A HIBONITE-RICH MURCHISON INCLUSION WITH ANOMALOUS OXYGEN ISOTOPIC COMPOSITION: A. Hashimoto[1], R. W. Hinton[2], A. M. Davis[3], L. Grossman[1,2], T. K. Mayeda[2] and R. N. Clayton[1,2,4]. [1]Dept. of Geophysical Sciences, [2]Enrico Fermi Institute, [3]James Franck Institute, [4]Dept. of Chemistry, University of Chicago, Chicago, IL 60637.

SH-7 is an ∿2 mm diameter, lens-shaped, hibonite-rich inclusion found by Dr. E. Olsen on a broken surface of the Murchison meteorite. It is by far the largest refractory inclusion recovered from a C2 chondrite. The large size allowed the first measurement of oxygen isotopes in an individual refractory inclusion from a C2 chondrite. When viewed on the broken surface, the central part of the inclusion was a porous aggregate of 100-200 μm, light blue, platy crystals, intergrown with a minor amount of small white crystals. Rimming this area is an ∿50 μm thick white zone which separates the inclusion from the Murchison matrix. Virtually all of the inclusion, ∿1.7 mg, was excavated from the matrix. Although most of the inclusion was used for oxygen isotopic analysis, small samples were taken for INAA and for preparation of a polished grain mount for petrographic and ion probe studies.

Oxygen isotopic analysis gave $\delta^{18}O$ = -25.90‰ and $\delta^{17}O$ = -26.59‰. During sample preparation for isotopic analysis, silicon is converted to SiF_4. A low SiF_4 yield was found for SH-7, indicating little silicate was present, and X-ray diffraction of a split of the sample shows that the material taken for isotopic analysis was nearly pure hibonite with traces of perovskite, melilite and possibly spinel and diopside. The remarkable feature of the oxygen isotopic composition of SH-7 is that it is displaced from the Allende oxygen isotope mixing line in the opposite direction from Allende FUN inclusions. SH-7 lies -2.3 ± .2‰ (2σ) in the $\delta^{18}O$ direction or +2.1 ± .2‰ in the $\delta^{17}O$ direction from the least squares line through all data points for non-FUN Allende inclusions and mineral separates therefrom. Oxygen isotopic analyses of olivine- and pyroxene-rich density separates and a spinel-rich acid residue, 2C10c200, from bulk Murchison define a straight line parallel to, but slightly displaced from, the Allende mixing line by 0.8‰ (1), also in the opposite direction from Allende FUN inclusions. SH-7 is also significantly displaced from this mixing line by -1.5 ± .4‰ in the $\delta^{18}O$ direction or +1.3 ± .4‰ in the $\delta^{17}O$ direction. Because of the unusual oxygen isotopic composition of SH-7, we performed the following petrographic, mineralogical and chemical studies to see if it has any unusual properties compared to those of other refractory inclusions in Murchison.

The polished grain mount was made from a 400 x 125 μm piece of SH-7, most of which was blue but which also had a small amount of attached white material. SEM study shows that it is composed almost entirely of hibonite which poikilitically encloses 1-8 μm euhedral perovskite crystals and sparse, 5-10 μm melilite grains. The hibonite also contains rectangular cavities, some of which are adjacent to and embay melilite. No secondary alteration phases were found in the cavities. A band of melilite, 15 μm wide and 170 μm long, covers one edge of the hibonite and corresponds to the attached white material seen in the rough sample. Spinel was not observed. The great abundance of hibonite and relatively small amount of melilite in SH-7 are typical of many refractory inclusions in Murchison (2), but the absence of spinel is most unusual.

Nine analyses of hibonite by electron microprobe (EPMA) gave 4.6 - 5.3 wt.% TiO_2, 2.2 - 2.5 wt.% MgO and <0.10 wt.% FeO. Concentrations of Si, Sc and V are 200-2500, 300-1200 and <200 ppm, resp., by EPMA. Two hibonite analyses, spot #1 and #2, by ion probe gave 700 and 1450 ppm for Si, 230 and 280 ppm for Sc, and 30 and 60 ppm for V, resp. The minor and trace element contents of SH-7 hibonite are thus within the ranges previously reported for Murchison hibonite (2,3). Melilite in SH-7 is nearly pure gehlenite, Åk 0.5 - 1.1, like melilite from some blue spherules and melilite-rich inclusions in Murchison (2).

