EVALUATING SILICON CONDENSATION IN TYPE 1AB CHONDRULES USING IN-SITU SILICON ISOTOPES.
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Introduction: Type 1AB chondrules have a mantle of pyroxene and contain interior olivine and pyroxene phenocrysts. We have initiated a study to determine if fractionations in silicon and magnesium isotopes in type 1AB chondrules show evidence that the pyroxene formed from olivine in a reaction similar to:

$$Mg_2SiO_4 + SiO + H_2O \rightarrow Mg_2Si_2O_6 + H_2 \quad (1)$$

where SiO gas is shown here to be oxidized by water to form SiO_2 in the melt of a molten or partially molten chondrule. A similar model is used by [1] to explain oxygen isotope data obtained from CR and CV chondrules. This reaction involves the condensation of silicon-oxide from the gas phase. The isotopic fractionation due to condensation of silicon can be modeled using the equation:

$$\alpha_{cond} = \frac{\alpha_{Eq}\alpha_{Kin} s_i}{\alpha_{Eq}(s_i - 1) + \alpha_{Kin}} \quad (2)$$

where s_i, $= p_i/p_{i,\mathrm{Eq}}$, p_i is the partial pressure of gaseous species i and $p_{i,\mathrm{Eq}}$ is the equilibrium partial pressure of species i [2]. The fractionation factor α_{kin} embodies the isotope fractionation associated with condensation inclusive of collision frequency and zero point energy effects [3].

Samples and Methods: Silicon isotopes in pyroxene rims and interior olivine phenocrysts were measured in-situ using UV laser ablation and the ThermoFinnigan Neptune MC-ICPMS at UCLA. EMPA analyses (UCLA, JEOL) were used to confirm the mineralogy of the phases following the isotopic measurements. Analyses that contained mesostasis or a mixture of phases were discarded for this study.

Silicon isotope ratios were measured in one type 1AB chondrule from the CV chondrite Allende [4] and two type 1AB chondrules in the CR chondrite Elephant Moraine (EET) 87747. In addition, magnesium isotope ratios were also measured in the two chondrules from EET 87747.

Results: Silicon isotopes were previously measured in Allende Section 458 Chondrule 1 [4]. The fractionation between olivine and pyroxene ($\delta^{29}Si_{px} < \delta^{29}Si_{ol}$) is ~0.3‰ on average. Using α_{Eq} between pyroxene and SiO gas (1.001) [5] and α_{kin} (0.97) [4], this isotope fractionation corresponds to s_{SiO}=1.04 and *to* an undercooling of –1.9 K if reservoir effects are ignored (Figure 1).

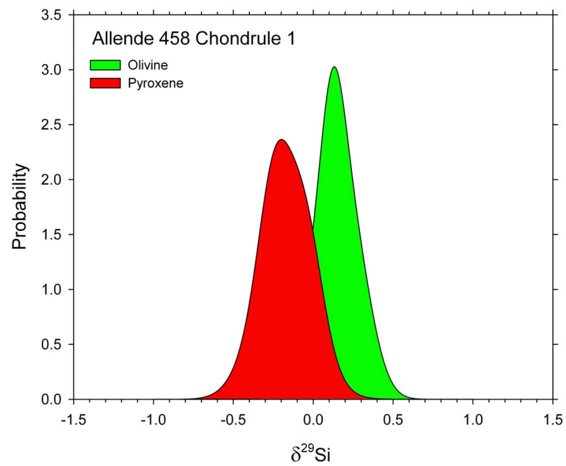

Figure 1. Probability density plot for δ^{29}Si measured in olivine and pyroxene in Allende Section 458 Chondrule 1 relative to NBS 28. Olivine data (n=5) are in green and pyroxene data (n=5) are in red.

Chondrule 3 from EET 87747 has $\delta^{29}Si_{px}$ less than $\delta^{29}Si_{ol}$ by 0.17‰ on average. This corresponds to s_{SiO}=1.025 and an undercooling of -1.2 K if reservoir effects are ignored (Figure 2).

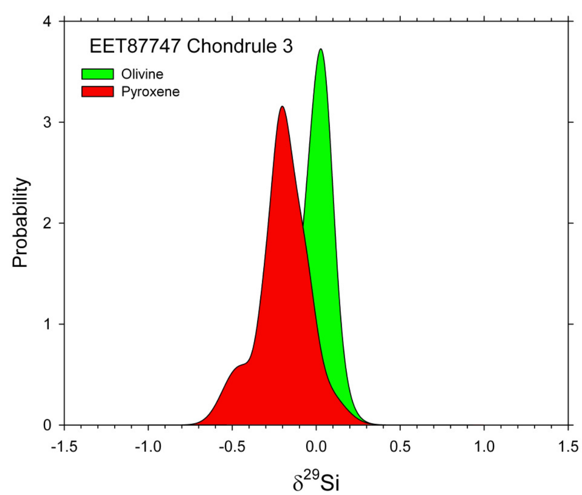

Figure 2. Probability density plot for δ^{29}Si measured in olivine and pyroxene in EET 87747 Chondrule 3. Olivine data (n=6) are in green and pyroxene data (n= 16) are in red.

