Partial fluorescence yield X-ray absorption spectra of nitrogen K-edge from various carbonaceous chondritic materials

*Yoko Kebukawa[1], Hiroki Suga[2], Masanori Suzuki[3,1], Minori Ogino[3], Yoshio Takahashi[4], Mike Zolensky[5]

1. Institute of Science Tokyo, 2. JASRI/NanoTerasu Promotion Division, 3. Yokohama National University, 4. The University of Tokyo, 5. NASA-Johnson Space Center

Carbonaceous chondrites contain organic compounds, including amino acids, which may have contributed to the origin of life on Earth. However, amino acids make up only a small fraction of the organic material, with the majority consisting of solid macromolecular organic matter containing small amounts of nitrogen. Thus, the chemical nature of nitrogen-containing functional groups in these materials is not well understood, and detailed chemical information is desired.

We analyzed nitrogen-containing functional groups in various carbonaceous chondrites and carbon-rich clasts from ordinary chondrites, as well as insoluble organic matter (IOM) from some of them, using partial fluorescence yield X-ray absorption spectroscopy at BL27SU, SPring-8. This allows us to obtain highly sensitive nitrogen K-edge X-ray absorption near-edge structure (N-XANES) spectra.

Most chondrites exhibited three nitrogen-related peaks: (A) 398.7 eV (pyridinic N), (B) 399.7 eV (pyridinic N/nitriles), and (C) 400.8 eV (pyrrolic N, amines, amides, or ammonium salts). The Zag meteorite clast showed an intense peak at 400.8 eV, similar to the Tagish Lake and Tarda meteorites, suggesting that these meteorites contain abundant amines/amides rather than N-heterocycles. This nitrogen composition supports the idea that these parent bodies formed in the outer Solar System, where ammonia and hydrogen were more abundant. Significant differences were observed between intact chondrites and IOM, suggesting that acid demineralization removed or altered amide bonds and ammonium salts. These results indicate that nitrogen-bearing compounds in meteorites are more diverse than previously thought, offering new insights into the potential delivery of prebiotic molecules to Earth.

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