**SYSTEMATIC VARIATION OF VOLATILE ELEMENTS IN A PETROLOGIC SUITE OF R CHONDrites.** Rahat Khan, Naoki Shirai and Mitsuji Ebihara, Department of chemistry, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan (khan-rahat@ed.tmu.ac.jp).

**Introduction:** Chondrites are the most pristine extraterrestrial objects and representing the history of the early stage of our solar system. In this study we have analyzed 15 Rumuruti-like chondrites (RCs) covering all petrologic types (3-6). From the previous bulk chemical studies [e.g., 1], RCs are compositionally relatively uniform regardless of their petrologic types and their bulk chemical compositions are comparable with those of ordinary chondrites (OCs), except for moderately volatile elements (e.g., Zn and Se). Highly volatile elemental abundances such as Pb, In, Bi, Cd and Tl have not hitherto been analyzed in a petrologic suite of RCs. These elements are strongly depleted in chondritic meteorites [2] and often vary greatly [3]. The unique factors about the cosmochemistry of volatile elements are that they are thermally more labile [4] and are important tool for explaining the nebular and/or parent body processes [2-3]. In ordinary chondrites [5], volatile elements abundances anti-correlate with the petrologic types, which is not conspicuous in the case of thermally metamorphosed Karoonda-like carbonaceous (CK) chondrites [6]. RCs and CKs both are the highly oxidized chondrites in terms of their negligible metallic Fe-Ni [1]. Presence of amphibole and biotite indicates some degree of aqueous alteration [7] in RCs. Selenium abundances in RCs [1] are comparable with those of aqueously altered CM chondrites [8]. Due to some similarities with different classes of chondritic (i.e., OCs, CKs and CMs) meteorites, RC’s parent body must have a diverse formation history which can be investigated by volatile elemental abundances. So, the aim of this study is to present the accurate and precise volatile elemental abundances in a petrologic suite of RCs to study their formation process(es).

**Analytical methods:** Isotope dilution inductively coupled plasma mass spectrometry (ID-ICP-MS) was used for the determination of Zn, Cd, In, Tl and Pb, whereas for Bi, Pb/Bi ratio was used. Solvent extraction (for Tl) and anion exchange column chromatography (for Zn, Cd, In) were used for separating the matrix elements. Accuracy and precision were ensured by the repeated analysis of Smithsonian Allende powder (split/position: 22/6) and comparing our data with those of previously published literature data (Fig. 1). Our data are consistent with literature data [9-11] and relative standard deviations (RSDs) are less than 3% (n=4) for Zn, In, Cd and Tl whereas for Pb and Bi RSDs were 9-15% (n=4).

**Results and discussion:** CI-normalized [12] Zn, Pb, In, Bi, Cd and Tl abundances in RCs are quite variable (Fig. 2). Variation in Zn abundances is not significant whereas Pb (0.33 – 0.64 xCI), In (0.15 – 0.56 xCI), Bi (0.15 – 0.63 xCI), Cd (0.03 – 0.81 xCI) and Tl (0.02 – 0.79 xCI) vary over a wide range. Excluding MIL 11207.8 and Y 793575.44, volatile elemental abundances in RCs show a depleting trend with the increasing degree of metamorphism (Fig. 2). Sometimes it is difficult to separate the petrologic types 3 from 4, or petrologic types 4 from 5/6, but petrologic types 3 and 6 can easily be distinguished from their volatile elemental abundances.

![Fig. 1 Literature data-normalized Zn, Pb, In, Bi, Cd and Tl abundances from replicate measurements of Allende (A1–A4) and the mean (n=4) value of our study as well as compiled data [9] and purdue mean data [10]. For normalization Chicago mean values [10] were used for all elements, except for Pb [11].](image1)

![Fig. 2 CI-normalized Zn, Pb, In, Bi, Cd and Tl abundances in a petrologic suite of RCs.](image2)

**Volatile elements fractionation.** In Fig. 3, average CI-normalized abundances for type 3, 4 and 5/6 are plotted. LAP 02238.13 (R) and PCA 91002.64 (R3.8-6) are included in petrologic type 3, as their volatile abundances are consistent with the type 3 RCs. MIL 11207.8 and Y 793575.44 were excluded from the re-
pective mean values because of their unexpectedly high and low volatile elements abundances, respectively. A clear fractionation of volatile elements among the petrologic types is observed in Fig. 3.

Fig. 3 CI-normalized average Zn, Pb, In, Bi, Cd and Tl abundances in RCs of different petrologic types. Error bars are due to the standard deviations.

Considering that the interior chips for all the RCs were used in this study and that our data quality was ensured by the repeated analysis of Smithsonian Allende powder, the systematic variations of volatile elements in RCs are neither due to the experimental artefact nor due to the terrestrial weathering. We have investigated a total of 15 RCs, which are about 10% of total RCs inventory. So, we can confirm that the systematic variation of volatile elements with the petrologic types is an intrinsic chemical characteristic of RCs, inherited from nebular and/or parent body process(es).

Nebular and/or parent body process(es). Thermal labiality can provide a provisional explanation for the distribution of volatile trace elements according to the metamorphic grade. Radioactive decay (internal heating) and/or impact (external heating) can be a good source of parent body heating for thermal metamorphism. Parent body heating can drive the volatile elements from the interior to the surface which could results the volatile elements fractionation shown in Fig. 3. But the redistribution of volatiles requires the degassing followed by transportation. But, if the system was not opened, transportation will not occur. Then we need to invoke some nebular processes for a possible explanation of volatile elements fractionation in RCs.

In the fractional condensation process, high temperature condensates are supposed to be depleted in volatile elements while the low temperature condensates are comparatively enriched in volatile elements. If the accretion and sequential condensation with the temperature gradient were taken place simultaneously, then the inner portion of the RC’s parent body would contain lower amounts of low temperature condensates than the outer portion of RC parent body. Consequently the outer portion (less metamorphosed) will contain the higher amount of volatile elements. For such scenario, we need to consider a parent body of onion-shell structure.

**Comparison with OCs.** Volatile elements abundances in unequilibrated RCs are comparable with those of unequilibrated OCs, but the volatile elements abundances in equilibrated RCs are comparatively higher than the equilibrated OCs (e.g., Indium in Fig 4). Assuming a simultaneous accretion followed by condensation and an onion-shell structure for both the RC and OC parent body, a lower accretion temperature of RC’s parent body compared with those of OCs is suggested.

**Conclusion:** Unlike refractory and moderately volatile elements in RCs, volatile elements vary by a factor of 2 to 40. Variations of volatile elements show anti-correlation with the petrologic types. Sequential condensations of high-temperature and low-temperature condensates with simultaneous accretion of RCs parent body are apparently conceivable for explaining the systematic variation of volatile elements. A lower accretion temperature is suggested for RCs compared with those of OCs.

**References:**