

PHYSICAL CHEMISTRY OF REFRACTORY INCLUSIONS IN CV3 CHONDRITES. L. Grossman, Dept. Geophys. Sci. and Enrico Fermi Inst., Univ. of Chicago, Chicago, IL 60637. (yosi@midway.uchicago.edu)

The mineralogical compositions of Types A (perovskite + melilite + spinel), and B (melilite + spinel + fassaite clinopyroxene + anorthite) inclusions in CV3 chondrites match those of the highest temperature condensates (*e.g.*, 1500-1450K at 10^{-3} atm) predicted from thermodynamic calculations to form during cooling of a gas of solar composition, although bulk chemical compositions, particularly of Bs, are depleted in MgO and SiO₂ relative to CaO and Al₂O₃ compared to predicted compositions. Textural and mineralogical features indicate that, after condensation, compact Type As were melted at ~1800K and Type Bs at ~1700K. Phase equilibrium studies yield a solidus at 1500K and show that the equilibrium crystallization sequence is spinel, melilite, anorthite and fassaite. Melilite is a solid solution of gehlenite, Ge (Ca₂Al₂SiO₇) and åkermanite, Åk (Ca₂MgSi₂O₇). Because Ge has a higher melting point than Åk, melilite crystals that formed from a silicate melt have Ge-rich cores and Åk-rich rims, a feature referred to as normal zoning. Kinetic studies that reproduce narrow bands of reverse zoning (more Ge-rich toward the outside) observed within melilite crystals in Type Bs show that cooling rates were fast enough, ~ 0.5 to < 50 K/hr, that anorthite crystallized after fassaite. These rates are much greater than the cooling rate of the nebula, indicating local re-heating. The facts that the inclusions were molten and that the magnitude of oxygen isotope anomalies in different minerals does not decline in the same sequence as their crystallization temperatures give rise to the idea that the internal oxygen isotopic heterogeneity was established after the liquid froze. Fassaite has Ti³⁺/Ti⁴⁺ ~1, which is experimentally reproduced only at an oxygen fugacity of ~10⁻¹⁹ at 1500K, very close to that of a solar gas. This ratio varies from core to rim within individual fassaite grains, however, indicating interrupted liquid-gas equilibration during crystallization. Veins of fine-grained grossular, Ca-pyroxenes and feldspathoids that preferentially cross-cut melilite are evidence of secondary alteration, probably due to relatively low-temperature gas-solid reactions, that has affected inclusions in the oxidized subgroup of CV3s more than those in the reduced subgroup, and may be the cause of disturbed ²⁶Al-²⁶Mg isochrons. The inclusions are mass-fractionated favoring the heavy isotopes of Mg and Si, indicating that they underwent evaporation of 10-30% of their Mg and Si during the few-hour to few-week period that they were molten, and accounting for the discrepancy between their bulk chemical compositions and those of primitive condensates. Since more evaporation occurred and the temperature fell as time passed, calculations suggest that, within individual melilite crystals, the degree of Mg and Si isotopic mass-fractionation should increase with increasing Åk. Within some individual melilite crystals, the Na content increases with increasing Åk, indicating that the melilite crystallized from a Na-bearing liquid and thus that melting may have occurred after secondary alteration. Because Na is so much more volatile than Mg and Si, it is doubtful that Na would have been retained while Mg and Si were evaporating. In such cases, Mg and Si evaporation occurred in an earlier melting event, and isotopic zoning of melilite would have been erased in the later melting episode in which Na was retained.

References: Grossman L. (1980) *Ann. Rev. Earth Planet. Sci.* 8, 559-608. Grossman *et al.* (2002) *Geochim. Cosmochim. Acta* 66, 145-161.