A SIMPLE MECHANISM FOR FRACTIONATING OXYGEN ISOTOPES IN THE SOLAR NEBULA

Joseph A. Nuth III Solar System Exploration Division, Code 691, NASA's Goddard Space Flight Center, Greenbelt MD 20771 Joseph.A.Nuth@NASA.gov

Lightning in the Solar Nebula is caused by the tribo-electric charging of dust grains carried by massive turbulent flows and driven by the accretion energy in the disk (1): it has long been one agent assumed responsible for the formation of chondrules (2). The degree to which charge separation can occur is dependent upon a number of factors, including the concentration of radioactive sources and the total level of ionization in the nebula, and these factors determine the maximum energy likely to be released by a single bolt. While chondrule formation requires a massive discharge, even a small lightning bolt can vaporize grains in the ionized discharge channel. Experimental studies have shown that silica, iron silicate and iron oxide grains formed from a high voltage discharge in hydrogen rich gas containing some oxygen produces solids that are enriched in ^{17}O and ^{18}O relative to the composition of the starting gas (3). Vaporization of silicates produces SiO, metal and free oxygen atoms in each discharge and these species will immediately begin to recondense from the hot plasma. Freshly condensed grains are incrementally enriched in heavy oxygen while the gas is enriched in ^{16}O. Repeated evaporation and condensation of silicates (4) in continuously occurring lightning discharges will monotonically increase the fractionation of oxygen isotopes between the ^{17}O and ^{18}O rich dust and the ^{16}O rich gas.

The first mass independently fractionated refractory oxide particles were produced in the lab (3) following the condensation of a flowing gas mixture containing variable amounts of hydrogen, silane, pentacarbonyl iron and oxygen that passed through a high voltage discharge powered by a Tesla coil. While the exact chemical pathway (3) is still uncertain, the most probable reaction mechanisms involve oxidation of the growing refractory clusters by O_3, OH or O atoms. This model has some interesting consequences for chemical processes in the early solar nebula.

Chemical fractionation of recondensed dust evaporated via lightning discharges should be strongly time dependent. At earlier times, the accretion rate is maximal, thus driving strong turbulence, energetic grain-grain collisions, tribo-electric charging and charge separation, leading to frequent, powerful lightning discharges (1). As the accretion rate diminishes, turbulence decreases and lightning discharges will become both less powerful and less frequent, thus decreasing the rate of dust-gas fractionation. The most rapid increase in the formation of ^{16}O poor dust will occur early in nebular history. Generation of fractionated dust should be distributed throughout the inner disk. Once condensed, grain dispersal (5, 6) would average out any significant isotopic anomalies within the inner disk.

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