GENERATION OF HYDROGEN AND OXYGEN FROM WATER BY SOLAR ENERGY CONVERSION

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Abstract

The Sun is the main source of energy on our planet. For several billion years, biological systems have acquired the unique ability to efficiently convert energy from the sun through photosynthesis. The study of photosynthesis is a topical area of scientific research that will make it possible to solve the problem of obtaining environmentally friendly energy from water.

In photosynthesis, the source of electrons is water, the oxidation of which produces electrons, protons and molecular oxygen. Oxidation of water takes place in photosystem II (PS-II). X-ray structural studies showed that the PS-II molecule consists of one or two subunits. The latter includes 108 electro-photoactive molecules, has 2 clusters with a spatial configuration in the form of a “chair”, the chemical composition is Mn_4CaO_5. Manganese and calcium atoms in the cluster do not interact with each other, forming chemical bonds only with oxygen. The Mn_4CaO_5 cluster contains 4 water molecules, two molecules each of Mn in position 4 and Ca, forming a complex as $Mn_4O_5Ca(H_2O)_4$. Analysis of the PS-II structure indicates that the components of the enzyme molecule form charge-transfer complexes (CTC) with each other and form a semiconductor structure that performs light-harvesting and electron transport functions.

Based on the structure of PS-II, the mechanism of the generation of H+, O2 ↑ , e^- ions from water as a result of photoenzymatic reaction can be described with a high degree of certainty. The energy of light from light harvesting molecules and their complexes migrates along the semiconductor structure of PS-II into the active center of the biocatalyst. This is accompanied by conformational changes in $Mn_4O_5Ca(H_2O)_4$ cluster, the consequence of which is the breaking of chemical bonds of water and the formation of atomic oxygen and 2 protons. Atomic oxygen in an aqueous medium forms hydrogen peroxide. Catalytic oxidation of hydrogen peroxide by the Mn^{4+} ion leads to the formation of oxygen, hydrogen ions, and heat is released in the reaction $H_2O_2 - 2e^- \rightarrow O_2 \uparrow + 2H^+ + 23.5$ kcal. Mn^{4+} is reduced to Mn^{2+} and then oxidised to Mn^{4+} by transferring the reducing equivalents of PS-I. Two protons in water form hydroxonium ions by the reaction $H^+ + H_2O \rightarrow H_3O^+$, which are electrochemically reduced to molecular hydrogen by the scheme $2H_3O^+ + 2e^- \rightarrow 2H_2O + H_2 \uparrow$. Thus, the PS-II cluster is the key structural formation providing water splitting and hydrogen and oxygen production by solar energy conversion. In addition, it was found that PS-II cluster, as a crystal, does not lose its ability to split water under the action of light quanta. It should be added that a catalyst of similar qualitative composition $Ca(MnO_4)_2$, is used for hydrogen peroxide decomposition in space jet technology.

Keywords: *photosynthesis, photosystem II, cluster, semiconductor, CTC.*

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