Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.14914

Constraining Volatile Element Loss Processes by Germanium Isotopes in Iron Meteorites

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The concentrations of Ge and other moderately volatile elements (MVE) in iron meteorites vary by orders of magnitude, a feature that has been key for defining the major iron meteorite groups [1]. However, the origin of these MVE depletions is not well understood. They may either reflect early nebular heating processes [e.g., 2] or, alternatively, magma degassing and/or vaporization during planetesimal formation [e.g., 3]. To better constrain the origin(s) and process(es) of MVE depletion among planetary bodies, we measured Ge concentrations and mass-dependent Ge isotopic compositions of a set of variably MVE-depleted magmatic iron meteorites (IAB, IC, IIAB, IID, IIIAB, IIIE) by MC-ICPMS using a ^{70}Ge-^{73}Ge double-spike. To evaluate the meteorite data within the framework of degassing processes, we also measured Ge loss and isotopic fractionation in controlled metal melt degassing experiments.

The experimental run products exhibit Ge depletions from ~10% to >99% and, as expected for a kinetic isotope effect, increasingly heavier Ge isotopic compositions with increasing loss of Ge. By contrast, the magmatic irons display relatively uniform Ge isotope compositions with $\delta^{74/70}$Ge values of ~1 ($\delta^{74/70}$Ge is defined as the permil deviation of the ^{74}Ge/^{70}Ge ratio of a sample from the composition of the NIST SRM 3120a Ge standard), even though their Ge concentrations are highly variable. Thus, the Ge depletion of iron meteorites is not associated with the large kinetic isotope fractionation, which may be expected for evaporative Ge loss from exposed molten cores into vacuum. These results imply either that the variable MVE depletions of iron meteorite parent bodies do not reflect evaporative losses or that these processes operated at near-equilibrium conditions, in which case much smaller isotope effects are expected [4]. Experimental studies in this regime would help to further constrain the origin of MVE depletions in planetary environments.

References: [1] Scott E. R. D. and Wasson J. T. (1975) *Reviews of Geophysics*, 13, 527–546. [2] Cassen, P. (1996) *Met. Planet. Sci.*, 31, 793–806. [3] Hin, R.C. et al. (2017) *Nature*, 549, 511–515. [4] Young E.D. et al. (2019) *Icarus*, 323, 1–15.