Prediction of isotopic systematics of H, N and O between planets

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Hydrogen, Nitrogen and Oxygen are among the most abundant elements of the universe. Isotopic compositions of these elements between molecules are highly variable in molecular clouds. Due to highly volatile nature of these elements, the chemical forms are easily changed between vapor and solid (ice) by environmental temperature and pressure. Thus, the standard planetary formation model of the solar system suggests that inner planets deplete these elements, but outer planets enrich as major elements. Isotopic compositions for planets of these three elements should be determined spontaneously according to the standard planetary formation processes. Therefore, the isotopic variation between planets would be an important key to clarify how to form planets in the solar system. In this report, we propose new systematic approach to infer isotopic compositions for H, N and O of outer planets.

We have proposed a model for oxygen isotopic evolution in proto-planetary disk [1], and infered O isotopic compositions of outer planets [2]. The augmented model based on [2] in this study assumes the initial condition of isotopic compositions of molecules observed in molecular clouds and in chondrites, and includes two key points, i.e., 1) temporal preservation of chemical species fractionated in mass and 2) astronomical space separation by dynamic coupling/decoupling due to the chemical form changes for H, N and O in the disk.

The model infer systematic increase of heavier isotope components of H, N and O for outer planets towards increasing redial distance from the sun, whereas relatively uniform isotopic composition for inner planets. Infered H isotope variations between outer planets are quantitatively consistent with observation data by planet explorations [e.g. 3]. We infer enrichments of ^{15}N in the order of Jupiter, Saturn, and Uranus/Neptune. The $^{15}N/^{14}N$ ratio of Uranus/Neptune would be larger than the Earth's value. Oxygen isotope systematics between outer planets would be mass independent and ^{16}O component would be depleted in the order from Jupiter towords Neptune. The isotopic compositions of inner planets suggest significant accretions of ices from outer solar system during planetary growth and as late veneer.

Above is a main outline of my talk. In addition to the outline, I would like to introduce developments of novel analytical methods and instruments of our laboratory and discoveries from meteorites using the methods, which are basics to consider the systematics of H, N and O in the solar system described above.

[1] Yurimoto & Kuramoto (2004) *Science* **305,** 1763-1766. [2] Kuramoto & Yurimoto (2005) I*n Chondrites and the Protoplanetary Disk* **341,** pp. 181-192. [3] Hartogh *et al*. (2011) *Nature* **478,** 218–220.