

**LITHIUM ISOTOPE COMPOSITIONS OF CHONDRULES AND CAIs FROM ORDINARY AND CARBONACEOUS CHONDRITES:** H.-M. Seitz<sup>1</sup>, J. Zipfel<sup>2</sup>, G.P. Brey<sup>1</sup>, U. Ott<sup>3</sup>, <sup>1</sup>Institut für Geowissenschaften, University of Frankfurt, Altenhöferallee 1, 60438 Frankfurt ([h.m.seitz@em.uni-frankfurt.de](mailto:h.m.seitz@em.uni-frankfurt.de)), <sup>2</sup>Sektion Meteoritenforschung Forschungsinstitut und Naturmuseum Senckenberg, Senckenberganlage 25, 60325 Frankfurt, Germany ([jzipfel@senckenberg.de](mailto:jzipfel@senckenberg.de)), <sup>3</sup>Max-Planck-Institut für Chemie, Postfach 3060, 55020 Mainz, Germany ([ott@mpch-mainz.mpg.de](mailto:ott@mpch-mainz.mpg.de)),

**Introduction:** The composition of the inner solar system is directly linked to early solar system processes which are manifested in chondrites and their constituents. Several Li isotope studies of lunar samples, martian meteorites, achondrites (HED) and chondrites have been undertaken in the last decade. (e.g. [1-8]). The majority of the studied samples give an Li isotope signature close to  $\delta^7\text{Li} = +4\%$ .

Recently, Seitz et al. [9] have provided the first comprehensive overview of the Li-isotope composition of carbonaceous and ordinary chondrites. These authors found that the average Li-isotope composition of ordinary chondrites is slightly lighter ( $\delta^7\text{Li} = +2.2\%$ ) than the mean value for carbonaceous chondrites ( $\delta^7\text{Li} = +3.2\%$ ). The range in composition within a single Ordinary Chondrite group is however large (H:  $\delta^7\text{Li} = +0.5$  to  $+2.9\%$ ; L =  $+1.6$  to  $+3.3\%$ ; LL =  $+2.2$  to  $+3.8\%$ ) [9]. It was concluded that such variation within and between ordinary and carbonaceous chondrites was not a consequence of either spallation condensation, hydrous alteration or thermal metamorphism on a parent body or implanted solar wind. It was rather concluded that it could indicate the existence of isotope heterogeneities in the early solar nebular.

Such heterogeneities may be preserved within components of chondrites of low petrologic grade, e.g., in Calcium Aluminium-rich inclusions (CAIs), chondrules and matrix. In order to unravel the reason for the observed differences in the Li isotope compositions of bulk chondrites we have selected several carbonaceous and ordinary chondrites for detailed studies. Semarkona (LL3.0), Bishunpur (LL3.15) and Allende (CV3) were chosen because of their low petrologic type and low degree of hydrous or thermal alteration. In addition, more equilibrated ordinary chondrites Saratov LL4, Bjurböle L/LL4, Bremervörde H/L3.9 were investigated.

**Methods:** Chondrules and CAIs were carefully extracted from the chondrites matrix. The outer surface of the separates were thoroughly cleaned in order to remove any adhering matrix or potential contaminant. Chondrules were then divided into two, one portion for in situ investigations with electron microprobe (EPMA) and Laser-Ablation Inductively Coupled

Plasma Mass Spectrometer (LA ICPMS), the other for solution chemistry. Rock digestion and column chemistry for Li separation followed the procedure of [10]. The Multi-Collector ICPMS allows simultaneous measurement of both  $^6\text{Li}$  and  $^7\text{Li}$ . Because of the small sample volumes and low Li concentrations in the material to be analysed, demanding high ion yields at low sample uptake rates, measurements were performed using a Cetac Aridus<sup>®</sup> nebuliser fitted with a PFA spray chamber and an ESI microconcentric-nebuliser with an uptake rate of  $20\mu\text{l}/\text{min}$ . With the Finnigan standard cones (H-Cones) an intensity of 30-40 pA ( $=3-4$  V using  $10^{11}\ \Omega$  resistor) for  $^7\text{Li}$  at a 10 ppb concentration level is achieved. An analysis is carried out sequentially by 'bracketing' the sample with the L-SVEC standard [11]. Isotope compositions are expressed as per mil deviations from the NIST L-SVEC standard:  $\delta^7\text{Li} = \left[ \frac{^7\text{Li}/^6\text{Li}}{^7\text{Li}/^6\text{Li}} \right]_{\text{sample}} / \left[ \frac{^7\text{Li}/^6\text{Li}}{^7\text{Li}/^6\text{Li}} \right]_{\text{L-SVEC standard}} - 1 \times 1000$ . Internal precision is typically between 0.2–0.6‰ (2SE) and the long term reproducibility, determined on replicate measurements of the geological standard JB-2, is about 1.2‰ (2SD). For the samples, both lithium concentrations and lithium isotope values were simultaneously compared with the ion beam intensities of the 10 ppb NIST L-SVEC standard solution. The daily precision of these concentration measurements is typically 10% (2 SD), with the long term reproducibility being about 15% (2 SD).

