ROLE OF HYDROGEN AND METALS IN THE FORMATION AND EVOLUTION OF METABOLIC SYSTEMS

M. A. Fedonkin

Geological Institute, Russian Academy of Sciences, 119017, Moscow, Pyzhevsky per., 7, +7(495) 951-99-81, fedonkin@ginras.ru

Hydrogen metabolism seems to be a historical thread that connects recent biota with the very origin of life. Hydrogen is the most abundant chemical element in the Universe. Molecular hydrogen was a reducing factor in the primary environment of life; it formed the proton gradients as a mechanism of electron transfer that is the key universal feature of energy metabolism. The main sources of abiogenic hydrogen on early Earth were degassing upper mantle magmatic systems, the hydrolysis of iron minerals of mafic volcanic rocks, photolysis and radiolysis of water. High availability of H_2 on early Earth, extraordinary diffusion mobility, low activation energy of H_2, and formation of protons and electrons at the contact of molecular hydrogen with metals, - all these qualities gave H_2 a major role in the rise of the energy metabolism.

The reasons for this hypothesis are as follows. The H^+ gradient that is being used by the cell in the synthesis of ATP, is a universal mechanism for all living organisms. Molecular hydrogen as a key intermediate of the reactions of anaerobic metabolism plays a universal trophic role between micro-organisms that live on different substrates - the most important ecosystem factor from the very start of life and further on. Many groups of modern prokaryotes are using H2 as electron donor and energy source. Their enzymes carry out the H^+ cation transfer. Anion hydrogen H^- (the equivalent of two electrons) is known as the "energy currency" of the cell. The soft hydrogen bonds provide stability and versatility of the macromolecules.

Biochemical reactions involving hydrogen are catalyzed by hydrogenase, which are dominated by Fe-Fe- and Ni-Fe-proteins. The leading role of nickel and iron in the catalysis of reactions of hydrogen metabolism seems to be an ancient biochemical relic of those epochs when these metals were abundant and mobile in oxygen-free and hydrogen-rich reducing environments of early Earth.

The physical and chemical parameters of the biosphere irreversibly departed from the initial conditions due to the decreasing concentration of hydrogen in the early biosphere, declining Fe, Ni, W etc. in the volcanic products, rising concentration of oxygen in the ocean, the changes in the bioavailability of metals known as activators of enzymes - reducing the role of Fe, Ni, Co, V, W, and the growing role of Cu, Mo, Zn. The decreasing sources of molecular hydrogen gradually stimulated the involvement of its simple volatile compounds (CH_4, NH_3, H_2S, and, finally, H_2O in oxygenic photosynthesis) as the substrate of life. The by-products of metabolic reactions that involved those simple hydrogen compounds, ultimately determined the chemical composition of Earth's atmosphere with a high dominant nitrogen and oxygen.