Figure 3 shows the probability density plot for chondrule 2 in EET 87747. Electron beam petrography suggests that chondrule 2 exhibits greater weathering, perhaps explaining the comparatively large range in δ^{29}Si in both minerals.

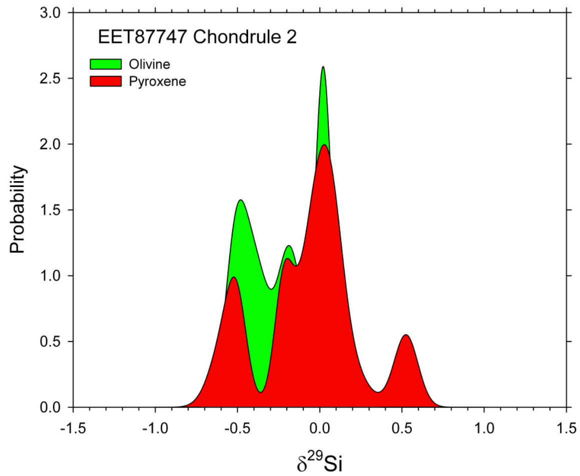

Figure 3. Probability density plot for δ^{29}Si measured in olivine and pyroxene in EET 87747 Chondrule 2. Olivine data (n=6) are in green and pyroxene data (n =11) are in red.

Magnesium isotope ratios were also measured for EET 87747 Chondrules 2 and 3 (Figure 4). The spread in ^{25}Mg/^{24}Mg is much less than ^{29}Si/^{28}Si in all cases.

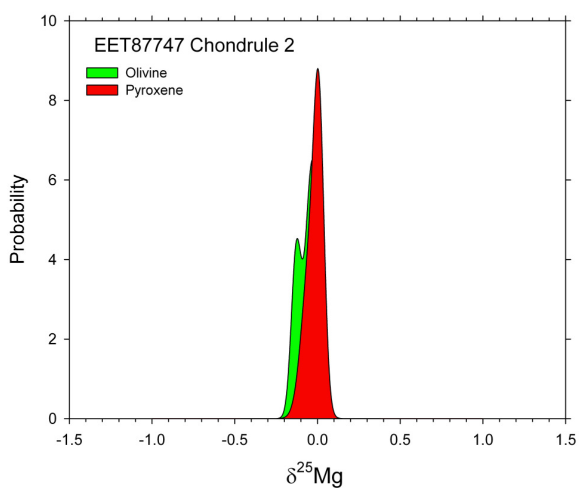

Figure 4. Probability density plot for δ^{25}Mg measured in olivine and pyroxene in EET 87747 Chondrule 2. Color scheme and range same as in Figures 1 through 3.

Discussion: For two of three samples, the δ^{29}Si probability density plots show overlapping, distinguishable δ^{29}Si values for pyroxene and olivine; it appears that the values for olivine and pyroxene are distinct. At equilibrium, pyroxene would be isotopically lighter than olivine by ~0.01‰ at 1700 K [6]. This implies that the difference in ^{29}Si/^{28}Si between pyroxene and olivine in Figures 1 and 2 is not an equilibrium fractionation between these phases. This in turn suggests that SiO may well have condensed into the melt of a molten or partially molten chondrule to form pyroxene with a partial pressure of SiO slightly greater than the equilibrium partial pressure of SiO. This same trend is not observed in the δ^{29}Si data for EET 87747 chondrule 2.

The proposed reaction requires silicon to condense into the melt and react with olivine. Large negative δ^{29}Si in pyroxene relative to both δ^{29}Si in olivine and relative to the magnesium isotope data suggests that we are seeing the isotopic consequences of reaction (1).

The implied undercooling of between 1 and 2 K implies that this process took place in near equilibrium conditions. We will look for this effect in more chondrules of type 1AB.

References: [1] Chaussidon, M. et al. (2008) *GCA, 72*, 1924-1938. [2] Young, E. D. and Schauble, E. A. (2012) *Meteoritics & Planet. Sci., 47,* Abstract #4382. [3] Simon, J. I. and DePaolo, D. J. (2010) *EPSL, 289,* 457-466. [4] Harju, E. R. and Young, E. D. (2013) *LPSC XLIV,* Abstract #2908. [5] Javoy, M. et al. (2012) *EPSL, 319-320,* 118-127. [6] Méheut, M. et al (2009) *Chem. Geol., 258,* 28-37.