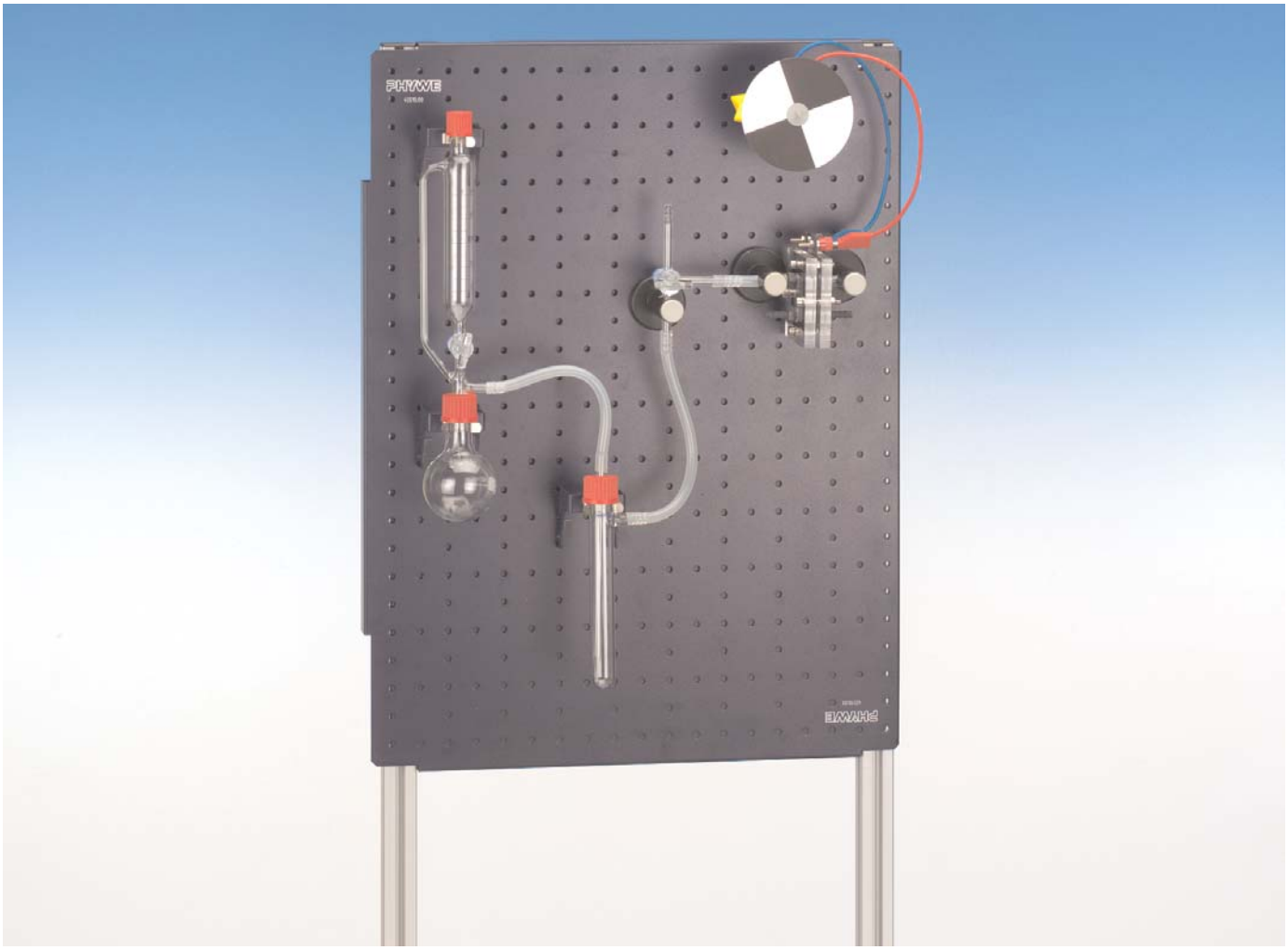
Materials

Frame for complete experiments	45500.00	1
Rear cover for complete experiment panel	45501.00	1
Panel for complete experimental set-ups	45510.00	1
Clamping holder, d = 0...13 mm, on fixing magnet	02151.07	3
Clamp on fixing magnet	02151.01	1
Clamping holder, d = 18...25 mm	45520.00	3
Spring plugs, 50 pieces	45530.00	1
G-clamp	02014.00	2
Round bottom flask, short necked, DURAN, 100 ml, GL 25/12	35841.15	1
Funnel for gas generator, GL 18, 50 ml	35854.15	1
Test tube, DURAN, with hose connection, GL 25/8, 22 x 180 mm	36330.15	1
Glass tube, straight with tip, l = 200 mm	36701.63	1
Glass stopcock, T-shaped	36731.00	1
PEM fuel cell kit, dismountable	06746.00	1
Motor, 2 V-	11031.00	1
Disc for motor, 2 V-	11031.01	1
Connecting cable, 4 mm plug, 32 A, red, 25 cm	07360.01	1
Connecting cable, 4 mm plug, 32 A, blue, 25 cm	07360.04	1
Silicone tubing, d = 6 mm	47530.00	1
Silicone tubing, d = 4 mm	47529.00	1
Funnel, glass, d = 80 mm	34459.00	1
Hydrochloric acid, 10%, 1 l	31821.70	1
Zinc, granulated, 500 g	31977.50	1
Glycerol, 99%, 100 ml	30084.10	1
Water, distilled, 5 l	31246.81	1

Safety measures

Dilute hydrochloric acid is highly corrosive to skin and eyes. Vapours irritate respiratory organs, in particular the mucous membranes of the upper respiratory organs. In contact with metals it can form gaseous hydrogen (danger of explosion!).
Do not inhale vapours or dusts. Avoid contact with eyes and skin. Wear suitable protective clothing, protective gloves and protective goggles when working with it.
Observe the detailed information on safety measures in the appendix.

