

ISOTOPIC COMPOSITION OF LITHIUM IN THE ALLENDE METEORITE. M. Channon¹, D. R. Bell^{1,2}, R. L. Hervig¹, and P. R. Buseck^{1,2}, ¹School of Earth and Space Exploration, ²Department of Chemistry & Biochemistry, Arizona State University, Box 871404 Tempe, AZ, 85287 (melanie.channon@asu.edu, david.r.bell@asu.edu, richard.hervig@asu.edu, pbuseck@asu.edu).

Introduction: Lithium has two stable isotopes, ⁶Li and ⁷Li with a mass difference of ~16%, resulting in appreciable isotopic fractionation during chemical reactions. The variability of ⁷Li/⁶Li in meteorites may be used as a geochemical tracer for the origin of meteoritic components and alteration processes.

The data for variability of ⁷Li/⁶Li in chondritic meteorites are few, but include relatively homogeneous compositions for bulk chondrules and chondrites [1-3], variations of a few per mil between separated bulk components of carbonaceous chondrites [4], and highly variable SIMS results on intra-chondrule components [5,6]. To shed further light on the cosmochemical behavior of Li and to explore its potential as a tracer, we performed a reconnaissance study of Li isotope variations within olivine of various types in the Allende CV3 chondrite.

Samples: Olivines of variable composition from a variety of petrographic associations within the Allende meteorite were analyzed. Results from a total of eleven chondrules or isolated matrix olivines are reported here. These include olivine within porphyritic and barred chondrules, and isolated euhedral and subhedral olivines in the matrix. A few analyses of included or adjacent mesostasis, and of adjacent fine-grained matrix were also performed (e.g., Fig. 1).

Analytical Techniques: ⁷Li/⁶Li and ⁷Li/²⁸Si ratios were measured on the Cameca IMS-6f secondary ion mass spectrometer (SIMS) at Arizona State University. A 15-30 nA primary O²⁻ ion beam was used to sputter secondary ions from craters ~30 to 50 μm in diameter. Mass resolution was set at ΔM/M of 600 to 2000 after no evidence for ⁶LiH was detected during high resolution mass scans. For each spot analysis, 100 ⁷Li/⁶Li ratios were determined, with a 3 to 5 minute presputter. Charge compensation was evaluated every 20 cycles, and ranged from 0 to -30 V. Each 100 cycle analysis was averaged manually, removing outliers and analyses affected by surface contamination or changes in primary ion intensity (as revealed by systematic trends or fluctuations in ⁷Li count rate). This procedure gave a standard error range of 0.4 to 2.2 ‰ per spot analysis for Li concentrations of 3 to 0.03 ppm, respectively.

⁷Li/²⁸Si was acquired prior to isotope analysis in the same crater in many cases, with each reported ratio the average of 20 cycles. ²⁴Mg/²⁸Si and ⁵⁶Fe/²⁸Si ratios were determined in the same routine. ¹¹B ion intensi-

ties were monitored as a control on terrestrial contamination.

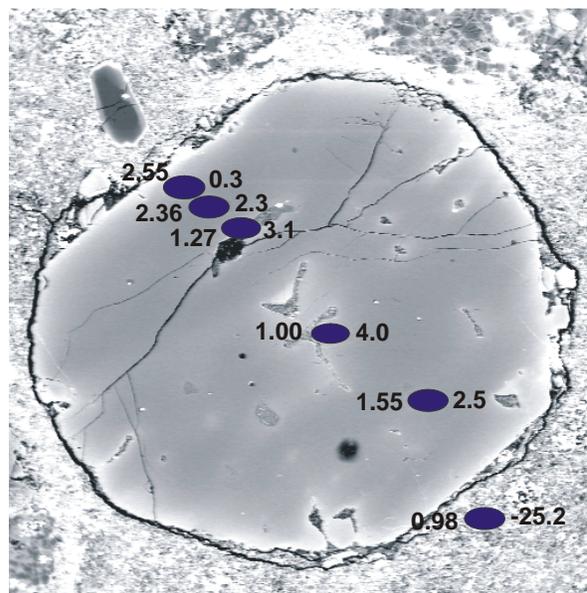


Figure 1. BSE image at 65X magnification of an isolated euhedral olivine grain showing SIMS analysis locations. The darkest regions correspond to Fo86, and lightest regions ~Fo70. Numbers on the left are Li concentrations (ppm), numbers on the right are $\delta^7\text{Li}$ values (permil).

The processed average ⁷Li/⁶Li and ⁷Li/²⁸Si ratios were referenced to isotope ratios derived from KBH1, a terrestrial olivine standard, analyzed concurrently. The olivine composition at each SIMS crater was determined by electron microprobe. A significant correction for the matrix effect of Fe on the instrumental mass fractionation of ⁷Li/⁶Li was applied, equivalent to 1.3 per mil in $\delta^7\text{Li}$ per Mg# (Fo) unit in olivine. The standards for the matrix-effect calibration were a series of natural terrestrial olivines from Fo74 to Fo94. Analyses of matrix and of Fe-rich olivine with <Fo70 may therefore suffer from systematic errors because these compositions extend beyond the range over which the matrix effect was calibrated.

