# Chemical characteristics of type 7 ordinary chondrites.

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**Introduction:**

Chondrites are petrologically classified into types 1 to 6. For ordinary chondrites, the degree of thermal metamorphism generally ranges from 3 to 6. Exceptionally, some meteorites which experienced recrystallization by higher thermal metamorphism than that type 6 experienced are classified as type 7. Bulk chemical compositions of type 7 ordinary chondrites have been studied for some meteorites [1-4]. Nevertheless, the effect on chemical composition by the strong thermal metamorphism type 7 ordinary chondrites experienced has not been made clear yet. On the other hand, there are some meteorites called “shock-melted” or “impact-melted” chondrites [1, 5, 6]. These meteorites are believed to have been strongly heated by impacts. However, impact-melted ordinary chondrites have not been compared with type 7 ordinary chondrites from the chemical compositional view point so far. Therefore, in this study, we determined the bulk elemental abundances of two H7 and two LL7 chondrites to understand the effect of strong heating on their chemical compositions.

**Samples and Analyses:**

Two H7 chondrites (Y-790960, A-880844) and two LL7 chondrites (Y-74160, A-880933) were analyzed in this study. Among them, only Y-74160 has been well analyzed by previous studies [1, 2, 4]. Each meteorite weighing 170-320 mg was ground into powder in an agate mortar. In this study, three analytical methods were used. About 40-50 mg of each powder sample was taken for instrumental neutron activation analysis (INAA). Neutron irradiation was done two times for each sample with different irradiation time at Kyoto University Research Reactor Institute (KURRI). Gamma-ray measurements were repeatedly done with four different cooling periods. JB-1 (a basaltic geological standard rock sample) was used as a reference material for determination of elements except for some siderophile and chalcophile elements (Ni, Se, Ir and Au), for which the Smithsonian Allende meteorite powder was used as a reference sample. Another 15 mg powder sample was used for inductively coupled plasma atomic emission spectrometry (ICP-AES) and ICP-mass spectrometry (ICP-MS) experiments, which were carried out at Tokyo Metropolitan University (TMU). Major elements and phosphorus were measured by ICP-AES, whereas the detailed abundances of rare earth elements (REEs), Th and U were measured by ICP-MS.

**Results and Discussion:**

From the results of INAA, it was revealed that two H7 chondrites have similar compositions to those of typical H chondrites [7, 8]. There was no depletion of Se and Zn which are the most volatile elements determined in this study. Other two LL7 chondrites also have similar compositions to those of typical LL chondrites except for Se. Selenium was depleted down to 49% and 65% for Y-74160 and A880933, respectively, compared with a typical LL chondrite value [8]. In Y-74160, siderophile element loss and coupled lithophile element enrichment were found. In particular, Ir was fractionated from Ni and Co (Fig. 1). To explain this fractionation of siderophile elements, we modeled the metallic partial melting in Fe-Ni-S system. Partition coefficients are from [9]. In this model calculation, it was assumed that the Fe-Ni-S system melt is in equilibrium with solid metal and sulfides. Typical H and LL chondrite metals were used as starting materials, and both metal compositions are from [10].

Modeling of the Fe-Ni-S system melting can reproduce the fractionation of siderophile elements in Y-74160 (Fig. 1). Some impact-melted LL chondrites and Y-74160 data from [1] are also plotted in Fig. 1, they follow the same trend as the calculated model trend, meaning that the similar partial melting occurred in metal phases of impact-melted LL chonr-

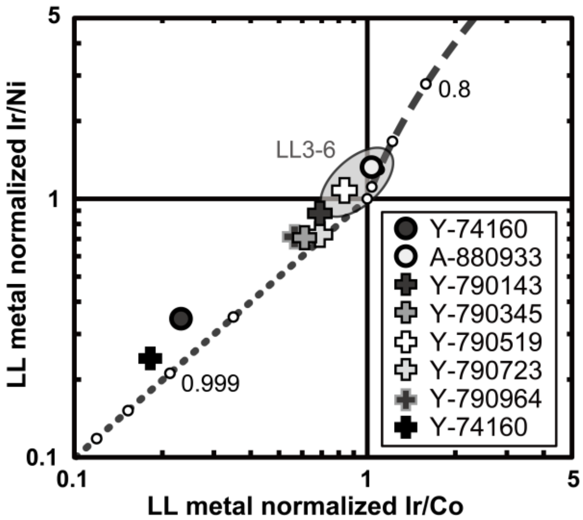


Fig. 1 LL chondrite metal (assuming as the starting material) -normalized Ir/Ni vs. Ir/Co ratios for bulk samples of type 7 LL chondrites. Dotted lines show model calculation results of the Fe-Ni-S eutectic melting. thin dotted line (left side) shows liquid metal compositions and thick line (right side) shows residual metal compositions. Cross-shaped symbols represent impact-melted LL chondrites and Y-74160 whose data are from [1]. The gray area shadow shows typical bulk LL chondrite compositions [7].

