Pressure-induced oligomerization of alanine at room temperature

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Amino acids are building blocks of proteins and the oligomerization of amino acids is the first step of the chemical evolution. We found pressure-induced oligomerization from alanine to alanylalanine and trialanine was reported at pressures from 5 GPa to 11 GPa at room temperauture (Fujimoto et al., 2015). Moreover, it was clarified that freeze concentration at high pressure enhances the oligomerization of alanine even on solid-free dilute aqueous solution of alanine. These findings may suggest that prebiotic oligopeptide formation at high pressure such as in the interior of icy planets. In the present study, we are going to report the maximum length of oligomers and the reaction mechanism of pressure-induced oligmerization of amino acids.

High-pressure experiments were conducted using a non-toroidal opposed anvil assembly with a sample volume of 10 mm^3. Alanine powder was loaded in a metal encapsulating gasket and soaked with pure water. In this study, we prepared deffect-containing alanine sample by grinding alanine powder for 20 hours for investigating effects of lattice defect to oligomerization at high pressure. The recovered samples were analyzed using an LC-MSMS.

We have detected up to 12-mers of alanine oligomers from a sample recovered from 11 GPa. Diketopiperaznie (DKP) which is a ring dimer of alanine was below the detection limit. Formation of long-chain peptides predominates in the pressure-induced oligomerization of amino acids. By grinding alanine powder for 20 hours, formations of alanylalanine (dimer) and trialanine increased for approximately 3 times. The results suggest that pressure-induced oligomerization was notably enhanced by introduning lattice defects in alanine. In natural enviroments, amino acid molecules confined in a cage of minerals such as zeolite may result in high yield of peptide formation at high pressure. We propose a possobility of prebiotic peptide formation at high pressure such as in the interior of icy planets.