Solar System and Planet Formation, Insights from Nucleosynthetic Anomalies

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The major consequences of the discovery of planetary scale isotopic anomalies include: (1) new models for the formation of the Solar Sytem are needed that accommodate initial isotopic heterogeneity; (2) the validity of chondrites as the basic building blocks of the Earth is challenged. Planet-scale isotopic anomalies can be roughly devided into two groups: iron-group elements (Ti, Cr, Ni, and Ca), and intermediate to heavy elements (Sr, Zr, Mo, Ru, Ba and Nd). Most meteorites show different levels of deficits in the s-process component in the Sr-Nd mass range, with C-chondrites showing the largest deficits. For heavier nuclides (Hf, W and Os), no planet-scale isotopic anomalies have been detected for most meteorites. In the mass range from Sr to Os, the degree of s-deficit in C-chondrites generally decreases with increasing atomic number. Iron group elements show correlated anomalies with one another in neutron-rich isotopes, with C-, O- and E-chondrites, respectively, demonstrating positive, negative and no anomalies compared to Earth. At least two nucleosynthetic production events are needed to explain the two distinct types of nucleosynthetic patterns. Given previous suggestions that the production of light and heavy r-process nuclides may be decoupled, we propose that one major contributor to the Solar nebula is an L-event supernova injection event that brought more light r-process nuclides (e.g. Sr, Zr, Mo and Ru) than heavy r-process nuclides. The injected material was gradually, but imperfectly, mixed with the inner Solar System material. The other major nucleosynthetic event is a SN II/AGB event that brought the neutron-rich nuclides into the Solar System just shortly before nebula collapse. The carrier phases of many isotopic anomalies have extreme isotopic signatures, so only very small amounts of these materials are needed to explain the extremely small levels of bulk meteorite isotopic anomalies depending on the mass proportion of newly synthesized to preexisting nebular abundances for a given element. The Earth could have accreted from inner solar materials shielded from these “salting”events.