

EXTREME ¹⁶O-RICH REFRACTORY INCLUSIONS IN THE ISHEYEVO CHONDRITE.

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Introduction: The oxygen three-isotope diagram shows fractionation and mixing of materials having different origins. Whole-rock oxygen isotopic compositions of chondrite groups plotted on the diagram provide mixing lines with different slopes (e.g. CO-CM 0.70, CR-CH 0.59) as a consequence of the interaction of primordial isotopic reservoirs in the solar system [1]. CV chondrites lie close to the carbonaceous chondrite anhydrous mineral line (CCAM, slope 0.941) defined by separated minerals from Allende refractory inclusions (CAI), implying that their isotopic compositions were determined by an exchange interaction between two reservoirs, one ¹⁶O-rich and the other ¹⁶O-poor [2]. An ¹⁶O-poor end member ($\Delta^{17}\text{O} = +85\text{‰}$) was found from cosmic symplectites composed of magnetite and iron sulfide, interpreted that the ¹⁶O-poor reservoir is H₂O water [3]. Although several candidates were reported for the ¹⁶O-rich reservoir from a chondrule named a006 ($\Delta^{17}\text{O} = -37\text{‰}$) [4], 4 refractory inclusions ($\Delta^{17}\text{O} = -37$ to -32‰) [5,6] from CH chondrites and the Sun ($\Delta^{17}\text{O} = -28\text{‰}$) [7] enriched in ¹⁶O relative to common CAIs ($\Delta^{17}\text{O} = -23\text{‰}$) [e.g. 8], the nature of the primordial ¹⁶O-rich reservoir is poorly understood. In this study, we surveyed extremely ¹⁶O-enriched refractory inclusions in the Isheyevu CH/CB carbonaceous chondrite.

Experimental: Thirteen thick sections of the Isheyevu chondrite were newly prepared. Al and/or Ca rich inclusions were picked up from combined X-ray elemental maps of the whole sections obtained by FE-SEM equipped with a X-Max^N 150 EDS detector. Oxygen isotope analysis were performed by ims-1280 and ims-1280HR SIMS instruments at Hokkaido University.

Results and Discussion: Oxygen isotopic compositions of 263 refractory inclusions were measured and 4 extreme ¹⁶O-rich inclusions were found. The extreme ¹⁶O-rich inclusions are composed of grossite core rimmed by thin layers of spinel, melilite and/or Ti-rich diopside. Although the grossite cores show heterogeneous oxygen isotopic composition ranging from $\Delta^{17}\text{O} = -32$ to -36‰ , high precision isotopograph clearly revealed that the grossite can be isotopically altered and the inclusions are enriched in ¹⁶O relative to common CAIs including the thin layers. On the other hand, the spinel grains in the thin layer have uniform ¹⁶O-rich composition ($\Delta^{17}\text{O} = -37\text{‰}$) and fall on somewhat lower than the CCAM line. In order to confirm the characteristic oxygen isotopic composition of the extremely ¹⁶O-rich material, the oxygen isotopic composition of olivine grains in the shell of the a006 chondrule were measured with high precision condition using three Faraday cups. The oxygen isotopic composition of the olivine grains in a006 chondrule ($\delta^{17}\text{O} = -77.26\text{‰}$, $\delta^{18}\text{O} = -75.15\text{‰}$, $\Delta^{17}\text{O} = -38.18\text{‰}$) was plotted close to the spinel data of the Isheyevu inclusions and makes a regression line with olivine grains of a porphyritic olivine chondrule $\delta^{17}\text{O} = (0.9882 \pm 0.0051) \times \delta^{18}\text{O} - (3.00 \pm 0.25)$. Cosmic symplectites are located at the terminal of the line passing through the chondrules [9]. The extreme ¹⁶O-rich materials also located on the extension of the lower limit of the standard deviation of the recommended group averages (area A, B, C and F) with a mass dependent fractionation line from the average of Genesis data [7]. If the extreme ¹⁶O-rich end member simply formed a line mixed with the primordial ¹⁶O-poor water, CAIs in CV chondrites ($\Delta^{17}\text{O} = -24\text{‰}$) formed in a distinct oxygen reservoir slightly fractionated from the Solar System line.

References: [1] Clayton and Mayeda (1999) *Geochimica et Cosmochimica Acta* 63:2089-2104. [2] Clayton et al. (1977) *Earth & Planetary Science Letters* 34:209-224. [3] Sakamoto et al. (2007) *Science* 317:231-233. [4] Kobayashi et al. (2003) *Geochemical Journal* 37:663-669. [5] Gounelle et al. (2009) *Astrophysical Journal* 698:L18-L22. [6] Krot et al. (2017) *Geochimica et Cosmochimica Acta* 201:185-223. [7] McKeegan et al. (2011) *Science* 332:1528-1532. [8] Kawasaki et al. (2018) *Geochimica et Cosmochimica Acta* 221:318-341. [9] Ushikubo et al. (2012) *Geochimica et Cosmochimica Acta* 90:242-264.