

Isotopes and the origin of the Moon

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The giant impact model of lunar origin predicts that the Moon predominantly consists of impactor material. As such, the Moon should be isotopically distinct from the Earth, but it is not. Potential solutions to this problem include Earth-Moon equilibration [1], making the Moon out of proto-Earth material [2-4], and formation of Earth and impactor from an isotopically uniform reservoir [5]. To distinguish between these scenarios, we here use Mo, Nd and W isotope variations among meteorites and the Earth and Moon. We show that the Earth's mantle is enriched in *s*-process Mo and Nd isotopes compared to *all* chondrites, and together with enstatite and ordinary chondrites plots on a cosmic Mo-Nd isotope correlation line. Thus, Earth's building material was distinct from chondrites. As most of the Mo in Earth's mantle was delivered during the last 10-20% of accretion [5], this Mo should predominantly derive from the Moon-forming impactor. The nucleosynthetic isotope composition of the impactor, therefore, was similar to that of Earth's building material, but different from chondrites. Otherwise there is no reason why the Earth's mantle should plot on a cosmic Mo-Nd correlation with chondrites. The lack of an Earth-Moon isotopic difference, therefore, reflects the same genetic makeup of the Earth and the impactor, and cannot be used to constrain the amount of impactor material in the Moon.

The Earth-Moon similarity for ¹⁸²W [6,7] is more difficult to explain, because ¹⁸²W reflects the differentiation timescales of Earth and impactor, and not their genetic makeup. To assess the likelihood of producing similar ¹⁸²W compositions for the Earth and Moon, we performed mixing calculations for different giant impact scenarios and using different impactor compositions. The calculations show that the Earth-Moon homogeneity observed for ¹⁸²W is an extremely unlikely outcome of the giant impact, regardless of how much impactor material is incorporated into the Moon. Thus, post-giant impact modifications affecting ¹⁸²W seem to be necessary, either by Earth-Moon equilibration (*e.g.*, in the aftermath of a high-angular-momentum impact [8]), or by addition of mass to the Moon following the giant impact [9].

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