

Soluble organic molecules formed under hydrothermal conditions in small bodies

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Extraterrestrial organic materials found in chondrites, micrometeorites, and IDPs record the processes in the Sun's parent molecular cloud, the protosolar disk, and parent bodies. Organic materials could be newly synthesized from simple molecules such as formaldehyde and ammonia (Cody et al., 2009) and/or altered by hydrothermal processes within parent bodies (Herd et al., 2011). The correlation between the L-enantiomeric excess of amino acids and the degree of alteration also indicates that organic materials evolved in parent bodies (Glavin and Dworkin., 2009). Recent studies on soluble organic matter in the Murchison meteorite (Schmitt-Kopplin et al., 2010; Yamashita and Naraoka, 2014) have shown that a large variety of soluble organic molecules are present in the aqueously altered Murchison, some of which could have been synthesized by parent body alteration processes.

In order to understand the formation of soluble organic molecules under hydrothermal conditions in Solar-System small bodies, we conducted hydrothermal experiments following the experimental procedure of Kebukawa et al. (2013). Paraformaldehyde, glycolaldehyde, calcium hydroxide, and ammonium water (8 wt%, NH₃) were put into pyrex glass tube with ultrapure water. The N/C atomic ratio of the starting material was set at 0.1. The glass tube enclosing the starting materials was sealed in the air, and the sealed glass tubes were heated at 90 degree C for 72 hours. We also made experiments without ammonia and only with ultrapure water for comparison.

The liquid phase changed its color from transparent to brownish after the heating, and solid organic components were found in the tube. The liquid phase was diluted by a factor of 100 with a water-methanol mixture (1:1), and was analyzed with Orbitrap Elite LC-MS (Thermo Fisher Scientific). A 10 μ l of the solution was first injected to a liquid chromatograph EASY-nLC 1000 (Thermo Fisher Scientific). The molecules separated through the LC depending on their polarities, were introduced to an electrospray ionization (ESI) source, and positively-charged ions were detected in the range of m/z=50-750 with a mass resolution of 240,000 at m/z=400.

The solutions from the heated samples both with and without ammonia contained molecules showing a broad peak at the retention time of 15-25 min on chromatogram. The averaged mass spectra at the retention time of 19-20 min were averaged and analyzed with the "mMass"-software. Most of the molecules show a successive increase of CH₂O, suggesting that they were formed by the formose reaction (polymerization of formaldehyde). The solution with ammonia contained molecules with an odd number of molecular weights, while that without ammonia did not. These molecules with an odd number of molecular weights should contain an odd number of nitrogen.

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