

# MAGNESIUM AND SILICON ISOTOPIC FRACTIONATIONS DURING EVAPORATION OF FORSTERITE-RICH MELTS: THE TEMPERATURE AND COMPOSITION EFFECTS.

R. A. Mendybaev<sup>1</sup>, F.-Z. Teng<sup>2</sup>, R. B. Georg<sup>3</sup>, and F. M. Richter<sup>1</sup>. <sup>1</sup>Department of the Geophysical Sciences, University of Chicago, Chicago, IL ([ramendyb@uchicago.edu](mailto:ramendyb@uchicago.edu)); <sup>2</sup>Department of Earth and Space Sciences, University of Washington, Seattle, WA; <sup>3</sup>Water Quality Centre, Trent University, Peterborough, ON, Canada.

**Introduction:** FUN CAIs are characterized by extremely large mass-dependent fractionations of silicon and magnesium isotopes (up to  $\delta^{29}\text{Si}$  ~15 ‰ and  $\delta^{25}\text{Mg}$  ~40 ‰), distinctive mass-dependent fractionations of oxygen isotopes, and mass-independent isotopic anomalies in many elements [1, 2]. The correlated isotopic fractionations of Mg and Si of FUN CAIs extends the trend of the normal CAI to much larger fractionations [1], and it is usually believed that these fractionations are result of the evaporation of Mg and Si from at least partially molten precursors.

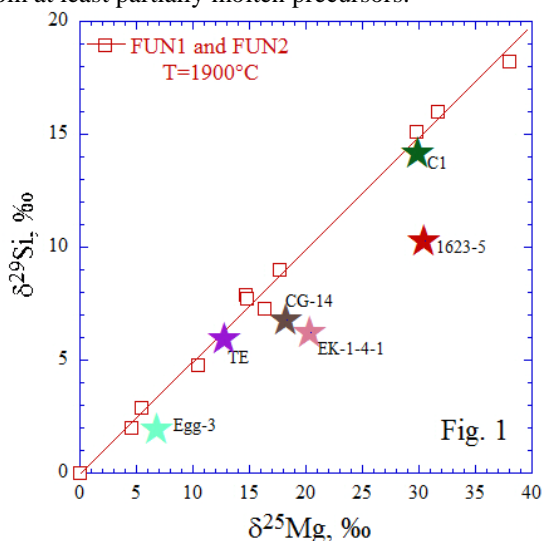


Fig. 1 shows Mg and Si isotopic compositions of natural FUN CAIs (stars) and MgO and SiO<sub>2</sub>-rich residues produced by experimental evaporation of two forsterite-rich melts (FUN1 and FUN2) into vacuum [3]. The bulk Mg and Si isotopic compositions of FUN CAIs plot surprisingly close to those of the evaporation residues, despite the fact that the residues have been produced by a single step isothermal (1900°C) evaporation while natural FUN CAIs could have experienced a more complex thermal history such as multiple heating and cooling events. While cooling to the solidus, Mg and Si would continue to evaporate from the CAI precursors and thus further fractionate the isotopes. If the fractionation law is temperature-dependent this could explain why EK-1-4-1 and 1623-5 are not on the trend defined by the other FUN CAIs and the experimental evaporation residues. Here we present the results of a new set of experiments on the chemical and

isotopic evolutions of FUN2 melt evaporated into vacuum at 1700°C.

**Experimental:** The starting material for the 1700°C vacuum evaporation experiments (FUN2B2) consists of 32.0 wt% MgO, 16.5% Al<sub>2</sub>O<sub>3</sub>, 39% SiO<sub>2</sub> and 12.5% CaO which is essentially the same as the FUN2 composition we used previously [3]. The experimental protocol was the same as described in detail in [3]. The run duration of the 1700°C experiments varied from 0 to 900 minutes.

