1

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

Fig. 2

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 upper mark from above (Fig. 3).

Caution:
Only use destilled water.

Fig. 3

Open the pinchcocks while holding the free end of the tubing high up, so that water flows down into storage without spillage (Fig. 4). Make sure that the gas storages are completely filled with water.

Fig. 4

Close the pinchcocks again.

Connect the junction modules to the direct voltage outlets of the power supply according to the shown polarity at the PEM electrolyser. A multimeter for current measurement (ammeter) must also be connected in series with the electrolyser (Figs. 5 and 6).
The power supply is in the switched off position.

Fig. 5

Fig. 6

Additionally connect the multimeter for voltage measurement (voltmeter) in parallel with the PEM electrolyser (Figs. 7 and 8).

Fig. 7

Fig. 8

Set the ammeter to the 20 A- measurement range and the voltmeter to the 20 V- measurement range. Make sure that you use the 20 A socket when you connect the cable to the ammeter.

Procedure

Turn the power supply adjusting knob fully anticlockwise.

Switch the power supply on. Turn the adjusting knob for current fully clockwise to 2 A.

Set the voltage (*U*) to 2 V and let the electrolyser run for about a minute.

Turn the adjusting knob for current (*I*) back to 0 A. Open the pinchcocks to allow the gas that has been produced to escape.

Close the pinchcocks. Quickly turn the current to 2 A and simultaneously start the stop watch and note the values of the voltage and the current in Table 1 at V = 0 cm^3.

Note further values of the voltage and the current in Table 1 after each additional production of 5 cm^3 of hydrogen until the gas storage is completely filled.

Also use the thermometer to measure the ambient temperature and note the value obtained.

Empty gas storage:
With the power supply switched off, remove the cable and junction modules. Make sure that the hose clips 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. 9).

Fig. 9

Carry out the same procedure with the second gas storage.

Report: Faradic efficiency and energetic efficiency of a PEM electrolyser

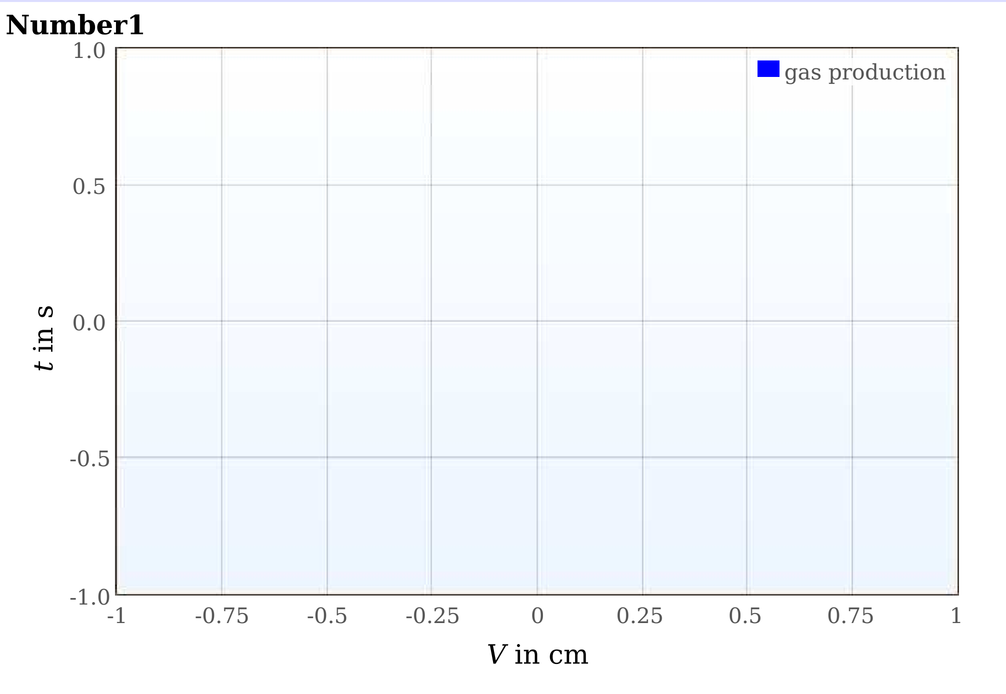
Result - Observations

Ambient temperature: T_C = ... °C

Result - Table 1

Record the measured values in the table.

V in cm^3	*t* in s	*U* in V	*I* in A	*P* in W
0	1 ±0	1 ±0	1 ±0	1 ±0
5	1 ±0	1 ±0	1 ±0	1 ±0
10	1 ±0	1 ±0	1 ±0	1 ±0
15	1 ±0	1 ±0	1 ±0	1 ±0
20	1 ±0	1 ±0	1 ±0	1 ±0
25	1 ±0	1 ±0	1 ±0	1 ±0
30	1 ±0	1 ±0	1 ±0	1 ±0



Evaluation - Question 1

Use the measured values in Table 1 to calculate the corresponding power and enter the values found in Table 1.

Also convert the value for the room temperature to Kelvin:

$T_K \approx T_C + 273 =$ .... K

Evaluation - Question 2

Describe the gas production over time shown by the plot in the graph of Table 1.

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Evaluation - Question 3

Calculate the energetic efficiency

The energetic efficiency describes the ratio of the actual useful energy to the energy supplied. The useful energy is in this case the energy used by the electrolyser for gas production.

Calculate the energetic efficiency as given. What does this tell you?

$$\eta_{energetic} = \frac{E_{usable}}{E_{sup\,plied}} = \frac{E_{hydrogen}}{E_{electrical}} = \frac{V_{H_2} \cdot H_0}{\bar{P} \cdot t}$$

$E = \text{energy}$

$\eta = \text{efficiency}$

$H_0 = \text{heating value of hydrogen} = 12{,}745 \cdot 10^6 \ \frac{J}{m^3}$

$V_{H_2} = \text{generated volume of hydrogen in } m^3$

$\bar{P} = \text{mean power of the electrolyzer}$

$t = \text{time in s}$

Evaluation - Question 4

Why is the energetic efficiency of the PEM electrolyser not 100 %?

Evaluation - Question 5

Calculate the faradic efficiency

The faradic efficiency describes the ratio of the energy supplied to the electrolyser and the actual volume of gas generated.

Faraday's second Law of Electrolysis is

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

and the ideal gas law

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

lead to the conclusion:

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

Have the faradic efficiency calculated now.

The faradic efficiency can now be calculated:

$$\eta_{Faraday} = \frac{V_{H_2}(\text{calculated})}{V_{H_2}(\text{used})}$$

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Evaluation - Question 6

Why is the faradic efficiency distinctly higher than the energetic efficiency?

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Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com