-ites and Y-74160. This model also says that, after melting, these meteorites captured the liquid metal phase. However, such a fractionation did not occurred in A-880933 and other two H7 chondrites. This means that partial melting have not occurred or have occurred in a closed system so that we cannot observe an evidence of partial melting from bulk meteorite compositions.

CI- and Mg- normalized REEs, Th and U abundances patterns for the four meteorites studied in this work are shown in Fig. 2. All samples have a negative Eu anomaly and are enriched in heavy REEs (HREEs). In particular, Y-74160 has the highest REEs abundance (about 1.5 times higher than those of typical ordinary chondrites), the largest Eu anomaly and obvious curve line at light REEs (LREEs). Negative Eu anomaly and LREE/HREE fractionation could be explained in terms of plagioclase loss. The degree of Eu anomaly represented by Eu/Eu* ratio, where Eu and Eu* are measured and interpolated values, respectively, and a CI-, Mg- normalized (Na+Al)/2 ratio are compared in Fig. 3. Sodium and Al abundances represent the amount of plagioclase. For A-880933 and two H7 chondrites, Eu anomaly correlates with plagiophile element abundances. Impact-melt LL chondrites from [1, 6] also have the same correlation. However, Y-74160 is not on the line. It has not only the largest negative Eu anomaly but also high plagiophile element abundances. Apparently a negative Eu anomaly and the LREE/HREE fractionation in Y-74160 cannot be explained only by loss of plagioclase.

**Summary:**

Two H7 chondrites studied in this work have similar compositions to those of typical H chondrites. CI-, Mg- normalized REE abundance of these meteorites show a negative Eu anomaly and HREE-enriched LREE/HREE fractionation, probably caused by plagioclase loss. In addition, although A-880844 has a low Th/U ratio, the other three meteorites studied in this work have high Th/U ratio. A-880933 had similar chemical composition to typical ordinary chondrites. This meteorite was reclassified as LL4-6 genomict breccia in [4]. Our data are mostly consistent with this reclassification. However, according to its REE abundance pattern, A-880933 has the same feature as those of other type 7 ordinary chondrites. Y-74160 experienced the strongest thermal metamorphism in the meteorites analyzed in this study. Probably, a liquid metal produced by partial melting was captured in this meteorite, causing the siderophile element fractionation. Plagioclase was lost judging from a large negative Eu anomaly. However, Y-74160 was enriched in plagiophile elements, so this meteorite must have experienced complex thermal history. It may be noted that this meteorite is chemically heterogeneous; CI-, Mg- normalized (Na+Al)/2 ratio are 0.79 in [1] and 0.96 in [2], while 1.19 in this study.

**References:**

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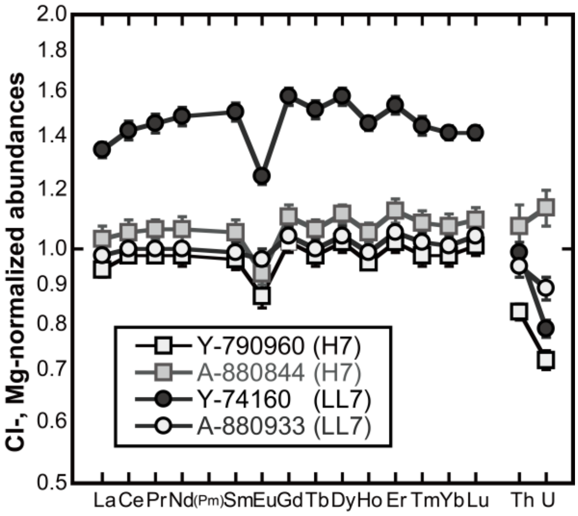


Fig. 2 CI-, Mg- normalized REEs, Th and U abundances for the four chondrites studied in this work. CI values are from [11].

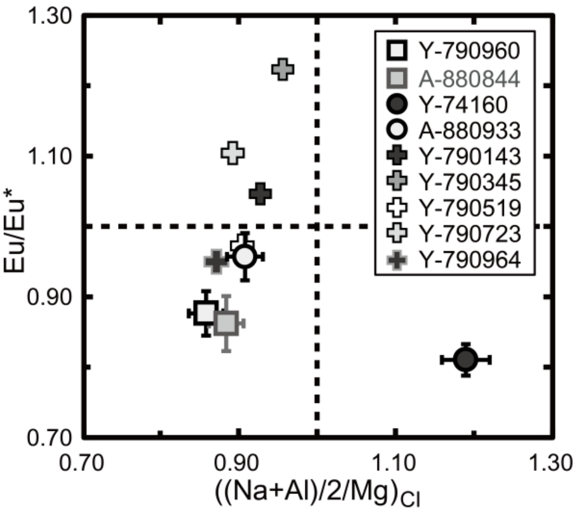


Fig. 3 Fig. 3 Eu/Eu* vs. CI-, Mg- normalized (Na+Al)/2 ratios for type 7 ordinary chondrites and impact-melted LL chondrites. Cross-shaped symbols are the same as Fig. 1. For impact-melted LL chondrites, major elements and REEs data are from [1] and [6], respectively.