ARTIFICIAL PHOTOSYNTHESIS

Dragos Marian ROTARU

Valahia University – Romania , Targoviste

E-mail: dragos_rotaru22@yahoo.com

Abstract

Cold fusion, the Higgs boson ... are some of the major goals of modern science, scientific aspirations who are dedicated to hard work, that makes them contemporary equivalents of the Philosopher's stone and the elixir of long life, which the old alchemists strove so earnestly to know. Amongst these contemporary "philosopher stones" is the artificial photosynthesis - reproduction in the laboratory - and then industrial scale, it is hoped - the miracle process, which for billions of years has enriched the Earth's atmosphere with oxygen and creates - from water, carbon and light - organic substances in thousands of diverse types and sustains the planet's life.

1. INTRODUCTION

In an effort to use natural sources for clean energy and transform solar energy from a marginal one into a main source, researchers have attempted to exceed the most important obstacle: capture and storing solar energy. One of the main problems raised by the use of solar power for energy was represented by the fact that the system can work only daily. The systems able to store the energy have been found to be expensive and inefficient. But researchers have recently realized that storing solar energy during the day is not really that complicated a process especially considering that the means are at hand and are found in nature. This process will use materials that are abundant and non-toxic in order to effectively use the most potent source of clean energy: the sun. The researchers who developed this system were inspired by the photosynthesis of plants. Solar energy will be used to separate hydrogen and oxygen gas from water using new catalysts. Later, the oxygen and hydrogen are combined inside a fuel cell, creating carbon-free electricity that can be used anytime day or night.

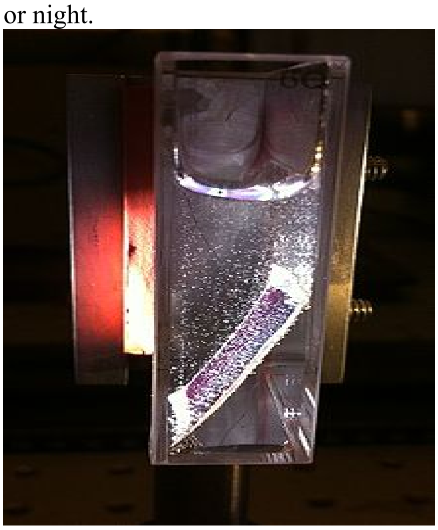

Figure 1. A sample of a photoelectric cell in a lab environment.

2. WHAT ARE SCIENTISTS ACTUALLY TRYING TO RECONSTRUCT

Photosynthesis is the process through the plants by using light as an energy source, can synthesize some complex organic substances starting from the carbon via simple inorganic substances (carbon dioxide). The operations are conducted in specialized cell organelles called chloroplasts which contain the green pigment essential for action - chlorophyll. Chlorophyll is a porphyrin related compound very versatile and stable compound. The process where chlorophyll is involved[3], is extremely complex, but to simplify the explanation, these are the key moments:

- In the first stage of photosynthesis - light dependent phase - chlorophyll absorbs photons of light radiation (a form of electromagnetic energy) and release instead an equivalent number of electrons.

- These electrons become protagonists of a whole series of complex reactions - electron transport chain - leading to the formation of enzymes required for the next stages of photosynthesis[4].

- Chlorophyll (which in the first phase has given up electrons), recovers its electrons from the water molecules, in a process known as water photolysis, with the participation of one of the enzymes previously formed and catalyzed by oxide reducing structures that contain manganese and calcium atoms. The water molecules are split into hydrogen and oxygen ions; hydrogen assists chemical reactions leading to the formation of ATP molecules (an enzyme that is the main source of energy in the living cell) and oxygen is, if you will, a byproduct; it is no longer necessary to the plant's photosynthesis process, so it is "thrown" - released into the atmosphere; here it is valuable as it is used by many organisms - including plants - in an entirely different physiological process, that of respiration[4].

- In the second phase - independent of light - the plants absorb carbon dioxide from the atmosphere and with the help of an army of enzymes, in a complex chain of operations, build, from the carbon extracted from CO2, carbohydrates such as sucrose or starch and based on them, other and other organic substances such as cellulose (the material of which, for the most part, the plant cell wall is composed), and fat (there are many oil-producing plants) or amino acids, the chemical "blocks" of which proteins are made of.

