Solar Nebulæ

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Lodders and Fegley [1] pointed out the necessarily multiple-component origin of the Solar System. Warren [2] argued for the bimodality in ⁵⁶Ti, ⁴⁰Cr, and O nucleosynthetic anomalies exhibited by planetary materials and suggested a division between carbonaceous and noncarbonaceous sources. Such a dichotomy is also visible in the Cu and Zn isotope compositions of the same material [3]. Using a novel presentation of oxygen isotope data, we show that all the analyzed material in the Solar Nebula can be accounted for by a component mixture not unlike Warren [2]’s two component mixture but involving three components. The new orthogonal coordinates clearly separate mass-dependent from mass-independent fractionation and unveil well-defined mixing trends. Most of the accessible material in the Solar System may be accounted for by a mixture of a non-carbonaceous (L chondrite-like), a CV and a CI end-members. Similar components are also found when other nucleosynthetic anomalies (Ti, Cr, Ni) are plotted against water content of meteorites. It is arguable that the CV component is of solar origin. The most common proportions of CV and CI components in the mixture are reminiscent of a CM composition. We suggest the approximate contributions of the noncarbonaceous sources: 90% for L chondrites, 80% for H chondrites and Mars, 70% for E chondrites, the Earth, and Moon, and 20-40% for ureilites.

A first far-reaching consequence is that the Solar System is not well mixed and that accretion time scales are shorter than nebular mixing time scales. The Solar nebula does not represent the condensation of a homogeneous cloud of gas and dust, but the accretion of a number of genetically unrelated streaks, two of which (L-type and CI) having resisted full accretion to the central star.

In a session honoring Mike Drake’s immense contribution, and more specifically to this issue [4], the origin of water in planets appears essentially pinned down on that of their CI component. Several correlation plots show that water is not a rogue component of the Solar System. It is remarkably well correlated with other gaseous (C, N) and lithophile (Zn) volatiles. Even if the history of water and of the CI component in terrestrial planets are intimately related, the timing of when the components discussed in this talk were mixed is still eluding final explanation.