REE, Th AND U FRACTIONATION IN R CHONDRITES. Rahat Khan, Naoki Shirai and Mitsuru Ebihara, Department of chemistry, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan (*khan-rahat@ed.tmu.ac.jp)*.

Introduction: R chondrites are highly oxidized noncarbonaceous chondrites having negligible amount of metallic Fe-Ni and the highest whole-rock $\Delta^{17}O$ value. Previously, bulk chemical compositions of R chondrites have been determined by INAA for major, minor and trace elements [1]. Boynton [2] demonstrated that detailed rare earth elements abundances as well as those of Th and U are informative for discussing the nebular and parent body processes. Phosphates are major host phases for REEs [3] and can control the Th/U ratio in ordinary chondrites [4]. In this study, we present the detailed REEs, Th, U and P abundances for better understanding the origin of R chondrites.

Analytical methods: The same suite of R chondrites described as in [1] have been used in this study. REE, Th and U were determined by ICP-MS [5], and P was determined by ICP-AES [6]. For precision and accuracy, seven replicate measurements of the Allende meteorite powder samples were performed and our data were compared with those of literature data.

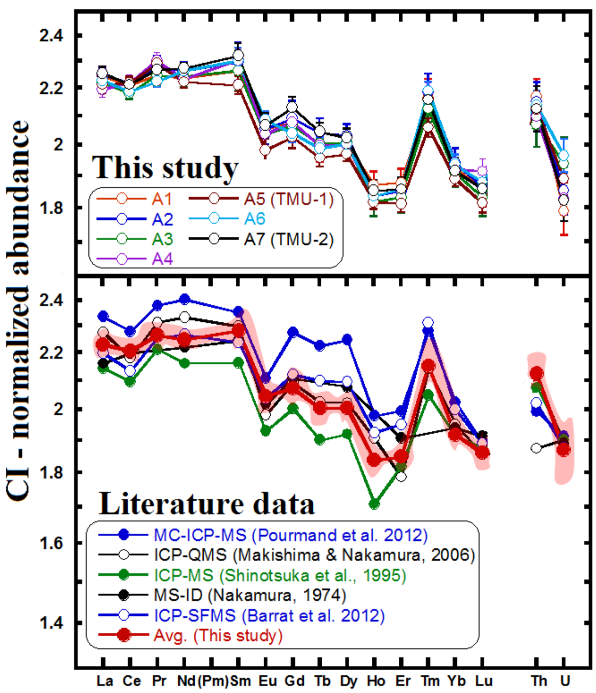

Fig. 1 CI-normalized REE, Th and U abundances of Allende for this work (top) and their comparison with literature values (bottom).

REE, Th and U abundances in the Allende samples (Fig. 1) are consistent with literature values and their relative standard deviations (RSDs) (1σ, in %; n=7) are less than 2% for all elements except for Er, Tm and U. For U, RSD is 3.4%, and, for Er and Tm, RSDs are less than 2.5%. Our P data for Allende are consistent with literature data and the RSD (1σ; n=7) is 1.2%.

Table 1. Phosphorus abundance data for Allende from this work and literatures.

Allende (split/position: 22/6)	P (ppm)
Average (This work; n=7)	**1059 ± 13**
Jarosewich et. al. (1987)	1048 ± 44
Wolf and Palme (2001)	1052 ± 7

Results and discussion: *LREE - HREE fractionation.* CI-normalized REE, Th and U abundances of R chondrites are shown in Fig. 2.

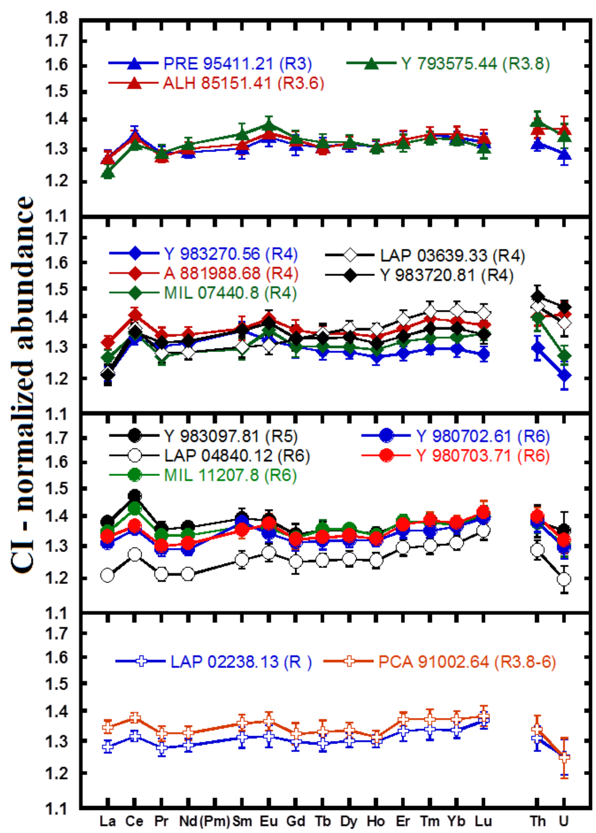

Fig. 2 CI-normalized REE, Th and U abundances of R chondrites of different petrologic types.

It can be noticed that heavy REE (HREE) are faintly enriched compared with light REE (LREE) with a subtle positive Ce anomaly. Uranium is slightly depleted compared with Th in R chondrites.

