Demonstration Fuel Cell in Chemical Education

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***Abstract**: A fuel cell prototype for demonstrations and training purposes is presented. A set of experiments has been developed and included in specialized handbook. An educational kit for school and extracurricular training is under development.*

***Keywords:** fuel cell, demonstrations, experiments, education.*

1. INTRODUCTION

Fuel cells are one of the most perspective energy converters, which possess numerous advantages over existing ones [1]. These electrochemical power sources typically convert the chemical energy of hydrogen combustion reaction into electricity. Besides hydrogen is the cleanest possible fuel, it possesses the highest energy density among all fuels. Comparing with other similar devices, fuel cells have also the highest efficiency, which reaches 85% when produced electricity and heat are co-generated. Other important advantages of fuel cells are their large scalability and quite operation due to lack of moving parts.

All this makes fuel cells rather attractive for practical application and is a base of the conception for a next generation energy system popular as hydrogen economy [2].

If look at the history of fuel cell technology, it is rather surprisingly that the first prototype was invented even before famous Leclanche element, lead-acid accumulator and other widely used batteries. However, its first application was at the late sixties of previous century, when Americans used the so-called Backon cell simultaneously as a power source and water supplying system during Apollo manned-flights [3].

Although the big progress in the research and development [3,4], especially in the last decades, fuel cells are still not very popular. The main reason is connected with relatively high price of supporting technologies for hydrogen production and storage as well as expensive precious metal electrocatalysts used in most of fuel cells.

Besides the problems, specialists are anonymous that an energy system based on the use of hydrogen as a main energy carrier is a real alternative of the current one for overcoming its substantial drawbacks - dependence of fossil fuels, which

resources are already half-exhausted, and dangerous environmental pollution. In addition, they predict that fuel cell will step on the wide market in the next 5-10 years and replace a big share of currently used autonomous power sources in a period of 20-30 years. Expectations are that this will affect in one or another aspect most of technologies and productions, which in fact is the meaning of hydrogen economy as a term.

That's why the biggest players on this potentially unlimited market have recently developed and offered various demonstration prototypes. Some of them are orientated to the educational system and are part of strongly supported, in some cases by the governments, educational programs [5,6]. This is a strong indication that the expert prognosis are in the right direction and people, mainly younger generation should be prepared for the expected changes in technologies.

In our country, however, fuel cells and, as a general, concept of hydrogen economy is familiar only to a group of narrow specialists. Except incident projects, no educational program in this very perspective direction exists.

For overcoming the retardation from world's tendency, we developed a prototype of demonstration fuel cell primary for educational purposes.

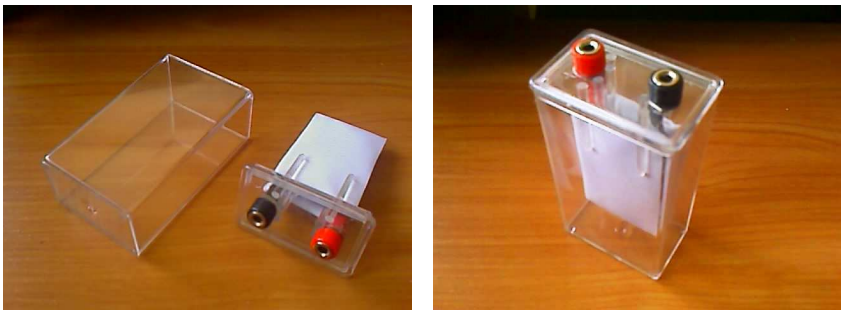
In this paper we present demonstrations, which may be implemented with our fuel cell during classes on physics or chemistry or as out-of-class activities.

2. DEMI CELL DESCRIPRION

Our demonstration fuel cell, named DeMi Cell, represents principles of operation of the so-called reversible fuel cells. When supplying power from outside, for example from a solar panel, it works as a water electrolyzer, producing gaseous hydrogen and oxygen. After obtaining enough amounts of gases, it may serve as a power supplier for some small consumer.

Among main advantages of DeMi Cell are its simple construction, easy and safety implementation of demonstrations and lab experiments, possibilities for direct observation of processes.

DeMi Cell consists of two removable parts - transparent corpus and lid, on which two electrodes inserted in special semitransparent bags, are assembled – figure 1. Neutral salt solutions as that of baking soda are mostly recommended, which guarantees absolutely safety work. Contrary to most of existing fuel cells, the use of non-precious metal catalysts for electrode production sufficiently lowers the price of DeMi Cell.



a) b)

Fig.1: View of DeMi Cell: a) detached; b) assembled.

