HYDRATED INTERPLANETARY DUST PARTICLES: IMPLICATIONS FOR OXYGEN RESERVOIRS IN THE OUTER SOLAR SYSTEM.

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Introduction: A re-evaluation of solar energetic particle (SEP) track densities in interplanetary dust particles (IDPs) show that many are derived from outer solar system parent bodies such as Kuiper belt objects (KBOs) or beyond [1]. Kuiper belt objects are widely believed to represent the frozen remnants from the birth of the solar system. The population of track-rich IDPs include members from both the anhydrous chondritic-porous and hydrated chondritic-smooth classes [1] and earlier work suggested that the hydrated IDPs may represent anhydrous IDP material that was aqueously altered [2, 3]. We are performing systematic studies of the mineralogy, chemistry and isotopic compositions of track-rich IDPs to gain a fuller understanding of the origin and evolution of KBOs. Here, we focus on the identification of hydrated Kuiper belt dust particles that allows for the direct evaluation of their O isotopic compositions and the implications for the oxygen isotopic composition of outer solar system ices.

Results: We have previously reported on the mineralogical and chemical properties of track-rich hydrated IDPs [4] and are briefly summarized here. Their mineralogy is dominated by fine-grained Mg-rich phyllosilicates (saponite and lesser serpentine) with finely dispersed Fe,Ni-sulfide grains (pyrrhotite and pentlandite), and Mg-Fe carbonates. The hydrated IDPs are superficially similar to CI chondrite materials but there are distinct differences. The hydrated IDPs are far more carbon-rich than CI (~4X CI on average) and contain carbon nanoglobules in addition to abundant finely dispersed carbonaceous material in the phyllosilicates. Unlike the CI chondrites, indigeneous magnetite is rare, and no Ca-rich carbonates ($CaCO_3$ or dolomite) are reported in hydrated IDPs, only $MgCO_3$-$FeCO_3$ compositions (breunnerites). The fine-grained Fe-Ni sulfides are not uniformly distributed, but occur in sub-micrometer-sized clusters within the phyllosilicate matrix of the IDPs.

The O isotopic compositions of track-rich hydrated IDPs fall within error of the slope 1 line in a plot of $\delta^{17}O$ versus $\delta^{18}O$, with the majority plotting in a region above the terrestrial fractionation line that is distinct from known hydrated carbonaceous chondrite meteorite groups [4]. The mineral assemblages in track-rich hydrated IDPs are consistent with low alteration temperatures (<100°C) and the presence of Fe^{2+} carbonates and the general lack of magnetite suggest that the alteration conditions were not as oxidizing as in the CI chondrites.

Discussion and Conclusions: Amorphous silicate grains with nanophase inclusions of FeNi metal and sulfides (e.g., GEMS grains) were the likely precursors to the phyllosilicates in hydrated IDPs based on observations of IDPs with mixed anhydrous/hydrated mineralogy, and the ease of aqueous alteration of GEMS grains from laboratory experiments [3]. Using the average GEMS grain bulk chemical composition from [5], but assuming that the sulfide component of GEMS does not participate in the alteration reaction, and further assuming the fluid is pure H_2O, an idealized alteration reaction can be written as:

$$4[(Mg_{0.65}Fe_{0.10})SiO_{2.75}] + 4(Fe_{0.14}) + 1.56H_2O = (Mg_{2.7}Fe_{0.3})Si_4O_{10}(OH)_2 + 0.56FeO + 0.56H_2$$
$$\text{GEMS} + \text{Fe metal} + \text{water} = \text{saponite} + \text{Fe-oxide} + H_2\text{ gas}$$

We assume an average O isotopic composition of ~($\delta^{18}O$,$\delta^{17}O$ = -6‰, -7‰) for GEMS and GEMS-rich IDPs using data from [5-7] and an average O isotopic composition of ~($\delta^{18}O$,$\delta^{17}O$ = +11‰, +10‰) for track-rich hydrated IDPs. From the reaction given above, we note that only 1.56 O out of a total of 12.56 O in the reaction products (~12%) come from the fluid phase. Using these averages, we estimate the O isotopic composition of the H_2O in the reaction as ~($\delta^{18}O$,$\delta^{17}O$ = +140‰, +140‰).

The number of hydrated IDPs with well-constrained isotopic compositions and coordinated track measurements is still small however, and the actual O isotopic composition of GEMS grains exhibits a wide range close to the terrestrial value [5]. Furthermore, the fluid phase was unlikely to be pure H_2O as the fluid was probably a mixed H_2O-CO_2 fluid in order to explain the minor but ubiquitous Mg-Fe carbonates in these IDPs. Regardless of these caveats, the combination of the SEP track densities, mineralogy, and O isotopic compositions of hydrated IDPs provide the first direct evidence of a ^{16}O-poor H_2O reservoir in the outer solar system.

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