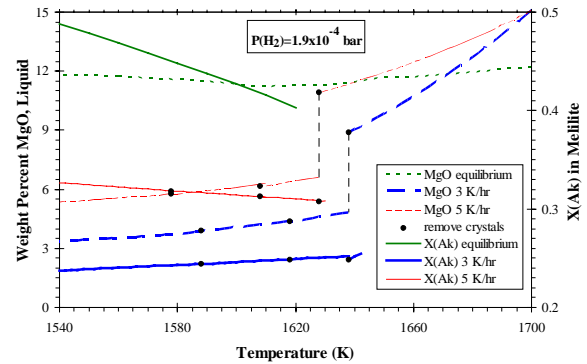


MELILITE ZONING DURING PARTIAL EVAPORATION OF CAI DROPLETS. D. S. Ebel and L. Grossman¹, Department of the Geophysical Sciences, 5734 South Ellis Ave., ¹also Enrico Fermi Institute, University of Chicago, Chicago, IL 60637 (debel@midway.uchicago.edu).

Introduction: The melilite solid solution series runs from gehlenite (Ge, $\text{Ca}_2\text{Al}_2\text{SiO}_7$) to akermanite (Ak, $\text{Ca}_2\text{MgSi}_2\text{O}_7$). Melilite crystals in Types A and B CAIs are often normally zoned: the molar fraction Ak (X_{Ak}), the lowest melting end-member, increases continuously from the core to the rim of individual crystals, due to isolation from the liquid of the first parts of the crystals to form during cooling by later melilite which coats them. Exceptions are reversely zoned bands inside crystals in Type Bs [1], and entire crystals which are reversely zoned in both Types A and B [1, 2]. The sequence of X_{Ak} in melilite expected during cooling of a CAI-type liquid can be inferred from known liquid-crystal phase relations [3,4] or, for a much wider range of compositions but less accurately, by computation using an activity-composition model for CMAS liquids [5], coupled with a similar model for melilite [6]. The melilite observed in a CAI, however, cannot be assumed to have crystallized from a melt having the bulk chemical composition of the CAI in which it resides, as the latter is merely the final composition reached by the inclusion. The liquid droplet from which the CAI formed lost large amounts of MgO and SiO_2 due to volatilization during cooling and crystallization [7]. The zoning profile of a melilite crystal is thus the result of a delicate balance between two processes: the thermodynamic tendency toward higher X_{Ak} at lower temperature and the progressive evaporative loss with time of MgO and SiO_2 , the components of Ak, from the parent liquid as it cooled.

Method: The starting composition was taken as the equilibrium solid condensate assemblage from solar gas at 1313K and 10^{-5} bar: 24.37 wt % CaO, 15.07 MgO, 30.79 Al_2O_3 , and 29.77 SiO_2 . We assumed that it was instantaneously heated to 1700K, the temperature (T) at which only a few melilite nuclei and some spinel exist in CAIB [3], and it was linearly cooled to the solidus, ~1500K. The evaporation rates of MgO and SiO_2 from droplets of CAI composition increase with increasing T and increasing $P(\text{H}_2)$ up to about 10^{-3} bar [8]. Using [8], if a CAI droplet with a typical radius of 0.5 cm were cooled from 1673K to 1500K in 1.90×10^{-4} bar H_2 at 5K/hr, the resulting evaporative loss of Mg would yield F_{Mg} of 5 %/amu [8], a typical CAI value. We calculated [7] the equilibrium $P_{\text{SiO}}=3.78 \times 10^{-6}$ bar over the liquid of [9] at their conditions [9], and calculated an evaporation coefficient, $\alpha_{\text{SiO}}=0.046$, from their evaporation rate of Si, J_{Si} [7, eqn.11]. We assumed $(\alpha_{\text{SiO}}/\alpha_{\text{Mg}})=1.347$ as in [7], and applied these α to all liquid compositions and T in what follows.

We calculated P_{SiO} and P_{Mg} as in [7], and calculated J_{SiO} and J_{Mg} at each 2K cooling step. From these, the droplet radius and cooling rate, we calculated the change in liquid composition due to evaporation for each T step, and then repeated the calculation at the next T step. The amounts and compositions (X_{Ak}) of crystalline phases that would be in equilibrium with each liquid were also calculated at each T.



Results: The variation with T of the liquid MgO content and X_{Ak} for each of two cooling rates, 3K/hr and 5K/hr, are shown in the figure. At selected T (marked ●), the liquid composition was further modified by subtraction of the equilibrium crystalline assemblage, to simulate the effect of fractional crystallization. Also shown for reference are results for equilibrium crystallization of the initial liquid, in which melilite crystallizes at 1620K and shows progressive increase in X_{Ak} from 0.40 to 0.49. At 3K/hr, melilite appears at 1642K and is reversely zoned from X_{Ak} of 0.26 to 0.23, primarily because so much time is spent at high T that evaporative losses of Mg outweigh effects of fractional crystallization. At 5K/hr, melilite crystallizes at 1630K and is normally zoned from X_{Ak} of 0.31 to 0.34 because evaporative losses are smaller. Although many simplifications have been made here, it can be concluded that slow cooling is much more conducive to development of reverse zoning in melilite. The total amounts of MgO and SiO_2 lost are also extremely sensitive to the maximum T.

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