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Condensation and chemical fractionation in the early solar disc

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Meteoritic and some planetary evidence that the bulk composition of chondrites are volatility-controlled and that the elemental isotopes excepting oxygen and rarely hydrogen are highly homogeneous suggests that the early solar disc had once totally evaporated at least within a few a. u. Chondrites and terrestrial planets show a systematic chemical fractionation in terms of volatiles and refractory elements, the latter of which is called as Cosmochemical fractionation, among which Mg/Si fractionation is one of the most major fractionation. The ration is smaller than the solar value in ordinary and enstatite chondrites and larger in CV chondrite. The volatility of Mg and Si in the solar nebula is fairly close, and phase-controlled fractionation is necessary in order to explain observed Mg/Si fractionation, and fractionation of early condensed forsterite dust from remaining Si-rich gas is one of the most plausible processes. In order to make quantitative evaluation of the Mg/Si fractionation, we have carried out reaction experiments between solid forsterite and Si-rich gas at conditions corresponding to the temperature and pressure when forsterite-gas reaction takes place in the cooling solar gas. Combining with kinetic condensation model, we have estimated the conditions of the fractionation.
The reaction experiments were conducted by generating SiO gas by heating SiO2 glass and independently heating forsterite substrate in vacuum chamber with or without flowing O2 gas. The condensates on forsterite at 1000C, which is the approximate formation temperature of enstatite in the solar nebula, was amorphous SiO without reaction to form enstatite regardless of experimental conditions. The condensation coefficient (condensation efficiency) of SiO is as small as 0.2-0.25 at the temperature, that is SiO condensation has large kinetic barrier. If forsterite dust was effectively separated from the remaining gas, large Mg/Si fractionation could take place. Bulk chemical composition of chondrites are understood by partial separation of early condensed refractory and forsterite dusts by inward or outward movement in the disc and condensation of remaining gas with relatively Si-rich composition to form O- and E-chondrites.
The kinetic condensation model predicts that the dust size separated from the gas ranged from 10 to 100um and the cooling time of the nebula was ~100 years.

Keywords: condensation, proto solar disc, dust, gas, forsterite, enstatite