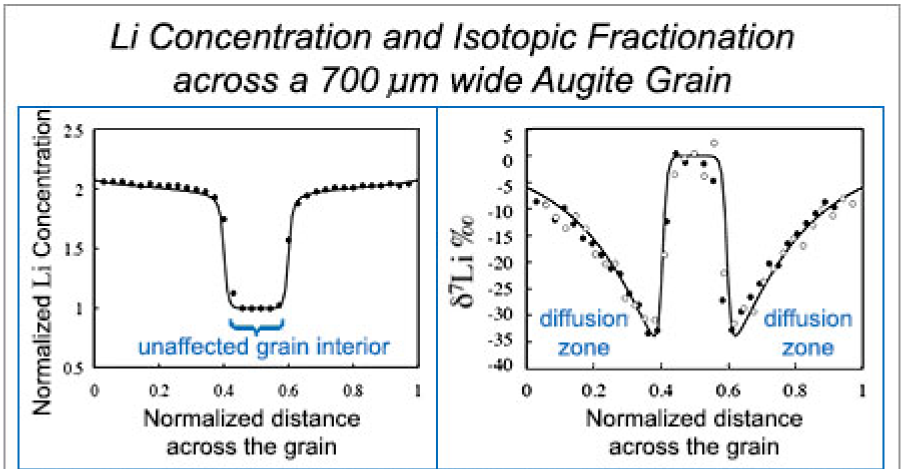
Laboratory Experiments to Understand the Chemical Origin of the Solar System

As part of a large effort to understand the chemical origin and evolution of our Solar System, cosmochemists are conducting experiments to calibrate ***isotopic fractionations*** in common meteorite minerals.



(From Richter *et al.*, 2014, *Geochimica et Cosmochimica Acta*, vol. 126, p. 352-370.)

Experimental results of the diffusion of lithium into an ***augite*** grain. [LEFT] Lithium concentration is normalized to 1 in the grain interior. The data points show an abrupt step in concentration toward the grain interior. [RIGHT] Richter and coauthors found lithium isotopic fractionations of $^{7}Li/^{6}Li$ of about 30‰ in the diffusion zones. The lines in both figures are profiles calculated using a diffusion model, described by Richter and coauthors in their paper.

Frank Richter and Ruslan Mendybaev (both University of Chicago), Bruce Watson and Dan Ruscitto (both Rensselaer Polytechnic Institute), and Marc Chaussidon (CRPG, Nancy, France) have looked at lithium concentration and isotopic fractionation in pyroxenes resulting from kinetic processes (differences in reaction rates of molecules or atoms) during ***diffusion***.

In particular, when a mineral grain such as a pyroxene, displays chemical zonation, researchers use isotopic fractionation data to determine if molecular diffusion was responsible for the zonation. If so, then researchers use relevant diffusion coefficients and the length scale of the zoning to constrain the cooling rate and duration of the diffusion process. Ultimately, these data can lead to estimates of the thickness and depth of the melt layer in a planetary body from which the mineral crystallized. Richter and colleagues used experimental capsules to diffuse lithium into augite grains, under known conditions of temperature and ***oxygen fugacity***. Results showed step-like profiles across the grain (see graphs) of lithium concentration and lithium isotopic fractionations of $^{7}Li/^{6}Li$ of about 30‰. Another case, not shown, resulted in a smoothly decreasing profile of lithium concentration toward the grain interior. Richter and colleagues used model calculations to explain both types of profiles, with the key idea that lithium can occupy two sites in augite crystals: (1) the step-like profile is attributed to slowly diffusing lithium filling metal sites and (2) the smoothly decreasing profile is due to rapidly diffusing interstitial lithium. They call this a two-species lithium diffusion model. Richter and colleagues also found that very large lithium isotopic fractionations continued in the augite grains even after the lithium concentration homogenized. The isotope fractionation parameter derived from the experiments compares well with the parameter used in previous studies of natural samples, including an augite grain from Martian meteorite MIL 03346. Studies such as these, aimed at quantifying the magnitude of isotopic fractionations, bear on our understanding of the processes, including chemical diffusion, by which Solar System bodies evolved to their present state.

See Reference:
· Richter, F., Watson, B., Chaussidon, M., Mendybaev, R., and Ruscitto, D. (2014) Lithium Isotope Fractionation by Diffusion in Minerals. Part 1: Pyroxenes, *Geochimica et Cosmochimica Acta,* v. 126, p. 352-370. doi: 10.1016/j.gca.2013.11.008. [***NASA ADS entry***]

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