PROCESSES GIVING RISE TO ISOTOPIC INHOMOGENEITIES IN THE EARLY SOLAR NEBULA. J. Ray, Dept. of Terrestrial Magnetism, Washington, D.C. 20015

Wood (1) has presented a cogent synthesis of a broad swath of cosmochemical data. As that work, however, is a lowest-order analysis within a context still rather novel to cosmochemical discussions, many points remain to be considered and several aspects require elucidation. This report is an attempt in that direction.

I. Oxygen isotopes Wood's identification of inherited interstellar dust in the protosolar nebula as 16-O enriched, relative to the gas, is persuasive. At least two further points remain to be addressed: i. Given the violent nature of the interstellar medium, it is unlikely that the inferred degree of dust/gas inhomogeneity is a typical occurrence unless it can be shown that a selective isotope fractionation mechanism routinely operates during the formation of the dust. Moreover, barring pure coincidence, the isotopic trend of anhydrous chondritic minerals toward a nearly pure 16-O composition surely must signal some special circumstance. I propose that the much-discussed "late nucleosynthesis event" (here labelled "B") introduced oxygen characterized by a terrestrial 17-O/18-O ratio into a parcel of gas and dust (labelled "A") possessing a very 16-O rich composition. If parcel B is chemically reducing (i.e., possesses little or no oxide grains) then the effect of not-too-violent mixture will be to produce a gas more 17,18-O rich than the dust. (Note that if parcel B is oxidizing and has a normal complement of oxide grains, no dust/gas differentiation will obtain.) ii. The complete range of oxygen isotopic compositions, including in particular the ordinary chondrites, cannot be explained by a simple dust/gas dichotomy alone. It is reasonable to suppose that the volatile reservoir itself consists of at least two components: gas (mostly CO) relatively 18-O poor and ice (H_2O) relatively 18-O rich. Gas phase fractionation is likely, probably through the agency of ion-molecule reactions, provided that the pre-existing ice in parcel A is effectively eroded during the A-B mixing episode.

In this picture, carbonaceous chondrite oxygen represents different mixes of dust and ice, while ordinary chondrites are mixes of dust and gas. The range of possible dynamical processes operating in the early solar nebula is obviously limited to those which do not obliterate the fractionation effect considered here. Notice also that the identification of parcel B with fresh supernova ejecta is effectively excluded on the present interpretation, contrary to widespread thought.

II. Titanium isotopes Wood's reasoning regarding the occurrence of systemic isotope heterogeneities in oxygen without comparable effects in other elements fails to account for the observed variations, possibly also systemic, in Ti isotope abundances. Very refractory Ti certainly requires a different mechanism, probably partial sorting of grain types as, for example, by differential sedimentation. In order that comparable effects not be pervasive in other elements (especially Mg and Si) a distinctive, chemically fractionating environment is indicated for the formation of one of the grain types--those of parcel B--consistent with the O isotopic analysis above.

III. FUN inclusions Elsewhere (2) I have suggested that the FUN properties of certain meteoritic inclusions can be understood as manifestations of the incorporation of giant interstellar grains ($\gtrsim 100 \mu m$) into a portion of proto-inclusion aggregates. Some process for grain sorting on the basis of size is required.

IV. Nucleosynthesis events Numerous considerations, including those above, suggest that parcel A formed in large part from the ejecta of a supernova which occurred some 10^8y before the formation of the solar system, as is commonly thought. Distinctive properties include extreme enrichments of 16-O, 24-Mg, and 28-Si together with the long-lived radionuclides 244-Pu and 129-I. The supernova ejecta was slowed by and mixed with material in the interstellar medium and evolved in typical fashion, allowing for the accretionary growth of grains upon the uneroded cores of swept-up dust.

Parcel B is notable for its near-terrestrial abundances of 17,18-O, 25,26-Mg, and 29,30-Si, the overabundance of C and/or N relative to O, and the presence of 26-Al and 107-Pd. Those properties can be most readily satisfied if parcel B formed largely from the ejecta of a relatively massive (roughly 5 solar masses) red giant star which lost its outer envelope in the form of a planetary nebula. The solid grains which formed in the ejecta material were either carbides or nitrides. The mixing and subsequent evolution of parcels A and B were sufficient to eliminate large-scale isotopic inhomogeneities without also homogenizing the dust/gas oxygen fractionation, indicating a relative encounter velocity of perhaps 20-30 km per second, a value consistent with parcel B being planetary nebula ejecta.

References

(1) Wood J.A. (1981) Earth Planet. Sci. Lett. 56, 32-44.
(2) Ray J. (1983) Earth Planet. Sci. Lett., submitted.