

Determining the Faraday constant

Objects of the experiments

- Producing hydrogen by means of electrolysis and measuring the volume V of the hydrogen.
- Measuring the electrical work W required at a fixed voltage U_0 .
- Calculating the Faraday constant F .

Principles

In electrolysis, current flow is accompanied by chemical deposition. The quantity of substance deposited is proportional to the charge Q which has flowed through the electrolyte. The charge transported can be calculated with the help of the Faraday constant F . This universal constant is related to the elementary charge e via the Avogadro number N_A :

$$F = N_A \cdot e \quad (I).$$

This means, the Faraday constant F is the charge quantity of 1 mole of electrons.

Inserting the number of moles n for the quantity of substance deposited and taking into account the valence z of the ions deposited, one obtains the relation that determines the charge transported:

$$Q = n \cdot F \cdot z \quad (II).$$

In this experiment, the Faraday constant is determined by producing a certain quantity of hydrogen by means of electrolysis. The hydrogen gas formed in the electrolysis is collected at an external pressure p and a room temperature T . Then its volume V is measured. The number of moles n_1 of hydrogen molecules produced is calculated with the ideal gas equation:

$$n_1 = \frac{pV}{RT} \quad (III)$$

with $R = 8.314 \frac{\text{J}}{\text{mole} \cdot \text{K}}$ (general gas constant)

Each H^+ ion is neutralized by an electron from the electrolytic current, that is, the valence z of hydrogen ions is equal to 1. 1 mole of H^+ ions thus acquires 1 mole of electrons in the process of neutralization, and for the production of 1 mole of H_2 2 moles of electrons are required. The number of moles n_1 of hydrogen atoms produced therefore corresponds to the number of moles

$$n = 2 \cdot \frac{pV}{RT} \quad (IV)$$

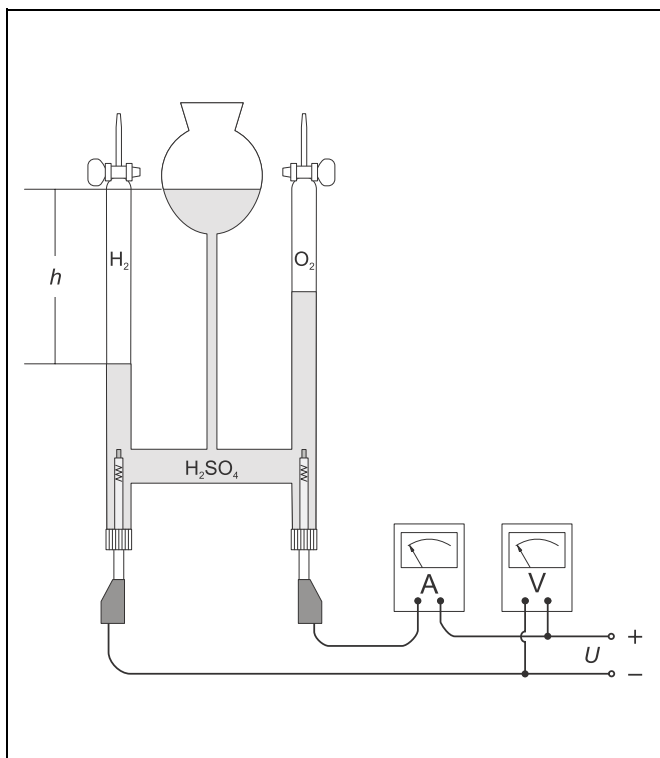
of electrons required.

At the same time the electrical work W that is accomplished in the electrolysis is measured at a constant voltage U_0 . The charge quantity to be determined is then

$$Q = \frac{W}{U_0} \quad (V),$$

and the Faraday constant is, according to Eqs. (II), (IV) and (V),

$$F = \frac{1}{2} \cdot \frac{W \cdot R \cdot T}{U_0 \cdot p \cdot V} \quad (VI).$$



Apparatus

1 water electrolysis unit	664 350
1 tray, 6 × 5 RE	649 45
1 joule- and wattmeter	531 83
1 DC power supply 0 ... ± 15 V	521 45
1 voltmeter, DC, $U \leq 30$ V e.g.	531 100
1 thermometer, -10 °C to + 40 °C	382 36
Sulphuric acid, diluted, 500 ml	674 492
Connection leads	

Setup

Remark: The water electrolysis unit may remain filled after the experiment is over so that it is immediately available for another experiment.

The experimental setup is illustrated in Fig. 1.

Water electrolysis unit:

- Set the water electrolysis unit up according to the instruction sheet (666 446), and put it on the tray.
- Raise the middle of the levelling bottle (**a**) to the height of the gas cocks (**b**), and open the two gas cocks.
- Fill diluted sulphuric acid (approx. 1 mol/l) into the levelling bottle until the liquid level reaches the gas cocks.
- Close the two gas cocks.

Electrical wiring:

- Connect the positive and the negative pole of the DC power supply to the pair of sockets (**c**) of the joule- and wattmeter, and connect the voltmeter parallel (measuring range: 30 V-).
- Connect the electrodes of the water electrolysis unit to the pair of sockets (**d**) of the joule- and wattmeter.

Carrying out the experiment**Preparing the water electrolysis unit.**

In order to saturate the liquid with gas:

- Switch the DC power supply on, set the voltage U_0 to 30 V (between the positive and the negative pole of the power supply), and allow the electrolysis to run for about 5 minutes.
- Switch the voltage U_0 off.
- Cautiously open the two gas cocks. Then raise the level of the acid immediately below the height of the gas cocks by lifting the levelling bottle.
- Close the two gas cocks.

