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Nucleosynthetic isotope composition of the siderophile and moderately volatile element Ge in the core of the early planetesimals

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A key challenge in planetary science is identifying the source of volatile elements in planetesimals, as this provides critical insights into the building blocks and formation pathways of rocky planets. Mass-independent isotopic variations of multiple elements have been widely used as tracers of the building blocks of the terrestrial planets. However, most studies have focused on isotope anomalies in Cr, Ti, Mo, Ru, Fe, Zn, K, etc. [1]. These elements are either refractory elements and, thus, provide limited insight into the origins of volatiles or lithophile (/less siderophile) elements. As such, they are unsuitable to investigate volatiles of iron meteorites, which sample the metal cores of >60 distinct planetesimals [2]. Consequently, a systematic investigation of the nucleosynthetic isotopic composition of an element that is both siderophile and moderately volatile is essential for constraining volatile reservoirs in the early Solar System.

Siderophile and moderately volatile element Germanium (Ge) is a good candidate. Germanium has five naturally occurring isotopes, namely the s-process only ^{70}Ge, s- and r- process ^{72}Ge, ^{73}Ge and ^{74}Ge, and r-process only ^{76}Ge. Using a ThermoFisher Neoma MC-ICP-MS new generation mass spectrometer, we analyzed all five Ge isotopes of grouped and ungrouped irons. The mass-independent Ge isotope data are reported as ppm deviation from SRM 3120a and normalized to ^{74}Ge/^{73}Ge=4.66234 using the exponential law. Our results show a clear dichotomy between Non-Carbonaceous (NC) IAB, IIAB, IIIAB, IC and IIG iron meteorites, and Carbonaceous (CC) IIC and IID iron meteorites, with the former showing neutron-poor ^{70}Ge and ^{72}Ge excesses, while the latter exhibits neutron-rich ^{76}Ge excess. Of the analyzed ungrouped iron meteorites Reed City and Butler have NC-like Ge isotopic compositions, whereas Bacubirito, Cruz del Aire, and New Baltimore overlap with CC Ge isotope signatures. The observed dichotomy suggests that mass-independent Ge isotope composition of early planetesimals has great potential to constrain the volatile source of the terrestrial planets and we will investigate that of terrestrial samples to better understand the source and the accretion history of volatiles to the Earth.

[1] Bizzarro et al. (2025). Nat. Rev. Chem., 9(7): 378–396

[2] Goldstein et al. (2009). Geochemistry, 69(4): p. 293-325.