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Oxygen isotopic composition of the solar nebula gas inferred from high-precision isotope imaging of melilite crystals

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High-precision isotope imaging analyses of reversely zoned melilite crystals in the gehlenitic mantle of Type A CAI ON01 of the Allende carbonaceous chondrite reveal that there are four types of oxygen isotopic distributions within melilite single crystals: (1) uniform depletion of ^{16}O (delta-^{18}O = -10 permil), (2) uniform enrichment of ^{16}O (delta-^{18}O = -40 permil), (3) variations in isotopic composition from ^{16}O-poor core to ^{16}O-rich rim (delta-^{18}O = -10 permil to -30 permil, -20 permil to -45 permil, and -10 permil to -35 permil) with decreasing akermanite content, and (4) ^{16}O-poor composition (delta-^{18}O $>$ -10 permil) along the crystal rim. Hibonite, spinel, and perovskite grains are ^{16}O-rich (delta-^{18}O = -45 permil), and adjoin ^{16}O-poor melilites. Gas-solid or gas-melt isotope exchange in the nebula is inconsistent with both the distinct oxygen isotopic compositions among the minerals and the reverse zoning of melilite. Fluid-rock interaction on the parent body resulted in ^{16}O-poor compositions of limited areas near holes, cracks, or secondary phases, such as anorthite or grossular. We conclude that reversely zoned melilites mostly preserve the primary oxygen isotopic composition of either ^{16}O-enriched or ^{16}O-depleted gas from which they were condensed. The correlation between oxygen isotopic composition and akermanite content may indicate that oxygen isotopes of the solar nebula gas changed from ^{16}O-poor to ^{16}O-rich during melilite crystal growth. We suggest that the radial excursions of the inner edge of the protoplanetary disk gas simultaneously resulted in both the reverse zoning and oxygen isotopic variation of melilite, due to mixing of ^{16}O-poor disk gas and ^{16}O-rich coronal gas. Gas condensates aggregated to form the gehlenite mantle of the Type A CAI ON01.

Keywords: Chondrite, Melilite, CAI, SIMS, Oxygen isotope imaging, Solar nebula gas