Evolution of oxygen isotopic and chemical composition in the early inner solar nebula due to fluctuation of disk accretion rate

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Primitive meteorites have mass-independent fractionation of oxygen isotope. They also contain both components which formed under oxidized environment and formed under reduced environment. It is one of the most important problems left for the present planetary formation theory to explain the scenario of material formation that achieves the feature of such isotopic and chemical composition.

For the problem of oxygen isotope, Yurimoto & Kuramoto (2004) have presented the following model: 16O-poor water ice made in the molecular cloud core is transported into the solar nebula and accretes toward the proto-Sun with nebula gas. Accretion velocity of dust is larger than that of gas due to gas drag. These velocities strongly depend on the mass accretion rate, and accretion velocity ratio of dust/gas increases with decay of the disk accretion. The dust particles partially evaporate when the temperature of the ambient nebula gas exceeds the sublimation points of dust constituents. According to the difference in the accretion velocities between gas and dust, evaporants concentrate compared to the solar composition in the downstream side of the region for the evaporation. The oxygen isotopic composition of the inner nebula changes in this way. The decrease in the mass accretion rate enhances the H2O concentration and the isotopic composition evolves toward 16O-poor direction in the inner nebula. They suggest that the dust size of a few mm and the accretion rate of about 10^-9 solar mass/yr are adequate to explain the 16O-depletion of meteorites and the Earth relative to 16O-rich CAI.

In this study, we extend the above model to explain the co-formation of oxidized and reduced materials and perform a numerical calculation taking into account the role of organic matter found in molecular cloud as well as H$_2$O ice by employing a advective-diffusion model for accreting proto-planetary disk. For simplicity, we assume steady temprerature and surface density profiles same as the ``minimum mass'' solar nebula model. We consider a stage when dust particles have grown up to 1 mm in radius. Water ice and organic matters are assumed to be contained in dust accreting to the solar nebula. The evaporation temperature is different for each constituent and the positions where they evaporate are 3 and 0.3 AU from the disk center, respectively. According to the above mentioned processes, evaporants will concentrate and diffuse toward the center of the nebula.

First, we consider a case that the accretion rate is large (10^-8 solar mass/yr) and steady. In this case, C/O ratio of the inner nebula is kept at solar proportion 0.5. Actual mass accretion rate however basically decreases by degrees but irregularly fluctuates, like the CTTS stage. Therefore we next consider a case that the accretion rate instantaneously decreases from this steady state. Both of the organic and water components begin to concentrate at their evaporation fronts respectively. If these evaporants are mixed in their original proportion, the C/O ratio will still become almost the same as the solar value. However, water vapor which evaporates at 3 AU takes some time to float over the center of the nebula. The lag time nearly equals the value which is derived from dividing the inner disk mass by the mass accretion rate. During this time C/O ratio of the inner nebula exceeds unity and reduced materials may be formed.

Large part of these materials must fall into the proto-Sun but small portion of them would be circulated into the nebula and taken up by meteorite parent bodies. The mechanism of the circulation and preferential capture of materials is not well known at present. We are going to perform the further calculation taking into account the temperature and density variation due to the fluctuation of the mass accretion rate and the change in size distribution of dust particles.