Magnesium isotope evidence that accretional vapour loss shapes planetary compositions

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Earth's depletion relative to chondrites in volatile elements and the main components Mg and Si [1] is frequently explained by vapour-condensate fractionation in the cooling proto-Solar nebula followed by formation of the Earth from such depleted precursor material. In such a model, however, Earth's proposed building blocks are often element-choice dependent and they are usually not compatible with the building blocks determined from studies of mass-(in)dependent isotopic compositions. Moreover, various features such as Earth's low Al/Mg remain poorly explained.

We investigated these issues by studying mass-dependent variations in Mg isotope ratios, analysed to high accuracy with a new 'critical mixture double-spiking' technique [2]. We find that the Mg isotope composition of the Earth is statistically indistinguishable from other differentiated bodies (Mars and eucrite and angrite parent bodies), yet all are heavier than chondrites. As Mg isotopes appear insufficiently fractionated during silicate melting or core formation, loss of light Mg isotopes by vapour depletion from the differentiated bodies is the most plausible cause for our observation.

We traced the composition of a residual liquid after vapour loss with a thermodynamic model and found the observed light Mg isotope depletion in Earth after ~40% vapour mass loss. This vapour loss also produces a residual liquid with a terrestrial major element and Si and Fe isotope composition when starting with an (enstatite) chondritic composition, potentially resolving the issues with nebular depletion described above. Further modelling efforts suggest that such large vapour masses can be lost from planetesimals above melt pools produced by collisional impacts, leaving Earth's precursors depleted by accretionary vapour loss.

[1] Palme, H. and O'Neill, H.S.C., 2003. In: *The Mantle and Core*, Carlson R.W. (Ed). [2] Coath, C.D. et al., 2017. *Chem. Geol.* **451**, 78-89.