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Amino acids as possible key components of prebiotic chemical evolution on Earth and Earth-like planets

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It is generally accepted that abiotically formed amino acids were present on the Hadean / early Archean Earth. Most probably they originated from atmospheric reactions of the Miller-Urey type [1, 2] and from carbonaceous chondrites which impacted on the early Earth [3]. In the parent bodies of the carbonaceous chondrites, amino acids were formed via Strecker synthesis during aqueous alteration [4, 5]. From these sources amino acids could have been (and could still be) available on other Earth-like (exo)planets, too. In several locations in space, amino acids are exposed to cosmic radiation. For example, it has been suggested that circularly polarized UV light in star forming regions produces L-enantiomeric excesses in amino acids and might be the ultimate cause of biological homochirality [6].

Amino acids in combination with liquid water and different energy forms (e. g. volcanic heat, UV radiation) are probably important factors of chemical evolution on Earth-like planets. For example, in the early Earth's oceans, amino acids were dissolved together with inorganic salts such as NaCl, KCl, $CaCl_2$ and $MgCl_2$. After evaporation of seawater at volcanic coast, amino acid-containing salt crusts must have remained. The embedding of the amino acids into salt crusts is of great importance for consecutive reactions. Further heating of these crusts results in the thermal transformation of the amino acids into new compounds.

In simulation experiments, artificial salt crusts with embedded amino acids (e. g. glycine, DL-alanine and α-aminoisobutyric acid) and corresponding model compounds were synthesized. Analytical methods used to characterize the products were elemental analysis, single crystal and powder X-ray diffractometry, and infrared and Raman spectroscopy. The results showed that in the salt crusts the amino acids are coordinated to Ca^{2+} or Mg^{2+} ions. For example, the previously unknown compound $Ca_3Cl_6(Hala)_2 \cdot 6H_2O$ was identified in DL-alanine-containing salt crusts. This interaction of amino acids with metal ions fundamentally changed their thermal behavior. The typically occurring sublimation of DL-alanine and α-aminoisobutyric acid was prevented, and instead organic compounds such as pyrroles, pyridines, diketopiperazines and polycyclic aromatic hydrocarbons were formed in thermolysis experiments conducted at 300–800 °C [7, 8].

Thus, on the early Earth, molecules chemically very different from amino acids could have been formed by thermolyses of amino acid-containing salt crusts. These processes are also conceivable for the prebiotic chemical evolution on other Earth-like planets in- and outside our solar system.

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