LIGHTNING PROCESSING OF DUST IN THE SOLAR NEBULA.

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Introduction: The remarkable discovery that oxygen isotopes in primitive meteorites were fractionated along a line of slope 1 rather than along the typical slope 0.52 terrestrial fractionation line occurred almost 40 years ago [1]. However, a satisfactory, quantitative explanation for this observation has yet to be found, though many different explanations have been proposed. The first of these explanations proposed that the observed line represented the final product produced by mixing molecular cloud dust with a nucleosynthetic component, rich in ^{16}O, possibly resulting from a nearby supernova explosion.

Donald Clayton [2] suggested that galactic chemical evolution would gradually change the oxygen isotopic composition of the interstellar grain population by steadily producing ^{16}O in supernovae, then producing the heavier isotopes as secondary products in lower mass stars. Thiemens and collaborators proposed a chemical mechanism that relied on the availability of additional active rotational and vibrational states in otherwise-symmetric molecules, such as CO_2, O_3 or SiO_2, containing two different oxygen isotopes [3, 4] and a second, photochemical process that suggested that differential photochemical dissociation processes could fractionate oxygen [5]. This second line of research has been pursued by several groups [6, 7], though none of the current models is quantitative.

Lightning as the Processing Agent: Based on experiments [8] done at GSFC that produced nonmass-dependently fractionated solid oxides from plasma, we have previously suggested [9] that dust processed via nebular lightning could explain the observed oxygen isotopic distribution in the solar system. Necessary conditions for nebular lightning have been previously discussed [10–12] and we will present preliminary work suggesting that lightning is a major component of protostellar nebulae. We will also present preliminary results of the time dependent evolution of oxygen isotopes in nebular dust and the largest uncertainties that remain in the model.

Other Consequences of Lightning Induced Oxygen Isotopic Fractionation: If the average isotopic composition of nebular dust increased from that of the sun up to that of SMOW, a change of 50 per mil, then a lot of dust destruction must have occurred. We will investigate the consequences for the preservation of presolar solids in such an environment and present an assessment of the probability of an individual presolar grain surviving to become incorporated into meteorite parent bodies. We will also look into the probability that organic grain coatings formed by Fischer-Tropsch type reactions survived lightning induced processing. As such materials should have been produced continuously, and the rate of their destruction may have been a time dependent phenomenon (an exponential decrease) the earliest formed materials might be rare, but those formed later could potentially survive for quite well.

Finally, if the nebula experiences large scale processing of dust grains via evaporation and recondensation of the resultant vapor phase materials, then it is reasonable to examine the grain size spectrum predicted to prevail in the nebula. Were this grain size spectrum to change over the course of nebular evolution, this might easily effect the triboelectric grain charging efficiency or the probability and degree of charge separation due to turbulence. We will examine the grain size distributions produced in the aftermath of nebular lightning under various assumptions concerning the cooling rate of the gas.

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