Mass-Dependent Stable Isotopic Constraints on the Moon Formation Giant Impact Model

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Any successful Moon formation model must explain the total angular momentum of the Earth-Moon system, the volatile element depletion of the Moon, and the isotopic similarity between the Earth and the Moon. The latter is investigated here by (i) first-principles calculations of mass-dependent fractionation factors for Mg, Si, K, Ca, Fe and Zn between condensed phase and vapor, (ii) modeling isotopic fractionations in the proto-lunar disk, and (iii) measurements of mass-dependent isotopic compositions in lunar bulk samples and minerals (Ca, Mg [this study], Fe [1] and Zn [2]). Because of inter-mineral isotopic fractionations, any estimates of the isotopic compositions of bulk Earth and Moon are model dependent, and thus do not allow a high precision (on the level of analytical uncertainty) comparison of bulk Earth and Moon stable isotopic compositions. This is corroborated by our new Ca and Mg isotopic data on lunar materials, which show measurable isotopic variations among lunar minerals. The Earth and Moon have essentially the same mass-dependent isotopic compositions for all the isotopic systems investigated so far (e.g. O, Mg, Si, Ca, Fe, K), except for Zn, with Moon being apparently heavier. This is inconsistent with some Moon formation models that argue for measurable mass-dependent isotopic differences between Earth and Moon. Lock et al. [3] have developed a new Moon formation model, where moonlets equilibrated with a well-mixed silicate vapor with bulk silicate Earth composition in a particular dynamical state generated by a high-energy high-angular momentum giant impact. The model explains the magnitude of the Moon's depletion in volatile elements, and predicts negligible mass-dependent isotopic fractionation between Earth and Moon, consistent with observations.

[1] Wang K. et al. (2015) *EPSL* **430**, 202-208. [2] Paniello R. C. et al. (2012) *Nature* **490,** 376-379. [3] Lock S. J. et al. (2016) *LPSC* #2881.