**Results:** So far we have studied 26 chondrules from the ordinary chondrites of distinct petrographic types Saratov LL4, Bjurböle L/LL4, Bremervörde H/L3.9, Semarkona LL3.0 and Bishunpur LL3.15 as well as from the carbonaceous chondrite Allende CV3. In addition, one CAI from Allende and one from Bishunpur were measured.

For this study, samples from two individuals of Allende were investigated. The average of both dissolutions reveals a mean Li isotope composition of  $\delta^7\text{Li} = +2.7\% \pm 1.5$ . This value is in good agreement with values from the literature [7, 9, 12]. Li concentrations of  $1.5 \pm 0.17\ \mu\text{g}/\text{g}$  are slightly lower than those reported by [7, 9] but consistent with data reported by [12]. Chondrules separated from the same two samples range in  $\delta^7\text{Li}$  from  $-4.4$  to  $+0.9\%$ , at 0.2 to 0.7

µg/g. One separated CAI has a Li-isotope composition of  $\delta^7\text{Li} = -0.6\text{‰}$  at 0.6 µg/g.

Bulk compositions of ordinary chondrites are  $\delta^7\text{Li} = +3.2\text{‰}$  at 1.1 µg/g (Bishunpur),  $\delta^7\text{Li} = +2.3\text{‰}$  at 1.37 µg/g (Semarkona),  $\delta^7\text{Li} = +1\text{‰}$  at 1.3 µg/g (Bremervörde),  $\delta^7\text{Li} = +2.1\text{‰}$  at 1.66 µg/g (Bjurböle),  $\delta^7\text{Li} = +2.9\text{‰}$  at 1.55 µg/g (Saratov) and fall in the compositional range determined for other H, L and LL chondrites [9]. The majority of individual chondrules in these ordinary chondrites range in compositions from  $\delta^7\text{Li} = -5$  to  $+4\text{‰}$  at 0.1 to 0.8 µg/g. Only two chondrules, one from Bishunpur and one from Bjurböle have relatively high Li concentrations of 2.7 and 3 µg/g, respectively. No correlation between Li concentration and  $\delta^7\text{Li}$  is apparent either for chondrules nor for CAIs.

Average Li-isotope compositions of chondrules in Allende and ordinary chondrites, except for Bishunpur (only one chondrule has been measured so far) are isotopically lighter and Li abundances are consistently lower than the bulk of their host chondrite (Fig. 1). The slope for average chondrule-bulk composition is slightly lower in ordinary chondrites of higher petrologic type (Saratov, Bjurböle, Bremervörde), which might reflect their higher degree of thermal equilibration. Our preliminary data from Bishunpur for CAI and chondrule do not follow any trend.

**Discussion and conclusions:** The majority of chondrules and CAIs have lower Li abundances and lighter Li isotopes than the bulk of their hosts. Various processes can be responsible, such as fractionation during condensation, melting and evaporation during chondrule formation, and/or precursor materials affected by pre-solar and early solar nucleosynthetic processes. The lighter Li isotopic nature of chondrules and CAI's has also been reported by [13-16], although on average heavier  $\delta^7\text{Li}$ -value of  $+10\pm 10\text{‰}$  (spot analyses) has been determined for chondrules from the Semarkona meteorite [17]. It was argued by [13, 16] that the Li isotope variations are the result of nucleosynthetic processes.

Based on our observations we conclude that (1) chondrules from ordinary chondrites and Allende are similar in their Li isotopes and Li compositions, implying that there are no significant differences in their source regions. (2) Higher Li abundances and heavier Li isotope compositions in chondrites compared to their chondrules and CAIs require the presence of at least one other component that is enriched in Li and heavier in its Li isotope composition. Whether this component is sited in the matrix or in Li-rich chondrules such as those analysed from Bishunpur and

Bjurböle needs further investigation. It remains unclear at present whether Li isotopes are fractionated as a consequence of condensation, high temperature thermal processing or whether observed signatures are a result of various nucleosynthetic processes. (3) The lighter bulk Li-isotope compositions observed in ordinary chondrite groups [9] are likely to be controlled by the proportions of CAI's and chondrules in the bulk chondrite.

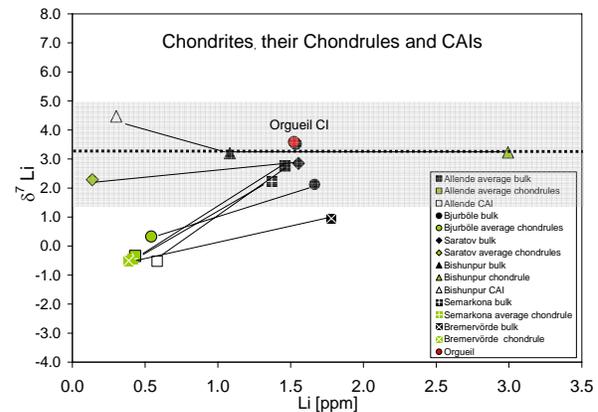


Fig 1: Average  $\delta^7\text{Li}$  values of Allende and ordinary chondrites and their chondrules and CAIs as a function of Li abundances. Data for Orgueil and the average Li isotope composition of carbonaceous chondrites (dashed line) as well as their isotope variation (shaded area) are taken from [9]. Li-isotope data from 6 Allende chondrules [14] have been incorporated.

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