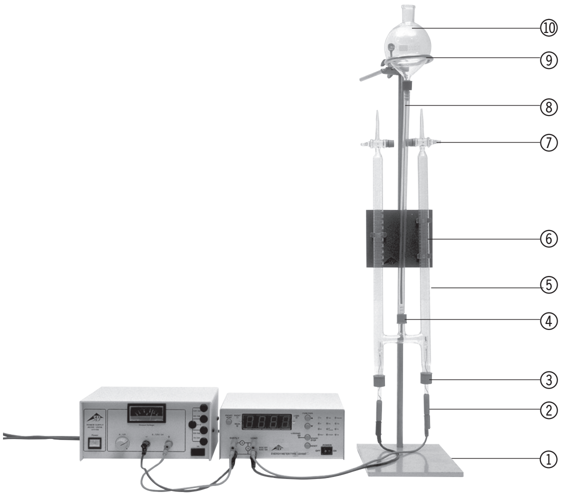
3B SCIENTIFIC® PHYSICS

...going one step further

U14332 Hofmann water-decomposition apparatus

Instruction sheet

11/03 ALF



① *Base-plate with stand rod*
② *Platinum electrodes*
③ *GL-18 screw fitting*
④ *GL-14 screw fitting*
⑤ *Gas collection tubes*
⑥ *Securing plate*
⑦ *Ground stopcock*
⑧ *Plastic hose*
⑨ *Stand ring*
⑩ *Leveling bulb*

The purpose of the water-decomposition is for the electrolysis of water (converting electrical energy into chemical energy), quantitative determination of the resulting gases and confirmation of Faraday's laws.

1. Safety instructions

- Since the conductivity of distilled water is too low, electrolysis is carried out using dilute sulfuric acid (c =1 mol/l approx.).
- Carefully add the sulfuric acid to the water while stirring. Never do this the other way round.
- Wear protective goggles when mixing the solution and when releasing the gases.
- Students should always be informed of the dangers of the chemicals needed for the experiment.
- Caution. Any acid that escapes can cause irreparable stains and holes in clothing.
- Be careful when taking the glass tubing off its securing plate.
- Do not subject the glass components of the water-decomposition apparatus to mechanical stress.

2. Description, technical data

The water-decomposition apparatus consists of an H-shaped section of glass tubing attached to a securing plate fixed to a stand rod that rests on a base-plate. The glass section involves two gas collection tubes each with a measuring scale. At the top of each tube there is a ground stopcock. Two platinum electrodes are secured at the lower ends via GL-18 screw fittings. A flexible plastic hose leads to a leveling bulb for equalising the pressure in the collection tubes.

Dimensions:

Water-decomposition apparatus:	
Height:	800 mm approx.
Width:	150 mm
Base-plate:	250 mm x 160 mm
Rod:	750 mm x 12 mm Ø
Securing plate:	120 mm x 110 mm
Gas collection tubes:	
Height:	510 mm
Width:	150 mm
Tube diameter:	19 mm
Scale:	50 ml each with 0.2 ml divisions
Leveling bulb:	
Volume:	250 ml

2.1 Scope of delivery:

1 Glass section with gas collection tubes
1 Base-plate with stand rod and securing plate
1 Pair of platinum electrodes with 4-mm sockets
1 Leveling bulb with plastic hose
1 Stand ring to hold the leveling bulb
1 Universal sleeve

2.2 Spares

U14333 Gas collection tubes
U14334 Pair of platinum electrodes
U14335 Leveling bulb, 250 ml

3. Theory

Unlike metallic conductors, where current is carried by electrons, current in electrolytes is transported via ions.

In water to which sulfuric acid has been added the following ions are present: HSO_4^-, SO_4^{2-} and H_3O^+. When a voltage is applied, ions begin to move and the water is electrolyzed. This leads to the liberation of hydrogen and oxygen gas. At the cathode (the negative pole) two 2 H_3O^+ ions combine to form an H_2 molecule. At the anode (positive pole) O_2 is formed. The sulfuric acid remains unchanged and acts solely as a catalyst for the electrolysis of water.

The charge Q transported between the electrodes during electrolysis can be calculated from the current I and the duration of the electrolysis t by means of the following equation:

$$Q = I \cdot t.$$

If an ion has a charge of z times the charge on an electron e, then Q/ze ions are released.

