The magnesium air element

Aims of the experiment

- Magnesium and air can form a galvanic element.
- Galvanic elements can also be made up of gaseous half-cells.
- Salt is required as an electrolyte for the magnesium air element.

Principles

In the magnesium air element, electrical energy is produced from magnesium electrochemically. With salt water as an electrolyte, magnesium reacts with the oxygen from the ambient air when combined with a consumer. In the process, metallic magnesium dissolves and oxygen reacts with hydroxide ions:

				Redox potential
Anode	$\overset{0}{Mg}$	→	$\overset{+II}{Mg^{2+}} + 2\ e^-$	+ 2.36 V
Cathode	$\overset{0}{O_2} + H_2O + 2\ e^-$	→	$2\ \overset{-II}{OH^-}$	- 0.56 V
Total	$Mg + O_2 + H_2O$	→	$Mg(OH)_2$	+ 1.8 V

Magnesium is oxidised at the anode and dissolves. The released electrons go through the electrical conductor. On the other side of the element, the cathode, oxygen moves out of the air through the element's membrane and absorbs the excess electrons. In the process, oxygen reacts with water and the electrons to form the hydroxide ion. In the overall reaction, magnesium and oxygen in the presence of water react to form magnesium hydroxide.

Salt acts as an electrolyte and catalyst here. Salt speeds up the reaction between magnesium and water by destroying the protective oxygen layer of the magnesium through local cells, and it enables charge exchange.

The magnesium air element can theoretically reach a voltage of 1.8 V. However, this is lower under real conditions. Magnesium air cells are also referred to as magnesium air fuel cells, since unlimited oxygen can be supplied subsequently, a characteristic of fuel cells. Due to the relatively high characteristic values, Mg/O fuel cells are suitable for various applications.

A magnesium air element is setup in this experiment. Then the role of table salt and temperature is investigated.

Risk assessment

The equipment and chemicals used are generally non-hazardous. After each experiment, dry and clean the anode plate (magnesium). Store in a dry place.

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Equipment and chemicals

1	Magnesium air element	664 4081
1	Electrochemistry demonstration unit, CPS	664 4071
1	Stand bases, pair	301 339
2	Adapter leads, 2/4 mm, 30 cm, red, 5 pcs	571 262ET5
2	Adapter leads, 2/4 mm, 30 cm, blue, 5 pcs	571 26
1	Connecting leads 2-mm plugs, 15 cm, red	571 231
1	Beaker, Boro 3.3, 150 ml, tall	602 010
1	Measuring cylinder, 25 ml, plastic base	665 752
1	Spoon-ended spatula, stainless steel	666 967
1	Glass stirring rod, 200 mm., set of 10	665 212ET10
1	Universal indicator paper pH 1...14, roll	MA9 0204
1	Electronic balance 440-3N, 200 g : 0.01 g	667 7977
1	Sodium chloride, 250 g	673 5700
1	Water, pure, 1 l	675 3400
	Hot water from the tap	

Set-up and preparation of the experiment

Place the electrochemistry demonstration unit on the stand bases. Place the magnesium air element on its stand and position it in front of the demonstration unit.

Make up 15 ml of a 10% salt solution. For this, weigh out 1.5 g of sodium chloride in the beaker and mix with 15 ml of water. Stir until the salt has fully dissolved.

Performing the experiment

Creating electrical energy

1. To open the magnesium air element, push in the two blue clasps at the side and pull the magnesium anode out of the tank.
2. Pour all of the prepared salt solution into the tank.
3. Reinsert the magnesium anode into the tank.
4. Connect the magnesium air element to the motor of the electrochemistry demonstration unit. For this, position the element so that all three connection jacks are at the front. Connect the red jack on the left-hand side to the red jack on the back with a red lead with a 2-mm plug (see figure).
5. Using the adapter leads, connect the black and the other red jack on the front to the corresponding jacks on the motor of the electrochemistry demonstration unit. Observe.
6. Connect the magnesium air element to the voltmeter of the electrochemistry demonstration unit (see figure). Note no-load voltage.
7. Connect the magnesium air element to the voltmeter and motor at the same time. Note voltage under load.
8. Leave the magnesium air element running for a while. Remove the electrode and measure the pH value with universal indicator paper.
9. Disassemble the magnesium air element and rinse the individual parts with water before drying them.
10. Observe the magnesium electrode. Are changes visible?

The function of salt in the magnesium air element

Repeat the experiment with pure water instead of salt solution. For this:

1. Pour 15 ml of pure water into the tank.
2. First connect the magnesium air element to the motor in the same way as in the first part of the experiment. Note observation.
3. Connect the magnesium air element to the voltmeter. Note observation.
4. Connect the magnesium air element to the motor and voltmeter. Note observation.
5. Disassemble the magnesium air element and rinse the individual parts with water before drying them.

Temperature dependence

Carry out the experiment with a hot salt solution. For this:

1. Prepare 15 ml of salt solution (10%) with hot water. For this, weigh out 1.5 g of salt and dissolve it in 15 ml of hot water.
2. First connect the magnesium air element to the motor in the same way as in the first part of the experiment. Note observation.
3. Connect the magnesium air element to the voltmeter. Note observation.
4. Connect the magnesium air element to the motor and voltmeter. Note observation.

Observation

The measurement results are illustrated in the following table.

The motor only turns when salt water is used as an electrolyte. The increase in temperature has a minor positive influence on the voltage.

	Motor	No-load voltage V0	Voltage under load (motor)
With salt, cool	Turns	1.49 V	1.11 V
Without salt, cool	Does not turn	1.15 V	1.15 V
With salt, hot	Turns	1.50 V	1.15 V

The pH paper turns a colour from green to blue, depending on how long the element generates current. The magnesium electrode is covered in black and white patches.

Result

The magnesium air element generates electrical current when it is filled with a salt solution. The generated voltage is somewhat lower than the theoretically calculated voltage. This is due to side reactions and not working under standard conditions.

Hydroxide ions are produced during the reaction. These increase the pH value of the electrolyte. It becomes alkaline, which can be measured with indicator paper. The magnesium electrode is consumed during the reaction. This can be seen by black patches and holes. Sometimes deposits of white salt can also be seen. This is the precipitated magnesium hydroxide.

Cleaning and disposal

The electrolyte solutions used can be disposed of in the laboratory drain. Disassemble the magnesium air element and thoroughly rinse and dry the individual parts. Store in a dry place.

Further experiments

Using an adjustable charge element, e.g. 664 406, characteristic curves can be recorded in the same way as in experiment C4.4.7.2. Then the capacity of the element can also be determined.