Figure 2. Natural photosynthesis

What is extraordinary is the efficiency of the process: almost nothing is lost, biochemical cycles operate with speed and accuracy which seem unlikely, enzymes are recycled and regenerated continuously, and when you look at the swiftness with which some plants grow and develop, you can only feel humbled in the face of such perfection: photosynthesis is a phenomenon which, although studied to the innermost intimacy that could be reached by analysis – at a biochemical and molecular level - still retains an air of miracle, of the supernatural[5].

So then what chance do scientists have to catch and harnessed this force of nature? Well, to honor those who strive to do so, in recent years there has been made remarkable progress. The first approach is the subject of water photolysis, one of the stages of photosynthesis. Thus the term artificial photosynthesis may refer to the laboratory reproduction process of the cleavage of water molecules under the influence of light. The purpose of such research is to obtain hydrogen, widely considered a cheap source of "clean" energy, the basis of a future high level economy, the so called hydrogen economy, the great hope of a mankind asphyxiated by the consequences of an economy based on fossil fuels, the one that we live in today.

Photocatalytic decomposition of water may provide large quantities of hydrogen, with a clean and efficient process, so sustainable. The key element is the catalysts - substances that facilitate, helps stimulate a process. In this case, it occurs the separation of the components of the water molecule in oxygen and hydrogen. One of these technologies requires a simple concept, meaning the catalytic substances suspended in water without the need of photovoltaic cells (which convert solar energy into electrical energy) and electrolyte systems (which decompose water using electricity)[2]. In other words, a tank full of water in which the suitable catalytic substances have been mixed, in direct sunlight would produce hydrogen![1] Simple and effective. The great challenge is to obtain catalysts that are also efficient and cost effective.

In a different approach, but dedicated to the same purpose - obtaining hydrogen by much cheaper means - researchers at the Massachusetts Institute of Technology have experimented with silicon chips - which photovoltaic panels are made of - coated with substances that serve as catalysts and submerged in water. Their great achievement is that they managed to do it much cheaper, replacing expensive catalysts based on gold, indium, rhodium and platinum, used in previous experiments with some much cheaper, based on cobalt. Recently, the team of researchers from MIT, led by Professor Daniel G. Nocera, announced that it has obtained what it calls the first "artificial leaf": a mini solar panel the size of a playing card, made of inexpensive semiconductor material coated with catalyst compounds, which submerged in water mimics photosynthesis (the photocatalytic decomposition of water) with high efficiency and it is stable and resistant to wear.

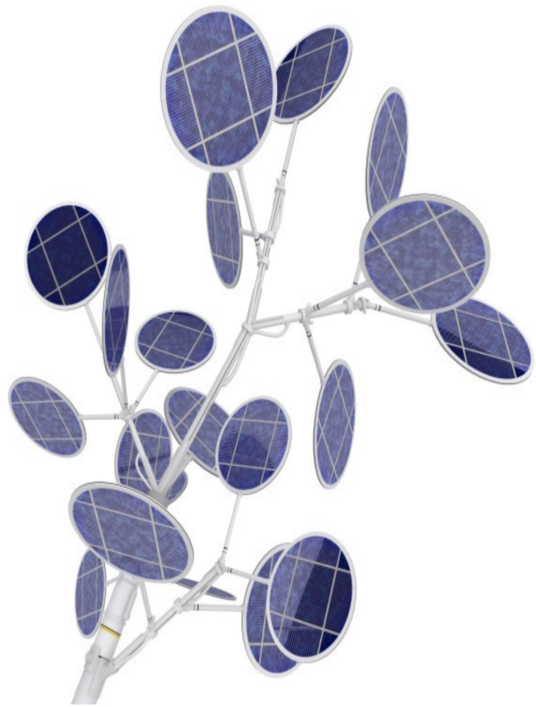

Figure 3. A sample of an artificial leaf

The most difficult aspect, which has given, for years, headaches to all researchers studying technologies necessary to the hydrogen economy - is finding effective ways to store hydrogen and oxygen resulted from reactions for their future use. Without an effective storage technology, the transition from the laboratory made prototype to the large industrial use installation is not possible.

3. WATER + LIGHT = SUGAR ?

A second meaning of the term artificial photosynthesis is associated with an even more lofty ambition: to be able to reproduce, with technological means, the performance of plants to take carbon from the air, hydrogen and oxygen from water and transform them by using light from the sun in carbohydrates. Simply speaking, imagine that we put in a jar of water suitable catalysts, the jar sits in the sun and after a few days, we have bottled water with interesting content - in quantitative terms - of sugar, which we could extract, purify and use: we could make of them ethanol (to use as fuel), acetic acid, and other substances for industrial use. The basic idea, for a large scale usage in the economy of the future, is to produce from water, light and a not too expensive catalyst, some substances that we can use as fuel in order to get rid of oil dependence (and other fossil fuels) and reduce CO2 pollution and its worst consequences - an artificial greenhouse effect and global warming [6,7].