For H_3O^+ $z = 1$ so that Q/2e H_2 molecules are produced. 2 ions are needed to produce one molecule. To release n moles of H_2 therefore requires a charge

$$Q = 2e \cdot N_L \cdot n$$

where N_L is the Loschmidt or Avogadro number that represents the number of molecules per mole ($N_L = 6.0 \cdot 10^{23}$/mol).

If n and Q are known, the equation can be used to find the Faraday constant F, which is the product of the two fundamental constants, the charge on an electron and the Avogadro number:

$$F = e \cdot N_L \sim 10^5 \text{ C/mol}$$

The number n of moles released can simply be determined from the volume.

The gas law

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

summarizes the relationship between pressure p, volume V , temperature T and the number of moles n. The temperature T in Kelvin can easily be determined from the temperature in Celcius t_c ($T = t_c + 273$ K). R is the universal gas constant and takes the value $R = 8.3 \text{ J mol}^{-1}\text{K}^{-1}$ (joules per mole per Kelvin).

A charge Q produces Q/2e H_2 molecules at the cathode. If the Avogadro number $N_L = 6 \cdot 10^{23}$/mol, we then obtain from

$$n = \frac{Q}{2e \cdot N_L} = \frac{p \cdot V}{R \cdot T} \text{ mol}$$

a value for the Faraday constant of

$$F = e \cdot N_L = \frac{Q \cdot R \cdot T}{2 \cdot p \cdot V} = 96500 \text{ C/mol}.$$

3. Example experiments

3.1 Investigation of the conductivity and composition of water

Required equipment:
Water-decomposition apparatus
Voltage supply (e.g. U11760 AC/DC power supply)
Connecting leads
Distilled water
Dilute sulfuric acid

Experiment procedure:

- Set up the experiment according to Figure 1.
- Pour distilled water into the leveling bulb with both stopcocks open.
  Fill the gas collection tubes completely by altering the height of the leveling bulb.
- Close the glass stopcocks. The water level in the leveling bulb should be higher than that in the collection tubes.
- Check the apparatus for leaks and tighten connections where necessary.
- Turn on the power supply and observe the electrodes.
- Since there is no perceptible reaction, turn the power supply off again.
- Add a few drops of dilute sulfuric acid (c = 1 mol/l approx.).
- After waiting for about 5 minutes, switch on the power supply again.
- Gas bubbles should rise from both electrodes.
- When the gas collection tube at the negative pole (cathode) is half filled with gas, turn off the power supply.
- To achieve a precise reading of the gas volumes, lower the leveling bulb until the water in the bulb is level with that in the tube to be measured.
- Release the gases through the stopcocks and collect them in upturned test tubes.
- Demonstrate the presence of hydrogen by the pop test and the presence of oxygen using a glowing splint.

Result:

- Electrolysis does not take place when distilled water is used on its own.
- Addition of dilute sulfuric acid has a catalytic effect so that the distilled water is electrolyzed into its two components, hydrogen and oxygen.
- The volume of hydrogen gas formed at the cathode is twice the volume of the oxygen gas formed at the anode.

Fig. 1

3.2 Determining the Faraday constant

Required equipment:

Water-decomposition apparatus
Voltage supply (e.g. U11760 AC/DC Power supply)
Ammeter (e.g. U13000 multimeter)
Connecting leads
Distilled water
Sulfuric acid
Stopwatch
Thermometer
Barometer
Hydrometer

Experiment procedure:

- Set up the experiment according to Figure 2.
- Pour distilled water into the leveling bulb with both stopcocks open.
  Fill the gas collection tubes completely by altering the height of the leveling bulb.
- Close the glass stopcocks. The water level in the leveling bulb should be higher than that in the collection tubes.
- Check the apparatus for leaks and tighten where necessary.
- Turn on the power supply and set the voltage so that approximately 1 A of current flows. Check to see that gas is being emitted into both tubes.
- Turn the power supply off again, open the stopcocks and release the gas.
- Close the glass stopcocks. Turn on the power supply and the stopwatch at the same time.
- When the glass collection tube at the negative pole (cathode) is nearly full, turn off the power supply and the stopwatch together and record the time.
- Determine the volumes of gas. The hydrostatic pressure should be equalized in order to do this.
- Measure the air pressure and room temperature.

Calculation:

- For a known current I (A), time t (s), air pressure p (Nm^{-2}), temperature T (K), volumes of gas VH_2, VO_2 (m^3) and universal gas constant R (8.3 J mol^{-1} K^{-1}) the Faraday constant F is given by

$$F = \frac{Q \cdot R \cdot T}{2 \cdot p \cdot V}$$

Fig. 2