Isotopic constraints on the formation of the Earth and the Moon

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Due to instrumental and analytical advancements, isotopic analyses at unprecedented precision have become possible within the past 20 years. This has boosted the detection of isotopic variations in meteorites, lunar and terrestrial samples. These variations are generated by different processes such as radioactive decay, galactic cosmic rays or the heterogeneous distribution of materials produced in different stellar environments (nucleosynthetic anomalies). They provide important constraints on the processes involved during the accretion and early planetary evolution of the Earth and Moon. The early compositional evolution of the Earth was shaped by accretion, core formation, and the loss/addition of volatile elements. The last important accretion step in the Earth's history is generally thought to be a catastrophic giant impact, which resulted in the formation of the Moon.

A growing number of elements show well–resolved nucleosynthetic isotope anomalies in bulk–rock meteorites compared to the Earth-Moon system, which displays identical isotope compositions. This indicates that each planetary body sampled its own mixture of nebular material. The anomalies are mostly limited to refractory elements and include e.g., Cr, Ca, Ti, and Zr. Based on the identical compositions of the Earth and Moon, the expected nucleosynthetic compositions of the impactor Theia can be modelled by taking into account different dynamical simulations of the giant impact scenario [1] [2]. Each successful scenario predicts that specific amounts of impactor material are added to the Earth and Moon [3-6]. The outcome of such models shows that the protoEarth and Theia likely shared very similar isotopic compositions [1] [2] [7]. This indicates that the inner solar system (or more precisely the accretion region of the Earth, Theia and enstatite chondrites) had uniform isotopic compositions. More samples from the inner solar system, and in particular Mercury, would be desirable to test whether this isotopic homogeneity encompasses the entire inner solar system.

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