A KINETIC MODEL FOR MASS-INDEPENDENT OXYGEN IN EARLY SOLAR SYSTEM MATERIALS

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Early Solar System materials, which include calcium-aluminum inclusions (CAI's) and chondrules, show oxygen mass-independent fractionation (MIF), with approximately equal depletions in the minor isotopes, O^{17} and O^{18} [1]. The partially-differentiated and differentiated meteorites, as well as some chondrites, exhibit enrichments in the minor isotopes [2] that are considered to have been inherited from precursor material, which was then subject to mass-dependent fractionation during accretionary melting [2-3]. Explanations for the oxygen MIF in the early Solar System include nucleosynthetic variations and self-shielding during CO photolysis [4, and references therein], along with symmetry driven fractionation during SiO_2 formation on the surfaces of particles [5]. In this study, we consider these cosmochemical measurements in the context of the equilibrium condensation sequence [e.g., 6-7] and conceptual models of disk evolution and transport [e.g., 8-9] to develop a kinetic chemical reaction network of H, O, Si and Mg in the early solar nebula.

Our hypothesis is similar to that of Marcus (2004) [5], except that SiO_2 formation is assumed to proceed in the gas phase, and the condensation of SiO_2 and CAI's is separated in both space and time. Preliminary results from kinetic modelling indicate that initial condensates of SiO_2 would have been enriched in the minor isotopes of oxygen; the lower condensation temperature of SiO_2 suggests that this may have occurred in the outer nebula. The residual gas, which includes SiO, MgO and H_2O, would then be depleted in O^{17} and O^{18} and may have been the source for more refractory mineral condensates (e.g. Mg, Al, Ca, Ti) that formed in the inner nebula, and may have been incorporated into CAI's and chondrules. In this scenario, the condensation of SiO_2 in the outer nebula would occur before the formation of the more refractory grains. This relative timing of condensates is supported by uncertainties in age-dating, such as that resulting from the heterogeneous distribution of the ^{26}Al nuclide in the early Solar System. Recent work indicates that chondrules formed concurrently with CAI's, and that planetesimals may also have formed in the very early lifetime of the protoplanetary disk [10]. The heterogeneous and localized condensation of silicates and refractory grains is supported by prior work on oxygen isotope heterogeneity in the Solar System [11], although our study relies on a kinetic chemical network rather than CO self-shielding.

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