CHEMICAL COMPOSITIONS AND ALTERATION OF PRIMITIVE CARBONACEOUS CHONDRITES

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Introduction: Carbonaceous chondrites are the most pristine solar-system material in terms of elemental abundance, and therefore they are an important source of information about processes occurring in the early solar system. Among the carbonaceous chondrites, CI chondrites are very rare compared with other groups. There are only five CI chondrites recovered as fall and among them only three have usable mass for chemical analysis. Recent collection of a few Antarctic CI chondrites increases the members of this group. Y-980115 is one of the newly recognized CI chondrites [1], for which detailed studies, especially for chemical compositions, are not available.

Many carbonaceous chondrites are believed to have been essentially unaffected by post-accretionary parent-body processes except aqueous alteration. This is especially the case for CI and CM chondrites. The aqueous alteration reactions replaced anhydrous phases with newly formed phyllosilicates [2,3]. However, dehydration of phyllosilicates in CM chondrites was reported in some Antarctic carbonaceous chondrites [4-6], suggesting that thermal metamorphism had occurred after aqueous alteration in their parent asteroids. B-7904 and Y-86720 are such carbonaceous chondrites having characteristics of both CI and/or CM-type carbonaceous chondrites or an intermediate nature between the two groups [5,7]. This study aims to obtain chemical compositions of an Antarctic CI chondrite (Y-980115) as well as non-Antarctic CI chondrites (Orgueil, Ivuna and Alais) and metamorphosed CM/C2 chondrites to compare compositional differences between Antarctic and non-Antarctic chondrites. The degree of thermal alteration such metamorphosed chondrites experienced is also evaluated based on their volatile element loss due to thermal alteration in their parent asteroids.

Experimental procedure: We analyzed four CI chondrites: one Antarctic (Y-980115) and three non-Antarctic (Orgueil, Ivuna and Alais), and four CM/C2 chondrites: three Antarctic (Y-86720, B-7904 and Y-793321) and one non-Antarctic (Murchison). Three replicate samples of Y-980115 and a single sample of the other meteorites each were analyzed by instrumental neutron activation analysis (INAA). A single sample of each meteorite was also analyzed by neutron-induced prompt gamma-ray analysis (PGA) except Murchison, which was only analyzed by INAA. Before analysis, powder sample of each meteorite (about 200 mg) was heated at 110 °C for 1 hour in an oven to remove the moisture adsorbed on the surface of the samples and cooled at room temperature in a desiccator for 30 minutes. A cycle of heating and cooling was repeated several times until the mass of the sample became constant.

For PGA, powder and particle samples (200 mg except for Alais (24 mg)) were wrapped in FEP film bag and measured in guided thermal neutron beam at JRR-3M of Japan Atomic Energy Agency. Detailed configuration and analysis procedure were described elsewhere [8,9]. Hydrogen, B, Si, S, Cl and Ti were determined by using PGA. Analytical grade chemical reagents and the Smithsonian Allende meteorite powder sample (prepared by E. Jarosewich; split/position = 22/6) were used as reference standards in relative method of PGA.

After PGA, powder samples (about 40 mg) of the meteorites and standards were analyzed by INAA for short (10 s irradiation, flux: 2.34 x 10^{13}) and long irradiation (4 h irradiation, flux: 2.75 x 10^{13}) at Kyoto University Research Reactor , Japan. Allende powder and geochemical rock sample JB-1 (a basaltic standard rock sample issued by the Geological Survey of Japan) were used as reference standards.

Results and discussion: The mass correction for adsorbed moisture resulted in 4-7% for the studied CI chondrites and 0.8-3% for CM/C2 chondrites. The CI-normalized abundances of 27 elements of an Antarctic CI chondrite Y-980115 along with those of non-Antarctic CI chondrites (Orgueil Ivuna and Alais) are plotted in Figure 1. For most of the studied elements, elemental abundances of all CIs are within 15% deviation from the CI group mean [10]. The elemental abundances of B, Si and Ti of Y-980115 are 37, 24 and 44%, respectively, higher than the CI group mean values, whereas H is 22% lower than that of CI group mean. For the above-mentioned elements (H, B, Si, Ti), abundances of non-Antarctic CIs (Orgueil, Ivuna and Alais) are within 15% deviation from the CI group mean values. No meaningful values of B, S and Ti were obtained for Alais by PGA due to small sample mass (24 mg) available. The high abundance of B in Y-980115 may be due to terrestrial contamination. CI chondrites are believed to be the most primitive meteorites, but large deviation of the abundances of Si, Ti and H of Y-980115 from non-Antarctic CIs indicate that this chondrite has experienced nebular and/or parent body processes to alter the primitive chemical composition.

Mineralogic-petrologic and chemical properties of B-7904, Y-86720 and Y-793321 indicated that they had been thermally metamorphosed in their parent bodies [4, 11-13]. The bulk chemical compositions of B-7904 and Y-86720 indicate that they are related to CM chondrites, although oxygen isotopic compositions are nearly similar to CI chondrites [7]. Our NAA data indicate the following chemical charcteristics; refractory lithiphiles are in the CM-CO range and volatile lithophile (Mn and Na) abundances are CM-like, whereas those for Cl and H are low. The refractory, common and volatile siderophile and chalcophile element abundances are all CM-like , although Os and Sb contents are lower, and Au and S contents are higher than their CM *mean* values [14]. The depletion trend of volatile elements As, Zn, Cl and H in these metamorphosed Antarctic CM chondrites indicates that B-7904 is severely altered while Y-793321 is least altered, with Y-86720 being in-between . This alteration trend is consistent with the results based on time-temperature-transformation diagrams for saponite and serpentine [4] but in disagreement with the trend derived from organic macromolecule and mobile trace element studies [12,13].A reason for causing such an inconsistency remains unanswered at this moment and is to be explained.

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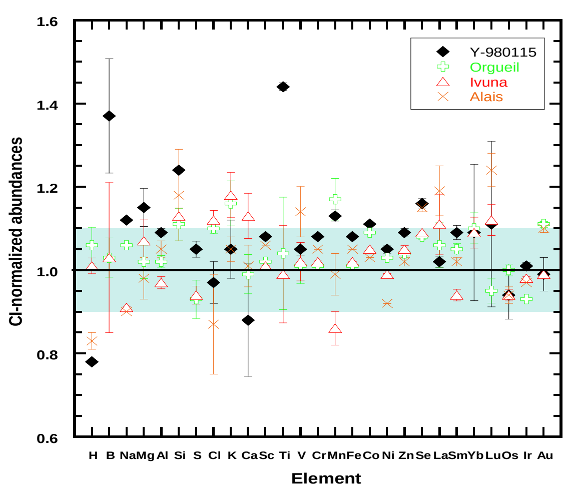

Figure 1. Abundance diagram for an Antarctic CI chondrite Y-980115 and non-Antarctic CI chondrites (Orgueil, Ivuna and Alais). Uncertainties with abundances of Y-980115 are standard deviation (1σ) for three replicate samples analyses while those for other chondrites are due to counting statistics (1σ) of single measurement.