In order to manage this , we need to pull off what nature already did: to use catalysts capable of self regeneration in a cyclic process, as it happens in the leaf with the coenzyme NADP + / NADPH. A photo-synthesized cell does not need an external catalyst because the NADP+/NADPH coenzyme reserves permanently recover in a cyclic process. Hence, the current ambition of specialists: to obtain a catalyst inspired by NADPH, which is able to recreate the cyclic process found in nature. This would imply a complicated chemical process involving hydrogen ion donors that would regenerate under sunlight while forming carbohydrates at the same time.[1]

One of the most competent teams of specialists involved in research on artificial photosynthesis - the Brookhaven National Laboratory, USA – pursue forward in this direction, using a ruthenium catalyst that behaves in the same way as the NADP + / NADPH complex, acting in the transfer of protons and electrons necessary for the transformation of acetone to isopropanol[4]. Acetone and isopropyl alcohol, are organic substances which contain two atoms of carbon, hydrogen and oxygen (the same elements as those of sugars) maybe not complicated in structure but complex enough, however, to provide researchers hope: if the reduction of the acetone to isopropyl alcohol is possible in the presence of light, then there is hope that one day, a more faithful replica of natural photosynthesis will be possible in artificial conditions and we can manufacture complex substances and especially[5].

The interest to master this process in the laboratory is evident today when we not only suffer from high fuel prices, but also from an overload of carbon dioxide in the atmosphere. Getting fuel through artificial photosynthesis would be made without occupying large agricultural areas (unlike conventional biofuels made from crops), a great advantage in the current state of the world, as more and more land is occupied by crops for biofuel production , which led to rising food prices in developing countries and forced millions of people to starve[8,9]. It is true, it is not all that easy to imitate nature: with all the studies, carried to the molecular level, plant life still has thousands of secrets misunderstood by man. However, progress so far - as small laboratory scale as it is now - helps us hope that when oil, coal and natural gas will be finished, we'll have something to replace them with - a better technology, more efficient, cleaner, learned from nature.

4. BIBLIOGRAPHY

1. Yarris, Lynn. "Turning Sunlight into Liquid Fuels: Berkeley Lab Researchers Create a Nano-sized Photocatalyst for Artificial Photosynthesis". *Berkeley Lab News Center*. Lawrence Berkeley National Laboratory.

2 Kalyanasundaram, K.; Grätzel, M. (June 2010). "Artificial photosynthesis: biomimetic approaches to solar energy conversion and storage". *Current Opinion in Biotechnology* 21 (3): 298–310. doi:10.1016/j.copbio.2010.03.021. PMID 20439158.

3. Hammarström, Leif; Styring, Stenbjörn (27 March 2008). "Coupled electron transfers in artificial photosynthesis". *Philosophical Transactions of the Royal Society* 363 (1494): 1283–1291. doi:10.1098/rstb.2007.2225.

4. Ion, R.M., & Mandravel, C. (1998). Conversia fotochimică a energiei solare prin reacția de fotooxidare a hidrocarburilor nesaturate: Analiza spectrală a hidroperoxizilor organici obținuți ca produși de reacție. *Revista De Chimie, 49*(8), 548-555.

5. McConnell, Iain; Li, Gonghu; Brudvig, Gary W. (28 May 2010). "Energy Conversion in Natural and Artificial Photosynthesis". Chemistry and Biology 17 (5): 434–447. doi:10.1016/j.chembiol.2010.05.005. PMID 20534342.

6. Ion R.M., Porphyrinic systems used in photochemical conversion of solar energy, Solar Energy in Romania, 2, 60, (1993);

7. Ion R.M., Pandele L., Fara V.L., New aspects on the photodimerization reaction for storage of solar energy, Solar Energy for sustainable development, 3,1-2,24(1994)

8. Ion R.M., Iosif A., Moise F., The photochemical conversion of solar energy in ecological systems, Solar Energy for sustainable development,3,1-2,81(1994);

9. Ion R.M., Teodorescu L., Zaides E., Solar energy and wind energy applications in chemistry, Electrotehnica, 12,576(1988);