ATP is a key molecule of prebiotic evolution

E.M.GALIMOV

V.I.Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Kosygin., 19, Moscow 119991, Russia

There are several concepts which relate to origin of life with dominated role of the specific substances: “the RNA world” (Gilbert, 1986; Joyce, 1989), “the protein world” (Fox and Dose, 1977; Dyson, 1985), “the lipid world” (Segre et al. 2001), the “sugar model” (Weber, 2000) etc. Indeed, these substances played an important role in the biological evolution. However, here I stress the role of adenosine triphosphate (ATP) as necessary prerequisite of biological evolution.

I start from formulation of certain mechanism of evolving ordering. Its main feature is a consecutive disproportionation of entropy in a chain of steady state reactions. The ordering (lowering of entropy) in such a process demands chemical conjugation with a process proceeding with the production of entropy and energy supply. The best candidate is hydrolysis of ATP. This water consuming reaction is conjugated with such water releasing reactions as formation of peptide bond, oligomerization of nucleotides etc., which obviously played an important role in prebiotic evolution.

Although the organic moieties of ATP (adenine and ribose) form from simple precursors: hydrogen cyanide (HCN) and formaldehyde (HCHO) respectively, there are some barriers, which might preclude its formation. This paper deals with a geochemical model of the early Earth environment, which allows overcoming these barriers.

Unlike existing models of self-organization (e.g. Prigogine, 1983) which suggested ordering, related to essentially non-linear processes, the mechanism of disproportionation of entropy in steady state reactions admits a process proceeding not far from equilibrium, that is described in terms of linear thermodynamic of irreversible processes. The isotopic evidences in favor of such a mechanism will be presented.

It is shown that principles of evolution that can be inferred from the suggested model are in agreement with the some important features of biological evolution.

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Dust settling and aggregation in the protosolar nebula

A. GALLI, J. A. WHITBY AND W. BENZ

Physikalisches Institut, Sidlerstrasse 5, 3012 Bern, Switzerland (galli@phim.unibe.ch)

Calculations of the accretion and growth of planetesimals are currently hindered by uncertainties in the physics controlling the sticking of small particles. To better understand the lifetimes of solid particles in the early solar system we have implemented a simple one-dimensional model of dust settling and aggregation, which can be used to rapidly assess the effects of changes in physical parameters.

Chondrules, which probably constituted a major fraction of planetary material, are widely believed to have formed from precursor dust aggregates. A natural feature of our settling model is the occurrence of dust aggregates with a size-distribution appropriate for that of chondrule precursor material without appeal to more complex processes such as turbulence.

Model: We have adapted an existing model of the gravitational settling of dust in the terrestrial stratosphere for nebular conditions. The model includes both coagulation by Brownian motion and growth by collisions due to the different settling velocities of spherical particles, but does’t yet incorporate any fragmentation effects. We assume an initially uniform dust/gas ratio, and follow the changes in the particle size-distribution at different heights above the nebular midplane.

Results: Using a wide range of values for the sticking coefficient, critical velocity and other parameters, our model yields approximately constant settling times of 10^5 years for 95% of the total mass of dust to fall to the midplane. This rapid settling is due to the ‘rain-out’ of large aggregates formed in thermal collisions and their efficient further growth. The size-distribution at the midplane has two distinct peaks after the ‘rain-out’ of larger particles has started: one peak corresponds to micron-sized dust, the second peak (see upper part of figure) is due to dust aggregates. Both the size of the larger particles and their mass fraction are decreasing functions of heliocentric distance due to the lower densities of gas and dust. The size-distribution of these aggregates is remarkably similar to that observed for chondrules, as shown in the figure which compares model results with chondrule sizes from the ordinary chondrite Bjurböle.

Size-frequency distribution of larger grains at midplane

At heliocentric distance 2 AU, after 60,000 years simulation time