Oxidation processes of I-type spherules during atmospheric entry

*Haruhi Yurimoto[1], Daisuke Nakashima[1], Tetsuji Onoue[2], Ryogo Minowa[1], Masakuni Yamanobe[1], Tomoki Nakamura[1]

1. Department of Earth and Planetary Materials Sciences, Faculty of Science, Tohoku University, 2. Earth and Environmental Sciences, Graduate School of Science and Technology, Kumamoto University

Oxygen isotope fractionation of atmospheric O_2 ($\delta^{18}O$ ~ 23.5‰) from ocean water (0‰) [1] is explained by photosynthesis and respiration of terrestrial biomes (Dole-Morita effect; [2-3]). One can expect that temporal variation of terrestrial biomass has been reflected in temporal $\delta^{18}O$ variation of atmospheric O_2, which may be recorded in iron-oxide rich cosmic spherules (I-type CSs) that were originally extraterrestrial FeNi metal and oxidized in the upper atmosphere upon entry. In this study, we analyzed oxygen isotope ratios of I-type CSs using ion microprobe in order to understand oxidation processes of I-type CSs.

Samples in this study are Antarctic I-type CSs and 3 iron-oxide spherules (MRs) artificially produced by melting of metallic iron powder. 9 CSs that show none or low Cr contents and contain coarse magnetite/wustite grains were selected and analyzed for oxygen isotopes using IMS-7f at Tohoku University. The analytical conditions were similar to those in [4].

The polished surface of the samples consists of wustite and magnetite. 4 out of 9 CSs are extraterrestrial in origin, given the low Cr_2O_3 contents (<0.2wt%). The $\delta^{18}O$ and $\delta^{17}O$ values of CSs and MRs plot on the terrestrial fractionation line with a slope of 1/2, indicating that oxygen isotope ratios of CSs reflect terrestrial ones. Similarly to deep-sea CSs (400-600 μm in diameter) [5], the $\delta^{18}O$ values of ~40‰ from 4 CSs (~100 μm in diameter) are higher than that of atmospheric O_2, suggesting oxygen isotope fractionation due to evaporation during atmospheric entry heating. But unlike the previous study [5], there is no correlation between radii of CSs and $\delta^{18}O$, suggesting that oxygen isotope fractionation requires factors besides particle radius. The $\delta^{18}O$ values of MRs are low at from 1‰ to 17‰ and similar to those of iron meteorite fusion crust [6], which are explained by kinetic isotope effect. It is suggested that MRs did not experience significant isotopic mass fractionation via evaporation and/or affected by adsorbed H_2O (~ 0‰) on metallic iron powder.

We performed numerical simulations of oxygen isotope fractionation during atmospheric entry heating of a FeO spherule with $\delta^{18}O$ of 15‰ by changing entry velocity, entry angle and initial radius based on the data in [7]. It is suggested from the comparison between results of simulation and measured CS data that entry velocity and angle besides particle radius may be the key factor for degree of oxygen isotope fractionation due to evaporation during atmospheric entry. The similar $\delta^{18}O$ values and different sizes between CSs in this study and those in [5] may be explained by difference in entry velocity (14-18km/s vs. 12km/s).

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