3. DEMONSTRATIONS AND EXPERIMENTS WITH DEMI CELL

Initially, we have used the developed prototype mainly for demonstrating operational principles of fuel cells. Typical demonstrations are conducted in the following steps:

1) DeMi Cell is detached to its parts, which are then displayed in a manner ensuring that all people could observe the procedure. As mentioned above, the cell is composed of two removable parts – transparent body and lid, on which two electrodes put separately into special bags, and connectors are assembled.

2) The function of each component is explained in details. It can be pointed out that the used bags, in which the electrodes are put, serve not only as separators, but they also hold the generated gases near and on the electrodes' surface in this case.

3) The working electrolyte is prepared – 5 to 10 g sodium bicarbonate (1-2 tea spoons) are put into a 400 ml beaker, 200 ml distilled water is poured into the beaker and then the mixture is stirred till the solid is fully dissolved. Thus prepared electrolyte is enough for filling up 2 cells.

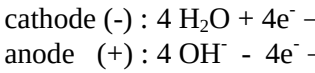
4) 100 ml of the electrolyte is measured by using a measuring cylinder and poured in each cell used. Otherwise, the electrolyte prepared in point 3) should be divided into two equal portions.

5) The separate cells are covered with lids, on which the electrodes are assembled, and afterwards the cells are connected in series with the help of cables.

6) The cell voltage, which is near 0V in the initial moment, is measured by digital voltmeter.

7) The end electrodes of the constructed stack cell are connected to the solar element (or 9V battery) terminals. It is important to connect the negative and the positive terminal of the external power source to the (-) and (+) marked electrode outlets of the tested cell, respectively.

8) Electrolysis is carried out for several (3 to 5) minutes. During the electrolysis, bubbles of evolved gases can be observed on the electrodes' surface. This observation is related to the following reactions taking place on the corresponding electrodes:



9) After producing remarkable amounts of gases on the electrodes, the used external power source is disconnected from the electric circuit.

10) Depends on the number of connected cells, different consumers can be powered to demonstrate the principles of operation of thus prepared fuel cell prototype.

In case of a single cell, the terminal voltage and the generated current is able to power up an electronic calculator (1.5 V). It is just necessary to replace the battery from the calculator with the fuel cell, connecting the corresponding outlets with proper cables. If you don't mistake the poles, the calculator display should be lightening on after pressing "ON" button and you can make some calculations during next several minutes. In most cases, the operating time is almost the same as the time of electrolysis carried out.

If use two or three connected in series single modules, the fuel cell may supply other consumers such as LEDs or even some alarm clocks.

11) In other set of experiments, after generating hydrogen and oxygen by water electrolysis, you may measure the terminal voltage and generated by the fuel cell current. Normally, the measured voltage is about 1.2 V for a single cell (3.6 V for three connected in series cells) and the current is in the range of some tenths milliamps.

You may also investigate the dependence of the electric characteristics (voltage, current, power) on the electrolyte concentration, temperature and the way of connection between separate cells.

12) After finishing demonstration, the fuel cell should be again detached to its components. All components should be gently washed with water and dry after it. If not used during next few days, the electrolyte is not necessary to keep. Otherwise, it can be stored for several days in a glassy or plastic bottle.

Later on, we developed a set of experiments, which can be carried out in universities, schools or even independently by students. The description of each experiment contains its aim, short theoretical background, necessary equipment, experimental procedure, typical results and discussion. Some of the basic experiments are published elsewhere [7]. Base on this, we prepared a specialized handbook [8] in collaboration with our German partners, which is under edition. Except experi-

ments, the handbook contains overview of fuel cells, extended description of DeMi Cell and safety operation precautions section.

We believe that the developed prototype as well as the handbook with experiments will be a useful tool for easier understanding of fuel cells – a milestone technology of the future energy system.

4. CONCLUSIONS

A prototype of reversible fuel cell for demonstrations and training purposes was developed. Based on numerous tests, a handbook including set of experiments was also prepared.

An educational kit and program for learning of fuel cell and related technologies for green energy production by Bulgarian students are under development. The program will be focused to extracurricular activities, but separate elements should be successfully used in classes of chemistry and physics at the secondary schools or universities.

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