INAA was performed on a 17 μg sample. Although it was entirely blue, the Ca and Ti contents suggest that some perovskite and melilite are present. The sample has a group III REE pattern, with most REE being enriched relative to C1 chondrites by a factor of ∿70 and Eu and Yb being depleted by a factor of >2 relative to them. Such patterns are common in hibonite-rich inclusions in Murchison (4). SH-7 is very low in V, 45 ± 20 ppm, and contains significant Ir, 2.7 ppm. Ion microprobe analyses of the two spots show that REE patterns vary within hibonite.

Those from spot #1 and the first 5 mass sweeps from spot #2 are typical of hibonite (5), either flat or gently sloping from La to Gd, then dropping sharply to Lu. Upon this pattern are superimposed negative Eu and Yb anomalies. C1 chondrite-normalized enrichment factors for La, Eu, Gd and Lu on spot #1 are 48, 11, 36 and 3, resp. On spot #2, the last 3 mass sweeps revealed a remarkable enhancement of heavy relative to light REE compared to the first 5 mass sweeps. The C1-normalized Ho/La ratios for the first 5 and last 3 sweeps were ∿0.5 and ∿16, resp. It is likely that the change in REE pattern is due to penetration of the ion beam into a buried perovskite grain, as this phase appears to favor heavy relative to light REE. Thus, SH-7 has a group III REE pattern overall, with heavy REE depleted relative to light REE in hibonite and enriched relative to light REE in perovskite.

Mg isotopic compositions determined by ion microprobe showed no mass fractionation in hibonite (Δ^{25}Mg = 0.5 ± 5‰/amu), as in the case of most Murchison hibonite analysed previously (6). No excess ^{26}Mg was found. In hibonite, δ^{26}Mg = -1.9 ± 2.8‰ and ^{27}Al/^{24}Mg = 35, implying $(^{26}Al/^{27}Al)_o < 3.6 \times 10^{-6}$. In melilite, δ^{26}Mg = -2.8 ± 7.6‰ and ^{27}Al/^{24}Mg = 222, implying $(^{26}Al/^{27}Al)_o < 3.0 \times 10^{-6}$. In lacking a ^{26}Mg excess, SH-7 is like DJ inclusions, MUCH-1 and BB-6 (6) and unlike some blue spherules, MUM-1 and the Blue Angel (6,7,8).

The only other sample that contains material from refractory inclusions in Murchison and whose oxygen isotopes have been measured is 2C10c200, an ∿50 mg acid residue (9) composed of ∿95% Mg-spinel and ∿5% Fe-, Cr-spinel and hibonite. This sample, which should be regarded as being close to the average spinel from refractory inclusions in Murchison, has δ^{18}O = -39.79 and δ^{17}O = -41.07 and plots at the extreme low end of the oxygen isotope mixing line for Murchison. HAL and Al NO-1, both from Allende, are the only other hibonite-rich inclusions whose oxygen isotopes have been measured. HAL, a FUN inclusion, plots well to the ^{18}O-rich side of the mixing line for Allende. Interestingly, the highest-density, most hibonite-rich fraction of Al NO-1 plots quite close to the composition of SH-7 at δ^{18}O = -24.3 and δ^{17}O = -26.5 (10) and significantly off the Allende mixing line to the ^{18}O-poor side.

Each point through which the oxygen isotope mixing line for Murchison is drawn represents an olivine + pyroxene separate or spinel separate from a bulk meteorite sample and is thus an average isotopic composition of material from many different inclusions and chondrules. Possibly, hibonite crystals from individual inclusions in Murchison scatter about this mixing line and the predominantly hibonite sample from SH-7 measured here is merely a relatively ^{18}O-poor member of this population. Alternatively, hibonite in SH-7 may be isotopically anomalous compared to that in other Murchison inclusions, which would require a special explanation for its isotopic composition. An intriguing idea, suggested by the anomalous isotopic composition of the hibonite-rich sample of Al NO-1 compared to other Allende samples and by the fact that SH-7 is the only hibonite-rich sample from Murchison whose oxygen isotopic composition has been measured, is that the oxygen isotopic composition of all hibonite from both meteorites is anomalous. To determine which possibility is correct, more oxygen isotopic data are needed for individual inclusions from Murchison, particularly hibonite-bearing ones, and also for hibonite-rich separates from Allende inclusions. Hopefully, petrographic and chemical data presented here will serve as a guide for such future work.

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