Task

To demonstrate how electrical energy can be stored chemically using, as example, a model of a lead accumulator.

Equipment

Plug-in board	06033.00	1
Changeover switch	39169.00	1
Wire building block	39120.00	2
Lamp holder E10	17049.00	1
Trough, grooved	34568.01	1
Lead electrode, 76 x 40 mm	45215.00	2
Connecting cables, 25 cm, red	07360.01	2
Connecting cables, 25 cm, blue	07360.04	2
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Crocodile clips, bare, 2 from 10	07274.03	(1)
Multi-range meter	07028.01	1
Power supply, 0...12 V-,6 V~, 12 V~	13505.93	1
Filament lamp, 4V/0.04 A, E10	06154.03	(1)
Sulphuric acid, 10%, tech. gr., 1000 ml	31828.70	1
Water, distilled, 5 l	31246.81	1
Emery paper, medium, 1 sheet from 5	01605.02	(1)
Watch		
Cloth or absorbent paper		

Danger!

Sulphuric acid is corrosive. Wear protective glasses!
Lead is harmful to health. Carry out the cleaning of the lead electrodes in a fume cupboard whenever possible!
Wear protective gloves! Wash your hands thoroughly after the experiment!

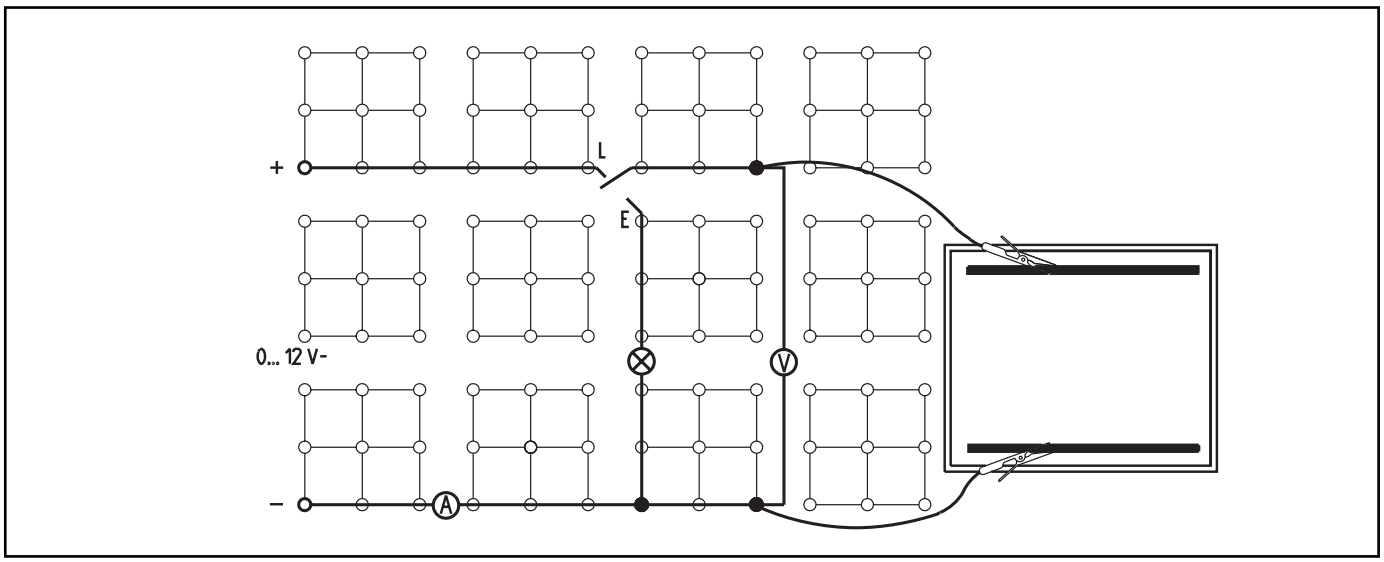
Set-Up and Procedure

— Fill the trough with dilute sulphuric acid (approx. 5%) and fit the lead electrodes in the trough after having cleaned them with emery cloth.
— Set up the experiment as shown in Fig.1, with the changeover switch at L (“load” = recharge); select the 300 mA- and 10 V- measurement ranges.
— Set the power supply to 0 V and switch it on.
— Adjust the power supply voltage so that the ammeter shows about 200 mA.
— After about 0.5 minutes, flip the changeover switch to position E (“empty” = discharge), observe the lamp and measure the voltage (for this, temporarily select the 3 V- measurement range); note the measured value under (1).
— Observe the voltmeter and lamp for some minutes, note your observations under (2).
— Again select the 10 V measurement range, flip the changeover switch to L; adjust the (recharging) current to approx. 200 mA.
— After about 0.5 minutes, flip the changeover switch to E, select the 3 V- measurement range and observe the lamp and voltmeter for some minutes.
— Compare your observations with those noted under (2) and note your realization under (3).
— Set the power supply to 0 V and switch it off.
— Remove the electrodes from the solution, rinse them with water and visually inspect them; note any changes in the electrodes under (4).
— Properly dispose of the aqueous solution; clean the trough and wash your hands with soap and water.

