CONSTRAINING VOLATILE ELEMENT LOSS PROCESSES BY GERMANIUM ISOTOPIC INVESTIGATIONS OF IRON METEORITES.

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Introduction: 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 classifying meteorites and defining the iron meteorite groups known today [1]. However, the origin of the MVE variations among the iron meteorite groups is not well understood and nebular (e.g., evaporation, condensation) as well as planetary processes (e.g., melting, vaporization/degassing) have been proposed [2,3]. For instance, the extreme MVE depletions of group IVA and IVB irons have been proposed to reflect evaporative loss of volatiles from exposed molten planetary cores after mantle stripping [4,5]. To better constrain the origin(s) and process(es) of MVE depletion among planetary bodies, we measured the Ge concentrations as well as mass-dependent Ge isotopic compositions of a set of iron meteorites and will, ultimately, compare these to controlled metal melt degassing experiments.

Samples and methods: In total, four IAB, four IC, two IIAB, two IID, one IIE, two IIIAB, and one IIIE iron meteorites were investigated for their Ge isotopic compositions. All samples were digested in $cHNO_3$, followed by chemical separation and purification of Ge. Germanium isotopic compositions and concentrations were measured on a Neptune Plus MC-ICP-MS at the University of Münster using a ^{70}Ge-^{73}Ge double-spike [6,7]. This not only allows determining precise Ge concentrations, but also enhances the precision of the isotope measurements compared to previous studies [8,9]. The Ge double-spike was calibrated against the NIST SRM3120a Ge solution standard using three different sample introduction systems (Apex IR, Aridus, Hydride Generator) at varying Ge concentrations. The results from the different introductions systems are consistent with each other, demonstrating that, depending on the amount of Ge in the samples and the sensitivity needed, the double-spike technique can be used with either introduction system. Besides investigating natural meteorite samples, we performed controlled degassing experiments of Ge from a metallic melt (Fe vs. FeS composition) to qualitatively and quantitatively evaluate the effect of melt degassing on the Ge isotopic composition of the residue, and to compare those observations to the Ge isotopic variations among iron meteorites. Therefore, we produced metal pellets, placed them in a graphite capsule and heated them in a vertical gas-mixing furnace at different temperatures, pressures, oxygen fugacities, and time periods. In a next step, we will determine the Ge concentrations and stable isotope compositions of these experimental run products.

Results: The Ge concentrations of the investigated meteorites as determined by the double-spike technique are consistent with literature data reported for the individual chemical groups [1] and range from ~35–40 ppm for the IIIAB and IIIE meteorites up to ~370 ppm for some of the IAB iron meteorites. The Ge stable isotopic compositions of the analyzed samples, including the first Ge isotopic data for IC, IID, and IIIE irons, are relatively uniform with a $\delta^{74/70}$Ge value of ~1 for all but the IIE irons, which exhibit $\delta^{74/70}$Ge values of around –0.4. The general results are largely consistent with literature data, but are much more precise due to the use of a Ge double-spike. Among the samples investigated so far, there is no resolved within-group variability for most of the groups. Only the IID and IIIAB irons seem to show some internal variability, and further investigation will show whether this is due to fractional crystallization of their parental cores or to cosmic ray exposure effects.

Discussion: Despite large variations of Ge concentrations, the different iron meteorite groups lack significant Ge isotopic variations among each other, but such variations would for instance be expected for simple evaporative loss of Ge during magma degassing in vacuum (e.g., by Rayleigh fractionation). As such, the new data for magmatic irons do not seem to support the idea that the volatile-depleted nature of their parent bodies is mainly the result of planetary processes like melting and degassing, but further studies are needed to better quantify the expected isotope effects during Ge evaporation. By contrast, the very distinct $\delta^{74/70}$Ge of the IIE irons is consistent with modelled evaporation processes [8,9], which in turn is consistent with the formation of these non-magmatic iron meteorites by impact-related processes.

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