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Oxygen Isotopes in Chondritic Interplanetary Dust: Parent-Bodies and Nebular Oxygen Reservoirs

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OXYGEN ISOTOPES IN CHONDRITIC INTERPLANETARY DUST : PARENT-BODIES AND NEBULAR OXYGEN RESERVOIRS. J. Aléon[1] , K. D. McKeegan[2] and L. Leshin[3]. [1]LLNL, Glenn T. Seaborg Institute, Livermore CA 94550, aleon2@llnl.gov . [2]UCLA, Earth and Space Sciences, Los Angeles CA 90095-1567, [3]NASA Goddard Space Flight Center, Greenbelt MD 20771.

Introduction: Planetary objects have preserved various amounts of oxygen issued from isotopically different oxygen reservoirs reflecting their origin and physico-chemical history [1]. An ^{16}O-rich component is preserved in refractory inclusions (CAIs) whereas meteorites matrices are enriched in an ^{16}O-poor component [2]. The origin of these components is still unclear. The most recent models are based on isotope selective photodissociation of CO in a ^{16}O-rich nebula/presolar cloud resulting in a ^{16}O-poor gas in the outer part of the nebula [3-5]. However because most meteorite components are thought to be formed in the inner 3AU of the solar nebula, the precise isotopic composition of outer solar system components is yet unknown. In that respect, the oxygen isotopic composition of cometary dust is a key to understand the origin of the solar system. The Stardust mission will bring back to the Earth dust samples from comet Wild2, a short period comet from the Jupiter family. A precise determination of the oxygen isotope composition of Wild2 dust grains is essential to decipher the oxygen reservoirs of the outer solar system. However, Stardust samples may be extremely fragmented upon impact in the collector. In addition, interplanetary dust particles (IDPs) collected in the stratosphere are likely to contain comet samples. Therefore, we started to investigate the oxygen isotopic composition of a suite of chondritic interplanetary dust particles that includes IDPs of potential cometary origin using a refined procedure to increase the lateral resolution for the analysis of Stardust grains or IDP subcomponents down to ~ 3 µm. High precision data for 4 IDPs were previously reported by [6], here we have measured 6 additional IDPs.

Analytical techniques: O isotopes were measured with the CAMECA IMS 1270 at UCLA in two different modes. IDPs were pressed into high purity gold foils and all measurements were done using the electron flood gun for charge compensation at the micrometer scale. A liquid N trap was used to limit contamination. The mass resolving power (MRP) was > 5000 to avoid contribution of the OH peak at mass 17. Data were corrected for background of the detectors and dead time of the electron multiplier. In the absence of OH tail and linear drift corrections, the results must be considered preliminary.

High precision analyses (HP) were performed using a defocused 20-30 µm Cs+ beam of 0.3 nA. ^{16}O, ^{17}O and ^{18}O were acquired in 30 cycles of 2, 10, 10 s, respectively, on a Faraday Cup (^{16}O) and an electron multiplier (EM, ^{17}O and ^{18}O). Pressure in the chamber was below 5×10^{-9} Torr. Standards were polished sections of a San Carlos olivine and a Burma spinel. In this mode, we obtained bulk O isotopic composition for most particles except L2036 R5, a big IDP, for which 3 analyses were taken. In these conditions, the overall precision on the samples is about 2 ‰ (2 σ).

High lateral resolution analyses (HR) were performed using a 2-3 µm Cs+ beam of 5 pA. All isotopes were measured on the EM. Because of a higher sensitivity to background contamination, all analyses were done with a pressure below 2×10^{-9} Torr. Standards were crushed grains of a San Carlos olivine mounted on Au. A first bulk analysis of each particle was obtained using a raster adjusted to the particle. ^{16}O-images on the EM were used to locate subcomponents larger than 3 µm and the raster was adjusted to analyze these components. The typical precision was better than 6 ‰ for δ^{18}O and 10‰ for δ^{17}O (2 σ).

Samples: All IDPs were mapped by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy before analysis to have an estimate of their morphology and mineralogy. H and N isotopes were available for some of the particles [7,8].

L2021 K1: Re-examination of the particle by SEM after O isotope analysis revealed that it was contaminated by a dust particle. The oxygen results were thus discarded.

L2036 R5: Smooth, non-cluster, 70 µm IDP. The H content suggests the particle is hydrated. It contains Fe-rich framboids, probably magnetite (mt).

L2021 A6: Fluffy porous cluster IDP < 8 µm, with δD up to 1900 ‰. The residue from H analysis was sputtered away during measurement resulting in a significant amount of contamination.

L2036 B3: Cluster IDP ~10 µm with smooth texture and Fe-rich framboids, probably mt. A 5 µm mt-rich region was analyzed individually by HR analysis.

L2021 N3: Cluster IDP ~11 µm, fluffy porous with Fe-rich and Ca-Al-rich grains. It contains a 5 µm crystal extremely Mg-rich probably forsteritic olivine, which was analyzed individually by HR analysis.

L2036 W1: Extremely fine-grained cluster IDP ~10 µm with homogeneous chondritic composition. Grain-size is < 100 nm from SEM images.

K1, R5 and B3 are probably hydrated IDPs of possible asteroidal origin, whereas A6, N3 and especially

W1 are probably chondritic porous anhydrous IDPs of possible cometary origin.

Results and discussion: All IDPs have bulk compositions comparable to chondritic components, close to the terrestrial fractionation (TF) line.

Hydrated IDPs (R5, B3 and U222C6 [6]) have the typical composition of hydrated chondrite matrices, suggesting that such IDPs are indeed from similar parent bodies. Notably, B3 has a very heavy composition similar to metamorphosed CI chondrites [9].

Anhydrous IDPs, on the other hand seem to align closely to the slope 1.00 line observed in several CAIs [e.g. 10], both above and below the TF line. Coarse-grained olivine (N3) and pyroxene [6] are similar to the bulk particles.

Interestingly, W1 shows a slight ^{16}O depletion comparable with mt from unequilibrated ordinary chondrites [11]. However, its granulometry and chemical homogeneity suggests it may contains glass with embedded metal and sulfides (GEMS). This is at odd with the previous report of a ^{16}O-rich GEMS-rich IDP [6]. Both IDPs could come from different parent bodies. Knowing the mineralogy of W1 will be essential for the interpretation of O isotopes.

Thus, potentially cometary IDPs do not show large isotope anomalies that would indicate that their parent bodies extensively sampled exotic oxygen reservoirs such as the ^{16}O-rich CAI-type reservoir or an ^{16}O-poor outer solar nebula gas expected from self-shielding models. Either these particles are not cometary and come from anhydrous chondrite matrices or the rocky component of comets is much more similar to carbonaceous chondrites than previously expected and is more akin to typical planetary materials than pristine interstellar dust. We note that not all comets may have sample the same nebular oxygen reservoirs.

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Figure 1 : Oxygen isotopes in chondritic IDPs. Grey symbols are literature data. Filled symbols are HP data and hollow symbols are HR data. Abbreviations other than in text are as follow : YR – Young and Russell, UOC - Unequilibrated Ordinary Chondrites, CCAM – Carbonaceous Chondrite Anhydrous Minerals, Ol – olivine. For clarity only 1σ error bars on IDP data have been reported