CI-normalized Nd/Yb and Pr/Tm ratios are plotted in Fig. 3. These ratios for R chondrites are systematically lower than CI values. Apparently, HREEs (represented by Tm and Yb) are enriched compared with LREEs (represented by Pr and Nd).

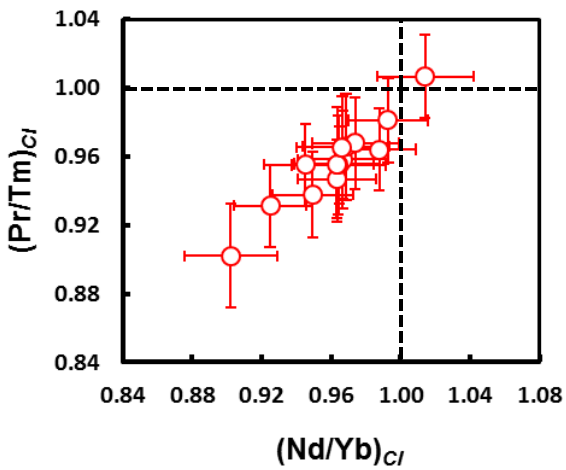

Fig. 3 CI-normalized Nd/Yb and Pr/Tm ratios for R chondrites analyzed in this study.

In Allende, HREEs are depleted compared with LREEs (Fig. 1). According to [7] and [8], high temperature early condensates (e.g., perovskite, hibonite, corundum etc.) enriched with refractory HREEs could have been removed from the nebular gas, making the remaining gas enriched with less refractory LREEs. It is likely that the Allende parent body formed from such later condensates of the remaining gas. In R chondrites, the inclination of CI-normalized REE pattern is opposite to the Allende pattern (except Tm) (Fig. 2). A simple interpretation is that R chondrites formed in the nebula where early condensates were relatively abundant.

Positive Ce anomaly. From our repeated analysis of Allende samples, we confirmed a mean negative Ce anomaly of 2 ± 1%, while from literature data shown in Fig. 1 Ce anomaly can be calculated to be 4 ± 1, about 2% higher than our values. In R chondrites, we observed a mean positive Ce anomaly of 5.4 ± 1.5 %. This positive Ce anomaly retains even after subtracting the 2% difference. It may be emphasized that our Ce abundance in Allende is consistent with that of MS-ID data [10]. Therefore, we are confident that a positive Ce anomaly is real for R chondrites.

Thorium-Uranium fractionation. Thorium and Er have the same nebular condensation temperature while U is less refractory compared with Th and Er [11]. In Fig. 4, CI-normalized Th/Er and U/Er ratios are plotted. Obviously U/Er values are smaller but Th/Er values are larger than their corresponding CI ratios for most R chondrites. This suggests that Th and U are fractionated from CI chondrite values.

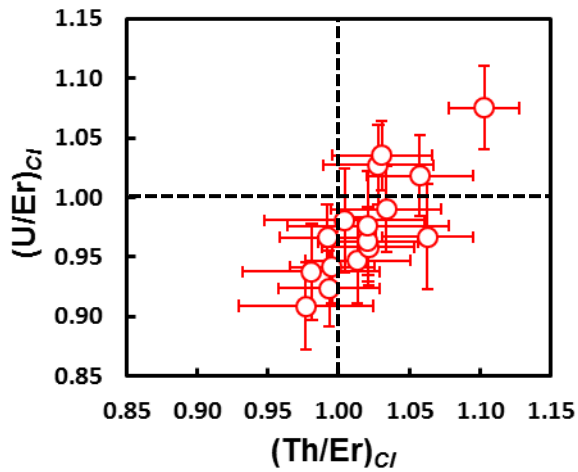

Fig. 4 CI-normalized Th/Er and U/Er ratios for the R chondrites analyzed in this study.

Th/U ratio. A mean value of Th/U ratio is 3.80 ± 0.10 for R chondrites and is higher than those of ordinary chondrites [4] and CI chondrites [12].

Phosphorus abundance. A mean P abundance in R chondrites is 1230 ± 70 ppm (1σ; n=15), which is higher than those of ordinary chondrites.

Conclusion: HREEs are faintly enriched compared with LREEs in CI-normalized REE abundances of R chondrites. A subtle positive Ce anomaly is also observed. Th/U ratios in R chondrites are higher than the CI-mean value. HREE-LREE and Th-U fractionations can be explained in terms of fractional condensation at the early stage of the solar system formation.

References: [1] Khan R. et al., (2013) *LPS*, ***44***, Abstract #2059. [2] Boynton W. V. (1978) *EPSL*, ***40***, 63-70. [3] Allen Jr. R. O. and Mason B. (1973) *GCA*, ***37***, 1435–1456. [4] Goreva J. S. and Burnett D. S. (2001) *MAPS*, ***36***, 63-74. [5] Shinotsuka K. and Ebihara M. (1997) *Anal. Chim. Acta*, ***338***, 237-246. [6] Asoh K. and Ebihara M. (2013) *Anal. Chim. Acta*, ***779***, 8-13. [7] Boynton W. V. (1975) *GCA*, ***39***, 569–584. [8] Davis A. M. and Grossman L. (1979) *GCA*, ***43***, 1611-1632. [9] Barrat J. A. et al. (2012) *GCA*, ***83***, 79-92. [10] Nakamura N. (1974) *GCA*, ***38***, 757-775. [11] Lodders K. (2003) *AstroPhy. J.*, ***591***, 1220-1247. [12] Anders E. and Grevesse N. (1989) *GCA*, ***53***, 197-214.