Lithium distribution in equilibrated ordinary chondrites: Implications for their cooling history

WATARU FUJIYA[13], KNUT METZLER[2] AND PETER HOPPE[3]

[1]Ibaraki University, Ibaraki 310-8512, Japan (wfujiya@mx.ibaraki. ac.jp)
[2]Institut für Planetologie, Universität Münster, 4400 Münster, Germany
[3]Max-Planck-Institut für Chemie, 55128 Mainz, Germany

Introduction

Knowing the cooling history of ordinary chondrites is important to constrain the thermal structure of their parent asteroids [1] [2]. Here we report the Li distribution in equilibrated LL chondrites and its implications for their cooling rates at low temperatures.

Experimental

Lithium abundances in olivine (Ol), low-Ca pyroxene (LPx), high-Ca pyroxene (HPx), and plagioclase (Pl) in four LLs, Sulagiri (LL6), DaG989 (LL6), NWA6935 (LL5), and NWA7545 (LL4), were determined with the NanoSIMS 50 at the MPI for Chemistry. Secondary $^{7}Li^{+}$, $^{25}Mg^{+}$, $^{30}Si^{+}$, $^{52}Cr^{+}$, and $^{57}Fe^{+}$ ions were detected simultaneously with an O^{-} primary ion beam (~50 pA, 3 µm).

Results and discussion

Li abundances in Ol from all LLs studied here are highly heterogeneous. The largest heterogeneity (0.0062-20 ppm) was found in Ol from the LL4 NWA 7545, while the studied LL5-6 have a smaller range of Li abundances (0.12-22 ppm). Pl and HPx have relatively homogeneous Li abundances in all the LLs. Lithium diffusion coefficients are in the order of Pl > HPx > Ol [3], consistent with our observation. Measurements of the Li partition coefficient between Pl of anorthite contents from 70 to 90 ($An_{70\text{-}90}$) and HPx have been performed at high temperatures from 900 to 1200 °C [4]. If we extrapolate the available data of the Li partition coefficient to lower temperatures and to An_{10} (commonly observed in LL4-6), equilibrium temperatures between Pl and HPx of 440 and 570 °C are obtained for the LL6 and LL4-5, respectively [5]. Therefore, the studied LL4 and LL5 may have cooled more quickly around 500 °C than the LL6, in which Li is mobile even at low temperatures resulting in low equilibrium temperatures. The relative cooling rates are consistent with the thermal structure of asteroids inferred from the onion shell model, i.e., high peak metamorphic temperatures and slow cooling rates in the inner parts of an asteroid compared to the outer parts.

[1] Trieloff *et al*. (2003) *Nature* **422**, 502-506. [2] Scott *et al*. (2014) *GCA* **136**, 13-37. [3] Dohmen *et al*. (2010) *GCA* **74**, 274-292. [4] Coogan *et al*. (2005) *EPSL* **240**, 415-424. [5] Coogan (2011) *Lithos* **125**, 711-715.