Joule- and wattmeter:

- Switch the joule- and wattmeter on, and allow it to warm up for 15 minutes.
- Set the time constant to 1 s, the current measuring range to 1 A, the voltage measuring range to 30 V and the function selector switch to “Ws”.

Offset compensation:

- Set the control switch to “Reset”, then to “Run”.
- Stabilize the display with the zero adjuster.
- Set the control switch to “Reset” again.

Safety note

Because of the low conductivity of distilled water, diluted sulphuric acid of a concentration of 1 mole/l is used for the electrolysis of water. Diluted sulphuric acid irritates the eyes and the skin.

- When the eyes get into contact with sulphuric acid, thoroughly rinse immediately and consult a doctor.

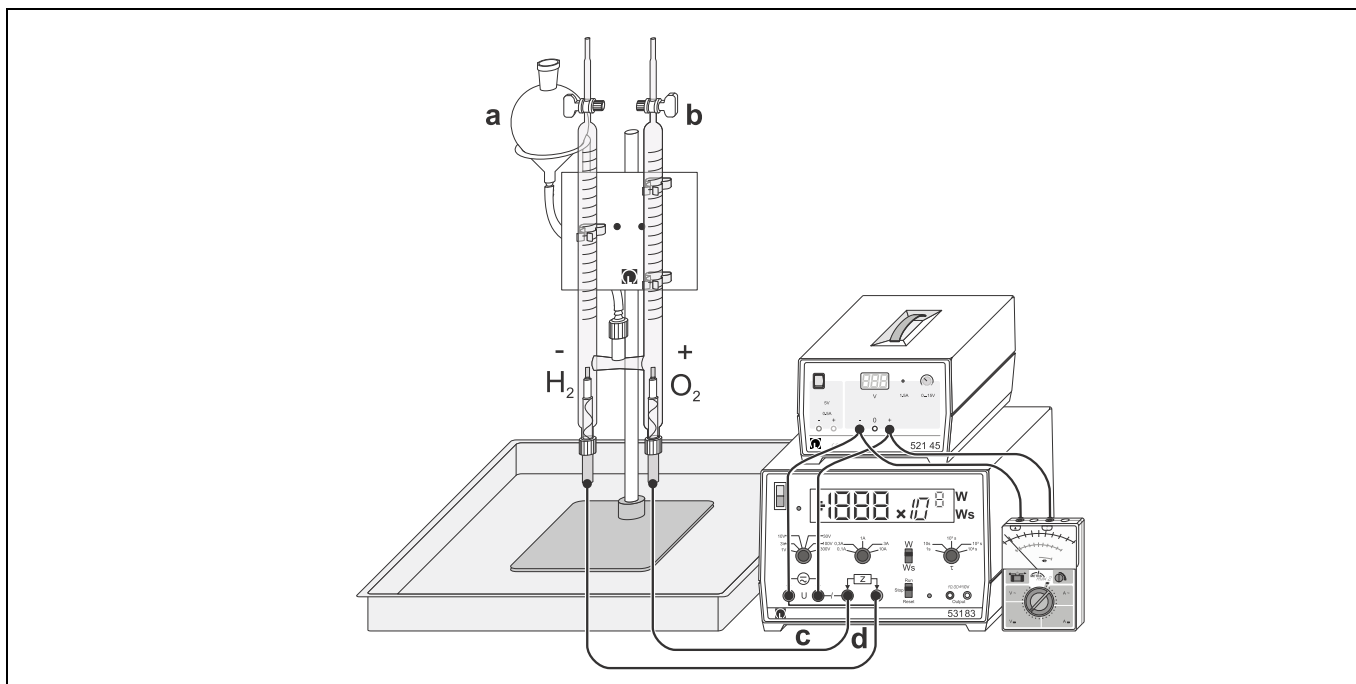


Fig. 1 Experimental setup for determining the Faraday constant with the water electrolysis unit.

Measurement:

- Set the voltage U_0 to 30 V.
- Observe the generation of gas at the H_2 leg (negative pole) of the water electrolysis unit. Continuously shift the levelling bottle downward so that the liquid level in the levelling bottle and the H_2 leg always have the same height.

As soon as the liquid level has reached the 5-ml mark:

- Set the control switch of the joule- and wattmeter to "Run".

As soon as the liquid level reaches the 25-ml mark:

- Switch U_0 off, and read the electrical work W from the joule- and wattmeter.
- Measure the room temperature ϑ , and take it down together with the pressure p .

Supplementary information

Systematic errors occur mainly because of oxygen and other gases dissolving in the electrolyte, gas bubbles adhering to glass walls and rises in temperature of the electrolyte and the gas due to the current flow.

Part of the atomic oxygen deposited during the electrolysis undergoes a reaction and forms sulphuric per-acid. Therefore, the quantity of oxygen collected is somewhat smaller than the quantity of oxygen liberated. That's why the evaluation is based on the quantity of hydrogen.

Measuring example

$$V_1 = 5 \text{ cm}^3, V_2 = 25 \text{ cm}^3, \vartheta = 22 \text{ }^\circ\text{C}, p = 1010 \text{ hPa}$$

$$U_0 = 30.0 \text{ V}, W = 4.65 \cdot 10^3 \text{ Ws}$$

Evaluation and results

$$V = V_2 - V_1 = 20 \text{ cm}^3, T = \vartheta + 273 \text{ K} = 295 \text{ K}$$

$$\text{Inserting the values into Eq. (VI) leads to: } F = 94000 \frac{\text{As}}{\text{mole}}$$

$$\text{Value quoted in the literature: } F = 96485 \frac{\text{As}}{\text{mole}}$$