Waste disposal

Pour the contents of the trough into the container for acid and alkaline wastes.
Clean the lead electrode with paper and rub it down with emery.
Put lead waste into the container for heavy metal wastes.

Fig. 1



Observations and Measurement Results

(1) Voltage between the electrodes: U = ...

(2)

(3)

(4)

Evaluation

1. Describe the construction and mode of action of a lead accumulator cell, taking the facts noted under (1) and (2) into consideration.

2. The ability of an accumulator to store electrical energy is called its capacity. It is measured in ampere-hours (Ah). How can the highest possible capacity of a new lead accumulator be reached? (Take the realization you noted under (3) into consideration.)

(How does a lead accumulator function?)

The storage of electrical energy is a significant problem for the supply of energy, particularly as the alternating current made available by power stations cannot be directly stored.
Direct current, however, can be stored by converting the electrical energy into chemical energy. The device which is suitable for this is called an accumulator, or storage battery. In practice, several accumulator cells are connected together in series to a battery.
The students are familiar with such accumulators. This experiment is intended to clearly explain the construction principle and the mode of action of a lead accumulator.

Notes on Set-Up and Procedure
Dilute sulphuric acid (approx. 5%) should be prepared in advance of the experiment..
For reasons of safety, the teacher should himself pour the required amount of dilute sulphuric acid into the troughs of each group of students.
The proper waste disposal of the aqueous solutions should be carried out centrally under supervision of the teacher.

Danger!
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Lead is harmful to health. Carry out the cleaning of the lead electrodes in a fume cupboard whenever possible!
Wear protective gloves! Wash your hands thoroughly after the experiment!

Waste disposal
Pour the contents of the trough into the container for acid and alkaline wastes.
Clean the lead electrode with paper and rub it down with emery.
Put lead waste into the container for heavy metal wastes.

Observations and Measurement Results
(1) Voltage between the electrodes: U = 1.9 V.
(2) The filament lamp shines weakly. The deflection of the voltmeter slowly moves back down and the brightness of the lamp decreases.
(3) The filament lamp again only shines weakly, but the deflection of the voltmeter moves more slowly back down and the brightness of the lamp also decreases more slowly.
(4) The electrode which was connected to the positive pole of the source of charging current, i.e. the anode, is coated with a blackish-brown layer. The surface of the cathode is clean lead.

Evaluation
1. A lead accumulator cell consists of two lead electrodes which dip into an aqueous sulphuric acid solution. When direct current is passed through the cell, it can store this electrical energy and supply electric current. The recharging and discharging currents are in opposite directions. The voltage of the cell is about 2 V.
2. The accumulator must be recharged and discharged several times.

Remarks
The process of repeatedly recharging and discharging a new accumulator is called forming.
The chemical reactions which take place during recharging and discharging are indeed complicated, but can be treated provided the students have sufficient knowledge:
Before voltage is applied, the two lead electrodes coated themselves with lead sulphate ($PbSO_4$), after they were dipped in the aqueous solution in which sulphuric acid was dissociated ($H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$).

Recharging, the reactions at the cathode:
$PbSO_4 \rightarrow Pb^{2+} + SO_4^{2-}$
$Pb^{2+} + 2e^- \rightarrow Pb$
$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$
The cathode takes up electrons, its surface is reduced to pure lead.

Recharging, the reactions at the anode:
$PbSO_4 \rightarrow Pb^{2+} + SO_4^{2-}$
$Pb^{2+} \rightarrow Pb^{4+} + 2e^-$
$Pb^{4+} + 2H_2O \rightarrow PbO_2 + 4H^+$
$PbSO_4 + 2H_2O \rightarrow PbO_2 + 4H^+ + SO_4^{2-} + 2e^-$

The anode donates electrons and binds oxygen; lead oxide is formed from lead sulphate at its surface.
The reverse reactions occur during discharging.

(How does a lead accumulator function?)

Room for notes