Fe isotopic fractionation in iron meteorites – a potential thermometer?

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Fe isotopic differences between coexisting taenite and kamacite in meteoritic irons have been recently reported by several studies. They all consistently show that the lamellae of Ni-rich mixture of phases (generally referred to as taenite) are isotopically heavier than the adjacent Ni-poor phase (kamacite). The extent of isotopic variation in individual meteorites varies from a fraction of permil to several permil and the δ^{57}Fe and δ^{56}Fe compositions suggest a mass dependent fractionation. The heavier Fe isotopic composition of taenite can be explained by its predominantly FCC structure with stronger Fe-Fe and Fe-Ni bonds compared to the predominantly BCC structure of kamacite. The spectroscopic data that could be used to predict the Fe isotopic fractionation in the meteoritic Fe-Ni alloys are not available but equilibrium isotopic fractionation of ~0.7 permil δ^{57}Fe at 750 ^{o}C (typical kamacite-taenite unmixing temperature) can be expected from the analogy with Fe metal [1].

Laser ablation MC ICP-MS study of meteoritic irons from different meteorite chemical groups revealed a systematic correlation between the kamacite-taenite Fe isotopic offset ($\Delta^{56,57}Fe_{kamacite\text{-}taenite}$) and the meteorite cooling rates (5-500 ^{o}C/My) calculated independently using metallographic methods based on Ni diffusion in taenite. This correlation is interpreted as resulting from Fe isotopic diffusion between kamacite and taenite lamellae and variable meteorite cooling rates.

Diffusion of Ni in taenite can normally be used to estimate the meteorite cooling rates between the kamacite-taenite unmixing temperature (~750 ^{o}C) and the temperature when Ni diffusion in Fe-Ni alloys effectively ceases (~450 ^{o}C). The low temperature histories of iron meteorites have so far been extrapolated from the Ni diffusion data. In contrast, the isotopic diffusion of Fe is effective even at lower temperatures and it can provide us with an important tool for deciphering the complete thermal histories of iron meteorites and their planetary parent bodies.

References

[1] Polyakov V.B., and Mineev S.D. (2000) *GCA* **64,** 849-865.