A GROSSITE-RICH REFRACTORY INCLUSION FROM THE MURCHISON (CM) CHONDRITE

L. Kööp1,2,4, A. M. Davis1,2,3,4, P. R. Heck1,2,4, N. T. Kita5, D. Nakashima5,6, T. J. Tenner5,7, A. N. Krot8, C. Park8,9, and K. Nagashima9. 1Department of the Geophysical Sciences, 2Chicago Center for Cosmochemistry, 3Enrico Fermi Institute, University of Chicago, Chicago, IL, 4Robert A. Pritzker Center for Meteoritics and Polar Studies, Field Museum of Natural History, Chicago, IL, 5Department of Geoscience, University of Wisconsin, Madison, WI, 6Tohoku University, Sendai, Japan, 7Chemistry Division, Nuclear and Radiochemistry, Los Alamos National Laboratory, Los Alamos, NM, 8HIGP/SOEST, University of Hawai’i at Mānoa, Honolulu, HI, 9Korea Polar Research Institute, Incheon, Korea. E-mail: koeoep@uchicago.edu

Introduction: Grossite (CaAl₂O₄) is among the first minerals predicted to condense from a cooling gas of solar composition [e.g., 1]. Yet, grossite is rare in CAIs except in those from CH chondrites [e.g., 2]. In our study of >200 CAIs recovered from density separates of the CM2 chondrite Murchison, only one grossite-rich CAI, 2-6-1, was found. Here, we present its petrology and isotopic (O, Mg, Ca, and Ti) composition, and discuss its origin.

Petrology: 2-6-1 is a CAI fragment (~120 µm) composed mostly of grossite, and surrounded by a discontinuous rim of FeO-rich silicates (Fig. 1). Set inside the grossite are multiple inclusions, e.g., rounded perovskite grains (~10 µm) as well as polymetallic assemblages. Assemblage 1, ~15 µm in diameter, is fully enclosed by grossite (Fig. 1c). Its core consists of hibonite surrounded by an oval band of amoeboid sub-µm-sized Ca-Ti-rich oxide grains (perovskite?), which are set inside hibonite. A larger hexagon (~1 µm) of the oxide phase is located at the boundary between hibonite and grossite. EDS analyses show that both grossite and the hibonite are stoichiometric and contain no detectable MgO or TiO₂. Assemblage 2 occurs close to the edge of 2-6-1, and consists of oxide and silicate mineral layers. The first layer directly adjacent to interior grossite consists of small hibonite platelets (up to ~5 µm across) followed by spinel and anorthite layers.

Isotope compositions: The CAI has a high inferred initial ⁶⁷⁶³Al ratio, (~4-5)×10⁻⁵, and has no resolvable nucleosynthetic anomalies in Ca and Ti isotopes. Calcium is isotopically heavy (~16‰/amu); Ti is isotopically normal. The oxygen-isotope composition of 2-6-1 (Δ¹⁸O of ~ −17‰) is offset from the CCAM line by ~13‰ in δ¹⁸O. Note that isotopic values are approximate, as the analyses may be affected by the matrix effect as Madagascar hibonite was used as a standard [3].

Discussion and conclusion: The mineralogy of 2-6-1 bears resemblance with the sequence of minerals predicted to condense at high temperatures upon cooling of a solar gas [1], e.g., the hibonite enclosed within grossite and perovskite (assemblage 1) could be understood in the context of grossite and perovskite forming by a reaction of hibonite with the nebular gas. Isotopically heavy Ca in grossite suggests that 2-6-1 may have experienced melt evaporation. If this is the case, CAI 2-6-1 should be devoid of Si- and Mg-bearing phases [5,6]. The presence of anorthite and spinel close to the edge of the CAI (assemblage 2) may thus suggest that the grossite reacted with the solar nebular gas after crystallization. The concave shape of assemblage 2 (Fig. 1a) is supportive of grossite erosion. The presence of extremely Mg- and Ti-poor hibonite in the interior of the CAI (assemblage 1) is unusual. The lack of Ti may be a result of crystallization in a Mg-free melt, as Ti⁴⁺ commonly enters the hibonite lattice in coupled substitution.

Isotopically, CAI 2-6-1 resembles two platy hibonite crystals from Murchison (2-2-1 and 2-8-3), which also show large fractionation effects in Ca, but not in Ti and O [7]. However, 2-6-1 is depleted in ¹⁶O relative to 2-2-1 and 2-8-3. Similar to 2-6-1, postcrystallization reactions with the gas are likely required for 2-2-1 and 2-8-3 to explain the presence of isotopically normal magnesium in these grains. In summary, CAI 2-6-1 is a complex and unique object that likely formed in multiple stages involving melt distillation and reaction with the gas.


Fig. 1. (a) BSE image of CAI 2-6-1. (b) Layered EDS intensity map (repolished). (c) BSE image of assemblage 1.