Evidence for distillation in the formation of HAL and related hibonite inclusions

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INTRODUCTION

Refractory inclusions in carbonaceous chondrites have given us important insights into the processes that were operative in the early solar system. These objects exhibit enrichments in the refractory lithophile elements and are isotopically anomalous; the former indicate that high-temperature processes played an important role in the formation of the inclusions, while the latter require that high temperatures were not so pervasive in the early solar nebula as to cause large-scale volatilization, thereby homogenizing initial isotopic heterogeneities.

For some time the FUN inclusions have provided a focus in the search for isotopic anomalies because large effects were first found in these inclusions. The characteristic feature of FUN inclusions is mass-dependent isotopic mass fractionation accompanied by isotopic variations that cannot be explained by mass fractionation and were attributed to then Unknown Nuclear components (WASSERBURG et al., 1977). Isotopic anomalies have been found in every element analyzed from the several FUN inclusions that have been identified to date. The mass-dependent fractionation always consists of heavy-isotope enrichments, which are a characteristic feature of residues left after partial evaporation (CLAYTON et al., 1985; DAVIS et al., 1990). It is tempting to invoke a causal relationship between the presence of the nonlinear isotopic anomalies and mass-dependent fractionations in these inclusions, but no explanation for this link has been widely accepted.

The FUN inclusions do not differ substantially in mineralogy from the majority of Allende refractory inclusions, although certain mineralogical types, such as pink spinel-rich inclusions, appear to have a higher propensity for FUN characteristics than others (PAPANASTASSIOU and BRIGHAM, 1989). The Allende FUN inclusion HAL is noteworthy, not only for its unusual isotopic characteristics, but also because it is a large inclusion composed predominantly of hibonite. Hbonite-bearing inclusions are common in CM meteorites but are generally rather small (<200 μm). Hbonite crystal fragments from CM meteorites have been shown to be carriers of 48Ca and 60Ti isotopic effects an order of magnitude larger than those in FUN inclusions (IRLED, 1988, 1990), but the large "UN" anomalies in most of these hibonites are not associated with isotopic mass-fractionation "F."

LEE et al. (1980) proposed that the large mass-dependent isotopic fractionation effects of O and Ca in HAL were the result of severe evaporation whereby the light isotopes were preferentially removed to the gas phase, leaving behind an isotopically heavy residue that was also depleted in the more volatile elements. This evaporation event could also have been responsible for the lack of Mg-isotopic effects and the...