Fig. 1



PEM fuel cell

Set-up

Position the clamping holders on the panel for complete experiments as shown in Fig. 2. Assemble the equipment as shown in Fig. 1. and fix it to the clamping holders.
Pour about 25 ml of hydrochloric acid in the dropping funnel, and place 4 to 6 zinc granules in the 100 ml round bottom flask. To keep any acidic vapours away from the fuel cell membrane, fill the side-arm test tube about one third full with distilled water. With the glass tube inserted in it from above, it acts as a wash bottle.

Procedure

To begin the experiment, slowly drop acid onto the zinc granules. For a little while to start with, position the stopcock so that the gas evolved can escape. Then turn the stopcock to a position that allows the flow of hydrogen to reach the fuel cell. As soon as the motor is running and the disc rotates, stop the reaction by closing the tap of the constant pressure gas generator.
Detailed instructions on the use of the fuel cell are supplied with it.

Results

On adding acid to the zinc granules, a colourless gas is evolved. This bubbles through the water in the test tube that is used as wash bottle and drives the motor on contact with the fuel cell.

Explanation

The colourless gas is hydrogen:

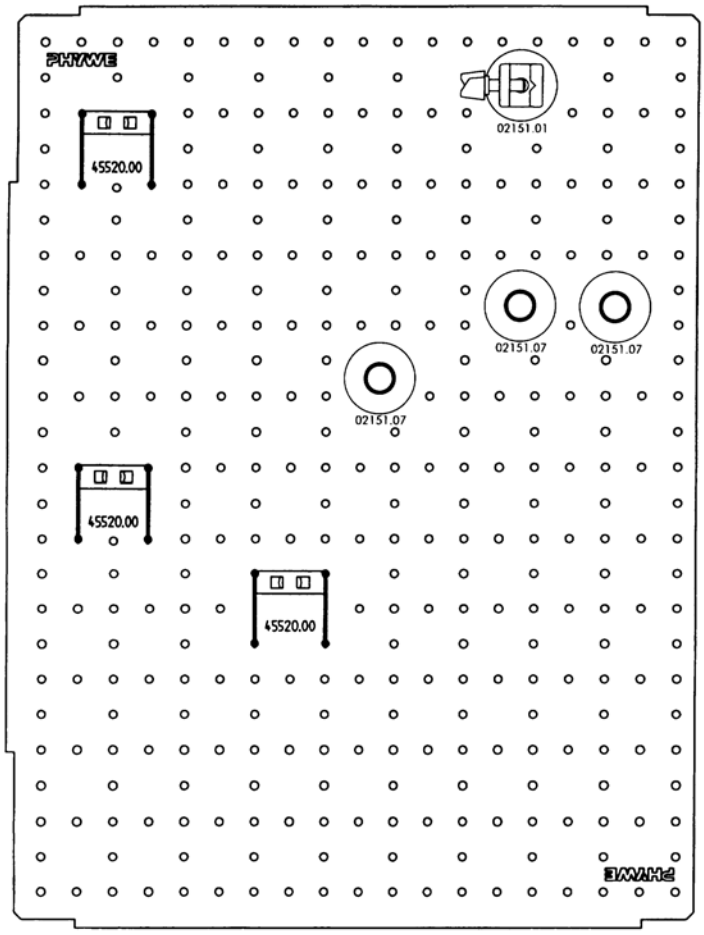
$$Zn + 2\,H^+ \rightarrow Zn^{2+} + H_2$$

The reaction of hydrogen with oxygen to form water serves as source of energy for the fuel cell:

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

The oxygen required is taken from the air. This reaches the fuel cell through the open nipple on the side opposite to the one where the hydrogen enters the cell.

Fig. 2



The following partial reaction takes place on the membrane surface:
Anode reaction (oxidation, negative pole):

$$H_2 \rightarrow 2\,H^+ + 2\,e^-$$

Cathode reaction (reduction, positive pole):

$$O_2 + 4\,e^- + 4\,H^+ \rightarrow 2\,H_2O$$

Please refer to the appropriate technical literature for the exact theory of fuel cells and galvanic elements.

Notes
It is best to connect the three-way stopcock to the fuel cell with a length of thin silicone tubing of 4 mm diameter. It is difficult to ease this tubing over the nipple of the three-way stopcock though, so that lubrication with a little glycerol is necessary. Alternatively, an „adapter“ can be quickly made by fitting only a very short length of silicone tubing on the fuel cell nipple, and using a length of 7 mm diameter tubing, which can be fitted over it, for the connection.
To protect the hose nipples, always also fit a piece of thin tubing over those nipples which are held in clamps with fixing magnets.
Should the generation of hydrogen not be sufficient to drive the motor, then either add a spatula tip of copper sulphate to the zinc granules, or increase the concentration of the acid in the dropping funnel. Neither of these should be necessary, however.

Room for notes