Equilibrium Fe-isotope Fractionation Applied to Cooling Rates of Iron Meteroites

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Iron meteorites are remnants of differentiation processes in planetesimals. Determination of their subsolidus cooling rates is one of the only available methods for estimating the sizes of their parent bodies. Cooling rates of iron meteorites are typically estimated by modeling the subsolidus evolution of exsolved kamacite and taenite [e.g. 1]. However, this approach is difficult to apply to meteorites with exsolution patterns that are either as coarse as the sample size (hexahedrites), or with no clear exsolution textures due to high Ni contents (ataxites) [2]. Some classes of meteorites also show variability in their estimated cooling rates (e.g. the IVA group), and independent estimates are valuable for understanding these variations.

Troilite is a ubiquitous phase in all iron meteorite groups [2], and the distribution of Fe isotopes between it and metal can provide information on the cooling rate. The equilibrium fractionation of Fe isotopes increases strongly as temperature decreases. Slowly cooled metal-troilite pairs will preserve larger Fe isotope fractionations than rapidly cooled pairs because they are able to equilibrate to lower temperatures.

We applied a fast grain boundary diffusion model, after [3,4], to simulate Fe isotope fractionation between metal-troilite pairs during slow cooling. Inputs to the model are equilibirium Fe isotope fractionation factors, determined from new NRIXS data for synthetic taenite and troilite and published data for kamacite [5], and Fe self-diffusion data for the metals and troilite [6,7]. The model is applied to infer the closure temperatures and cooling rates of iron meteorites containing metal-troilite pairs with well established grain size and Fe isotope compositions.

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