Chemical evolution of a protoplanetary disk and early determination of planetesimal chemical compositions

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Protoplanetary disk evolves physically and chemically, however, chemical evolution being consisiten with physical evolultion has not been studied. We have developed a model to describe chemical evolution of a protoplanetary disk that enables temporal and spatial change of chemical composition of the disk. The results were compared with the chemical composition of chondrites, and we discuss the plausible conditions for planetesimal formaiton.

Evolution of a protoplanetary disk is described by using the model by Ciesla (2010), which is a one-dimensional standard alpha viscosity disk and the surface density and temperature profiles are shown as a function of the distance from the proto-Sun. The particle tracking model by Ciesla (2011) was combined with the disk model, which enables us to track the trajectory of all the particles. We have made chemical equilibirum calculation for individual particles, which is again the function of the distance from the Sun. By summing up the number of particles and their chemical compositions, chemical composition of the disk was obtained. Because of the mostly inward transport and rundom walk by turbulence, various degrees of mixing of particles with different thermal histories were distributed over the disk, which varies non-linearly with time and space.

The results show that the disk tends to become homogenous with time due to the inward transport of particles that have not suffered thermal porcessing in the innser reigion, and that their chemcal composition is unfractionated, that is, CI composition. Chemically fractionated compositions were realized in the inner region of the disk and at the relatively early stage of the disk evooooolution. Bulk chemical composition of chondrites characeterized by the enrichment of refractory elements for carbonaceous chonrites and the depletion of volatiles for all the chondrites. These characteristics are explained by the determination of chemical composition of the disk at the disk evolution stage earlier than 10^5 years and in the region inner than several A.U., though it can be later if the disk was heavy and high temperature region extended to the outer region of the disk.