INVESTIGATING THE ORIGIN OF OXYGEN ISOTOPIC VARIATIONS IN METEORITES.

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Introduction: Oxygen isotopic analysis is a powerful tool in understanding the origin and history of meteorites. Different meteorite groups can be discriminated using oxygen isotopic ratios. Oxygen isotopic analyses have also identified extremely ^{16}O-rich refractory inclusions. One example are CAIs (calcium-aluminum-rich inclusions), which are believed to be the first condensates that formed in the nebula. Another example of ^{16}O-rich refractory inclusions are AOAs (amoeboid olivine condensates). Analyses of solar wind particles returned by the Genesis spacecraft indicate that the Sun has a bulk oxygen isotopic composition not far removed from that of "pristine" CAIs [1]. We are currently undertaking modeling to investigate how the oxygen isotopic variations seen in meteorites can be related to mixtures of simple end-member nebula components.

Oxygen Isotope Trends: There is considerable overlap in three-oxygen isotopic space between meteorites that fall in the CC (carbonaceous chondrite) region and those that fall in the NC (non-carbonaceous) region in a plot of ε^{54}Cr versus Δ^{17}O [2]. While nucleosynthetic anomalies such as ε^{54}Cr and ε^{50}Ti can be used to easily separate CC and NC meteorites, Δ^{17}O does not. Chromium and titanium are minor elements in meteorites; however, oxygen is a major element with abundances of ~50% in most meteorites.

The three-oxygen isotope diagram has a number of apparent compositional trends that do not appear random. For example, the "distance" (Δ^{17}O) that the enstatite, ordinary, and R chondrites fall away from the terrestrial fractionation line (TFL) appears correlated with the sequence that their primary mineral would have condensed out in the solar nebula [3]. Almost all known carbonaceous chondrites fall below the TFL. Almost all known meteorites that experienced melting fall below or on the TFL.

Model: Since so little is known about the oxygen isotopic composition of different constituents of the solar nebula and how they exactly combined to produce the variations that we see today in meteorites, our modeling is relatively simple and uses only three components. We mix material with a solar oxygen isotopic composition with material with a non-solar composition and water ice. We assume that the solar component had an oxygen isotopic composition similar to that of refractory inclusions and the Sun with a $\delta^{17}O = -50‰$ and a $\delta^{18}O = -50‰$. We use a variety of different possible oxygen isotopic compositions for the non-solar component and the water ice. At 1% increments, we adjusted the molar fractions of the three components from 0 to 100%.

One of the possibilities examined is whether oxygen isotopic variation in meteorites could be primarily due to the incorporation of ^{16}O-rich CAIs (or CAI-like) and AOAs that were subsequently "destroyed". We use the terms "CAI-like" or "refractory inclusion-like material" to recognize the difficulty of breaking down minerals like spinel (Mohs hardness of 7.5-8), which is a common constituent of CAIs. The refractory inclusions that we see today would have been incorporated "later" into their parent bodies or been "luckier." In this model, the Δ^{17}O value for a particular meteorite group would be primarily due to the abundances of refractory inclusions (or refractory inclusion-like material) incorporated by their parent body. Bodies that melted would have either formed earlier or accumulated more refractory inclusions (or refractory inclusion-like material) than bodies that did not melt.

Results: Since two of the three components have oxygen isotopic values that are unknown, our results are very unconstrained. However, the assumption that the condensing material had a $\delta^{17}O = 7‰$ and a $\delta^{18}O = 5‰$ and the water ice had a $\delta^{17}O = 35‰$ and a $\delta^{18}O = 55‰$ [4] does produce "destroyed" refractory inclusion (or refractory inclusion-like) concentrations that seem plausible and could produce the apparent trends on the oxygen isotopic diagram. We are also investigating scenarios where the condensing dust had a solar oxygen isotopic composition and incorporated a non-solar component plus water ice.

Conclusions: Our modeling attempts to gain insight on why a number of compositional trends are apparent on the three-oxygen isotopic diagram. Any model for forming the Solar System should also produce the distribution of oxygen isotopic ratios found for different meteorite parent bodies.

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