**Analytical:** The chemical composition of the samples was measured using a JEOL JSM-5800LV scanning electron microscope equipped with an Oxford/Link ISIS-300 energy-dispersive X-ray microanalysis system. The isotopic compositions of the evaporation residues were analyzed by a sample-standard bracketing method using the Nu Plasma MC-ICPMS at the University of Arkansas (for magnesium isotopes) and the Thermo Scientific Neptune Plus MC-ICPMS at Trent University (for silicon isotopes). For the details regarding element purification by ion exchange and the isotopic measurements see [4] and [5].

**Results and discussion:** Evaporation trajectories of the residues from our earlier 1900° and new 1700°C evaporation experiments using the FUN1 and FUN2 starting compositions are shown in Fig. 2.

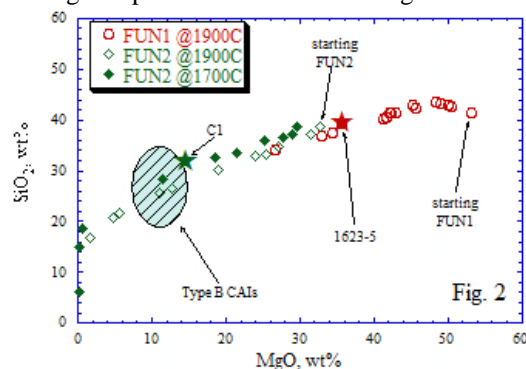


Fig. 2 shows that the evaporation trajectories of FUN2 residues are the same at 1900° and 1700°C experiments and continues the trend defined by the FUN1 residues toward the field of the normal CAIs. We note that the residues with >15 wt% MgO plot within forsterite field in the Geh-An-Fo diagram and quenched into a mixture of forsterite and glass, while the most evaporated residues with <15 wt% MgO plot

within melilite field and were quenched to a clear glass.

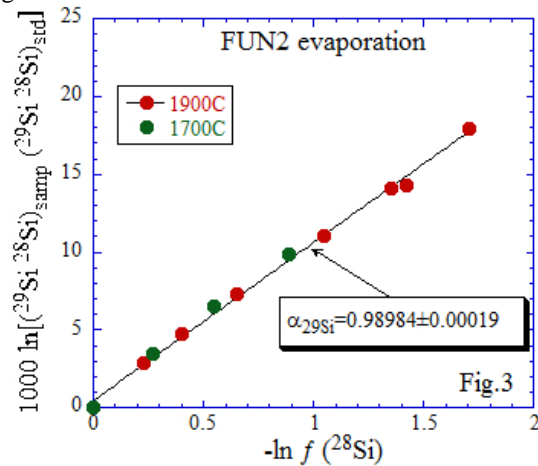


Fig. 3 shows the logarithm of the isotopic compositions of silicon in the residue relative to the starting ratio of FUN2 residues evaporated at both 1700° and 1900°C plotted as a function of the logarithm of the fraction  $^{28}\text{Si}$  remaining in the residues. When in such a plot the data fall along a straight line, the slope of the line corresponds to  $1 - \alpha_{29\text{Si}}$  where  $\alpha_{29\text{Si}}$  corresponds to the ratio of the isotopic composition of the evaporation flux to that of the evaporating substrate. The results clearly shows that FUN2 evaporation residues evaporated at both 1700° and 1900°C plot in Fig. 3 along a single line with a slope corresponding to the fractionation factor of  $^{29}\text{Si}$   $\alpha_{29\text{Si}} = 0.98984 \pm 0.00019$ . The value of  $\alpha_{29\text{Si}}$  for FUN2 residues is effectively the same as found earlier for FUN1 melt evaporated at 1900°C [3] and for CAI-like melt evaporated between 1600°C and 1900°C [6].

