The chemical evolution in open space: An experimental approach

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All young solar system objects are subjected to energetic processing by photons and ions. As a result, the chemical and physical properties of the materials composing these objects will change over time significantly. It was important to test experimentally how far the process of chemical evolution could take place on the surface of space bodies under action of energy sources available at that period.

The «simulated space ice conditions» experiments have shown the synthesis of simple biochemical compounds in the form of amino acid's precursors and bases of the nucleic acids. Our investigation dealt with further reaction of nucleic acid components to nucleotides – main components of RNA and DNA, and single aminoacids to oligopeptides.

We have shown experimentally that the solid mixtures of amino acids produce compounds that are more complex when they have been exposed to open space energy sources. Both irradiation and photolysis may destroy molecules as well as allow the synthesis of new and more complex ones. The chemical reaction of solid-state amino acids induced by different energy sources has been of increasing interest in several fields such as chemical evolution, polymerization of simple molecules, origin of homochirality in biomolecules and so on.

We investigated two types of reactions: (1) abiogenic synthesis of nucleotides from mixtures of nucleoside + inorganic phosphate; (2) abiogenic synthesis of dipeptides from mixtures of simple amino acids. The reaction mixture in the form of a solid film contains (1) nucleoside and dihydrogen phosphate; (2) two different amino acids. Seven different nucleosides (thymidine, cytidine, uracil, adenosine or deoxyadenosine, guanosine or deoxyguanosine) and four mixtures of aromatic (tyrosine or tryptophan) and aliphatic (glycine or alanine) amino acids have been investigated. Mixtures were irradiated as solid films with different sources of energy: (1) VUV-light of 145 nm; (2) high energy protons (2-6 MeV); and (3) were installed on the surface of biosputniks in outstanding container when they were exposed to the action of all spectra of the open space energy sources.

As a result of VUV irradiation of the mixture of nucleoside and inorganic phosphate the natural monophosphates of corresponding nucleosides were found. The main products were nucleoside-5'-monophosphates (5'NMP) and some amount of by-products (2'- and 3'-monophosphates, 2'3'- and 3'5'-cyclomonophosphates). The yields of products were small, however the effectiveness of the abiogenic synthesis on VUV irradiation is higher than on UV-radiation (254 nm) and heat. When investigated films were irradiated with protons, the full mixture of nucleotides also was found. The maximal summary yield was 9.43%. The main product was 5'AMP (3.19%) as under action of VUV.

The films containing a mixture of amino acids yielded various oligopeptides with summary yields of ~2.5% and ~2% after they were exposed to protons and VUV-radiation, respectively. Polymerization is an essential step in prebiological evolution and we have shown that this process probably could take place even at early stage of the Solar system formation, before planet accretion, on surface of small bodies.

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