Results: $\delta^7\text{Li}$ values in olivine are plotted as a function of Fo content in Fig. 2. For olivines with Fo>70, Li concentrations (0.02 – 3.2 ppm) and ⁷Li/⁶Li ratios ($\delta^7\text{Li}$ from -25 to +26 ‰) are highly variable. Even lower $\delta^7\text{Li}$ (to -41 ‰) were recorded from more Fe-rich olivines (40 > Fo > 70) where the matrix correction is potentially inaccurate. Forsteritic olivines

(Fo>95), whether isolated in the matrix or within chondrules, typically have Li contents <0.5 ppm and high $\delta^7\text{Li}$ (up to 26 ‰). Higher Li concentrations (>0.5 ppm) and $\delta^7\text{Li}$ similar to bulk chondritic values (i.e. 1 ± 4 ‰) [2,3] tend to occur in moderately fayalitic olivines ($70 < \text{Fo} < 95$). All such olivines with >1ppm Li have close to bulk chondritic $\delta^7\text{Li}$. No Li isotope fractionation between olivine and mesostasis was detected for one euhedral olivine grain where both were analyzed (Fo85, Fig. 1).

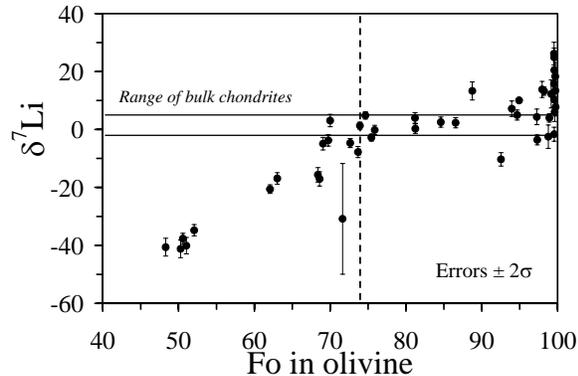


Figure 2. $\delta^7\text{Li}$ vs. Fo in olivine from Allende. Horizontal bar represents the range of $\delta^7\text{Li}$ in bulk chondrites [1-3]. Vertical dashed line shows lower compositional limit of the Fe matrix effect calibration. Reported $\pm 2\sigma$ errors in $\delta^7\text{Li}$ include uncertainties in sample and standard $^7\text{Li}/^6\text{Li}$ and Fe content.

Isotopic compositions vary by up to 20‰ within individual olivine grains as a function of location relative to grain margins, and in some cases according to position of olivine grains within chondrules. There is an apparent tendency for the margins of all types of olivines to approach the isotopic composition and Li content of adjacent fine-grained matrix (Figs. 1,3).

The edges of isotopically heavy forsterite grains commonly show higher Li contents and lower $\delta^7\text{Li}$, whereas those of fayalitic olivines (Figs. 1,3) are zoned to lower Li contents. In detail, these variations are not directly correlated with variations in FeO content of the olivine, suggesting decoupling of Fe and Li due to different diffusion rates in olivine.

Discussion: The high degree of variability in Li content and isotopic composition coupled to the common spatial coherence of these variations suggests that Li can be a valuable tracer of mixing and equilibration processes in chondritic meteorites. Diffusive exchange of Li between olivine and the surrounding matrix has apparently modified the compositions of individual meteorite components in Allende. However, such exchange appears restricted to olivine grain margins so

that earlier generations of intragranular and intra-chondrule variation are preserved.

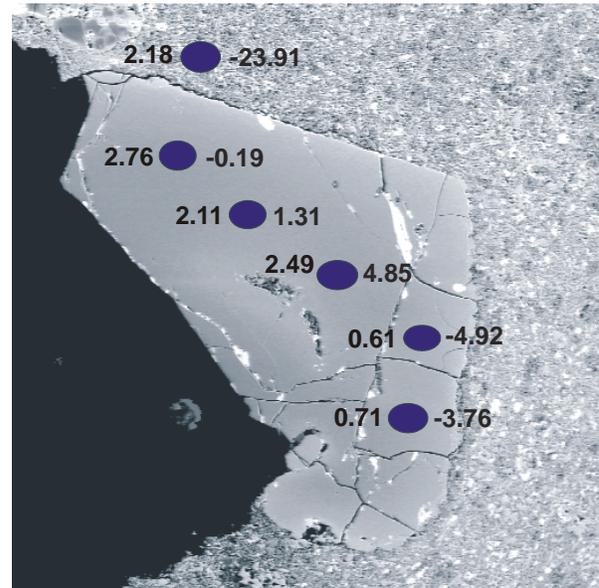


Figure 3. BSE image at 130X magnification of an isolated olivine grain in Allende showing SIMS analysis locations. Numbers on the left are Li concentrations (ppm), numbers on the right are $\delta^7\text{Li}$ values (permil).

The Allende data suggest partitioning of $^7\text{Li}/^6\text{Li}$ between high-temperature (forsteritic) components with low Li and the lower temperature, more Li- and Fe-rich chondrule components which approximate bulk chondritic and planetary values. Possible origins of isotopic variability include kinetic and Soret effects during high-temperature nebular processes, pre-chondrule isotopic heterogeneity [5] and both nebular and parent-body alteration [1,7]. The cause(s) of this partitioning may be investigated by more detailed spatial analysis of isotopic variability in individual grains and chondrules.

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References: [1] McDonough, W.F. et al. (2003) *LPSC* **34** #1934; [2] McDonough, W.F. et al. (2006) *LPSC* **37** #2416; [3] Seitz, H.-M. et al. (2006) *LPSC* **37** #1708; [4] Sephton, M.A. et al. (2004) *Astrophys. J.* **612**, 588-591; [5] Chaussidon, M. & Robert, F. (1998) *EPSL* **164**, 577-589; [6] Chaussidon, M. et al. (2004) *LPSC* **35** #1568; [7] Krot, A.N. et al. (1995) *Meteoritics* **30**, 748-775.