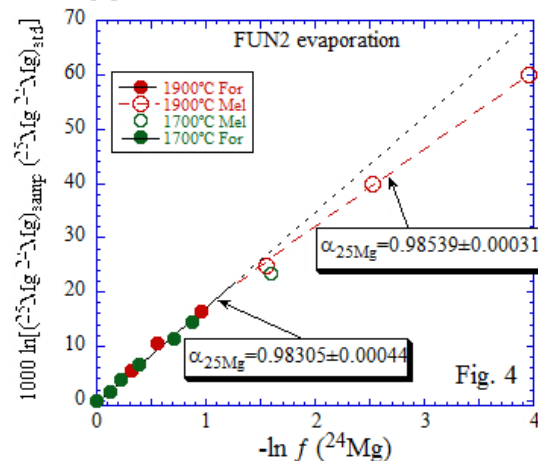


Fig. 4 shows the same as Fig. 3 but for the isotopic fractionation of magnesium. Similar to Si isotopes, we cannot resolve a temperature effect on the fractionation factor of Mg isotopes ( $\alpha_{25\text{Mg}} = 0.98305 \pm 0.00044$ ) for residues with >15 wt% MgO (closed symbols in Fig. 4). However, unlike Si isotopes, which are character-

ized with the same fractionation factors for all evaporation residues studied, fractionation factor  $\alpha_{25\text{Mg}}$  for FUN2 residues evaporated at 1900°C is significantly different for residues with <15 wt% MgO,  $\alpha_{25\text{Mg}} = 0.98539 \pm 0.00031$ . The later value is similar to  $0.98607 \pm 0.00017$  reported for Type B CAI-like melt evaporated at 1900°C [7]. Additional experiments at 1700°C will be needed to check whether the magnesium fractionation factor of the most evaporated FUN2 residues show the same temperature dependence as was found for CAI-like melts [7].

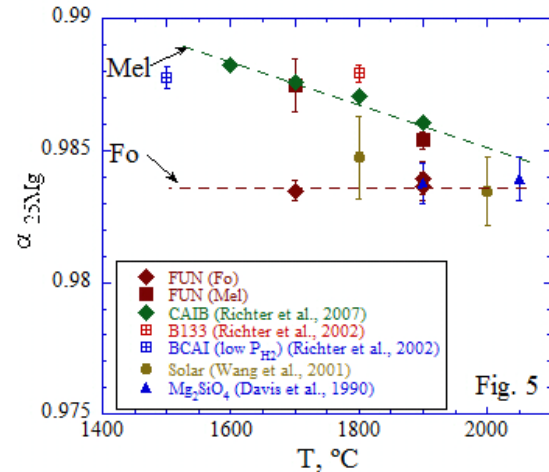


Fig. 5 is a summary plot showing the dependence of  $\alpha_{25\text{Mg}}$  on the melt composition: for the melts which plot within forsterite field in the Geh-An-Fo diagram,  $\alpha_{25\text{Mg}}$  is independent on temperature, but it is temperature dependent for melt compositions within the melilite field.

**Conclusions:** 1) Evaporation trajectories of Mg- and Si-rich melts are the same both 1900° and 1700°C. 2) Silicon isotopic fractionation law is independent of evaporation temperature and melt composition, and is the same as for CAI-like melts. 3) Magnesium isotopic fractionation law for the forsterite-rich melts is independent of temperature, but it is temperature dependent for the melilite-rich compositions. 4) Because of independence of  $\alpha_{29\text{Si}}$  and  $\alpha_{25\text{Mg}}$  on temperature and melt composition for the forsterite-rich melts, cooling of such droplet would not produce the Mg and Si isotopic fractionations of 1623-5 and EK-1-4-1 FUN CAIs.

**References:** [1] Clayton R. N. et al. (1988) *Phil. Trans. Roy. Soc. London*, 325, 483-501. [2] Krot A. N. et al. (2008) *LPS XXXIX*, Abstract #2162. [3] Mendybaev R. A. et al. (2013) *Geochim. Cosmochim. Acta* (accepted). [4] Teng F.-Z. et al. (2010) *Geochim. Cosmochim. Acta*, 74, 4150-4166. [5] Georg R. B. et al. (2006) *Ghem. Geol.*, 235, 95-104. [6] Knight K. B. (2009) *Geochim. Cosmochim. Acta*, 73, 6390-6401. [7] Richter F. M. (2007) *Geochim. Cosmochim. Acta*, 71, 5544-5564.