Dust formation through heterogeneous nucleation : the role of diffusion

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Recent astrophysical observation with infrared spectra has revealed that there are abundant silicate dusts around evolved and young stars. They are mostly amorphous, but smaller abundance of crystalline silicates has been reported. The spectra are well fitted by multiple silicate phases: crystalline forsterite, crystalline enstataite, amorphous olivine, amorphous enstatite, and amorphous silica with size distribution for all phases for discs around T-Tauri stars and Herbig Ae/Be stars. Contrary to silicates, presence of metallic iron is not reported because of absence of vibration or rotation bands in infrared. The occurrence and size distribution of dusts are critical for interpretation of infrared spectra and modeling of thermal structure of discs.

We have carried out a series of condensation ex-periments of Fe, and showed two important results: the condensation coefficient of metallic iron is approximated to be unity in the temperature range of metal condensation in discs around young stars, and Fe metal heterogeneously condenses on alumina oxide with the super saturation ratio at least seven. The latter gives us very important view that metal heterogeneously condenses on silicates, or oxides if any, in a cooling gas, which has not been investigated yet. The change of condensation mode and temperature is expected to affect the occurrence of condensing phases and grain size distribution, and therefore the IR spectra.

We investigate the phases and grain size distribu-tion in kinetically condensing system, where heteroge-neous nucleation of metal on silicate is taken into con-sideration. All the phases are assumed to be crystalline, though it is not evident.

The assemblage of final products is divided into two cases in the space of total pressure and cooling time; secondary Fo and Fe with Fo core +/- En and SiO2, and Fe with Fo core and SiO2. The grain size distribution is also obtained. Typical sizes increase with increasing cooling time, and the size distribution is generally less than an order.

The effect of diffusion on the formation of enstatite is taken into consideration, it hampers the reaction of forsterite and the SiO component of gas depending on the cooling time scale. In most conditions, formation of enstatite is hampered and the amoun t of SiO2 con-densate increases.

The present work shows an important result that forsterite always condenses prior to Fe due to smaller surface tension in astrophysical conditions including solar nebula is covered by Fe, which prevents the reaction between forsterite and gas that is expected in an equilibrium model. This finally results in condensa-tion of SiO2. It is easily expected that reactions actually take place in nature are somewhere between two extremes, equilibrium and totally kinetic, and the phases formed in young discs will be a mixture of the pro-ducts in these two environments, that is, Fo, En, SiO2, Fe on Fo, and Fe on En. This explains the infrared spectra that are well fitted by mixtures of several phases with size distribution. The abundant formation of grains with Fo core and Fe mantle may explain the spectra of some discs that show solely PAH, where most silicate components are coated by thick metal to show no silicate feature.