

Energies and time scales of the chemical evolution toward life in cosmic and terrestrial environments.

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The chemical evolution process toward the appearance of the first life from simple molecules to polymers is thermodynamically difficult and need external energy. In order to overcome this difficulty, we propose here a new mechanism of coupled organic-inorganic evolution by using a spontaneous transformation of unstable inorganic materials (minerals) under hydrothermal conditions (Nakashima and Shiota, 2001). Hydrous silica, phosphates and iron hydroxides/sulfides might be candidate mineral catalysts to provide thermodynamic free energies to the polymerisation of organic molecules such as amino acids, nucleotides and membranes. Thermodynamic values such as Gibbs free energy of formation for complex organic molecules are lacking and preventing the evaluation of these possibilities. Organic-inorganic pair experiments can be conducted in order to evaluate Gibbs free energies of the overall reactions.

Given that the polymerization reactions are feasible thermodynamically, then the kinetic constraints should also be taken into consideration. In particular, the kinetic competition between decomposition and polymerization processes are being evaluated experimentally. For example, an amino acid threonine (Thr) polymerization into membranous film (possibly polyester) appeared to be faster than the decomposition of Thr into glycine (Gly) at temperatures less than 140C (Shiota and Nakashima, 2003). The polymerization rates of Gly into glycylglycine (GlyGly: dipeptide) were much slower than the GlyGly decomposition in the 120-160C range, indicating the kinetic difficulty of the chemical evolution.

However, by introducing silica gel as a catalyst, the polymerization rates were quasi-linearly increased with the amount of silica gel. By extrapolating this trend, 120g of silica is necessary for 8 mL of 0.1mol/L Gly solution to attain the polymerization rates faster than decomposition rates (Haramaki and Shiota, in prep.). The presence of abundant hydrous silica is expected in submarine hydrothermal environments and the above results suggest the possible peptide formation in these environments.

All these thermodynamic and kinetic treatments are used to evaluate quantitatively the temperature conditions and time scales needed for the chemical evolution toward the first life both in early cosmic and terrestrial environments.

Nakashima, S, Maruyama, S., Brack, A. and Windley, B.F. (Eds.2001) *Geochemistry and the Origin of Life*, Universal Academy Press, Tokyo, 355p.