THE CRYSTALLIZATION OF IRON METEORITES AND THE EFFECT OF TROILITE ON TRACE ELEMENT CHEMISTRY. Evangela E. Shread[1], Nancy L. Chabot[1], Colin D. Hamill[2], Richard D. Ash[3], and Catherine M. Corrigan[4], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [2]Purdue University, West Lafayette, IN 47907, USA. [3]University of Maryland, College Park, MD 20742, USA. [4]Smithsonian Institution, National Museum of Natural History, Washington, DC 20560, USA.

Introduction: Iron meteorites provide unique information about the central cores of asteroids in the early solar system. Modeling the elemental trends observed in all magmatic iron meteorite groups has shown that early solar system cores contained a range of S contents, from being nearly S-free to having 15 wt% S or higher [1]. As the S-bearing cores cooled, troilite (FeS) formed, and troilite nodules are a common component in iron meteorites. However, despite troilite being an important phase for iron meteorites, there have been limited studies to examine how troilite formation has affected the elemental chemistry measured in iron meteorite samples.

In this study, we conducted a series of experiments at the Fe-Ni-S cotectic to determine the partitioning behavior of trace elements between the coexisting solid Fe-Ni metal, troilite, and S-rich liquid metal phases. We present the results of these experiments and discuss the implications for understanding the chemical signatures of iron meteorites and asteroidal core crystallization.

Experiments: Mixtures of powders of Fe, Ni, and FeS were prepared within the cotectic field predicted by the Fe-Ni-S phase diagram [2]. The experiments were doped with 21 trace elements at roughly ~100 ppm levels: Co, Cu, Zn, Ga, Ge, As, Mo, Ru, Rh, Pd, Ag_2O, Sn, Sb, H_2WO_4, Re, Os, Ir, Pt, Au, PbO and Bi. Experiments were run from 800–925 °C in an evacuated silica tube in a 1 atm vertical tube furnace for durations from 1 to 7 days. In total, nine runs that contained three coexisting phases, with each phase being large and distinct, were produced, as shown in Figure 1.

The abundances of major elements, Fe, Ni and S, in each phase were analyzed by a JEOL 8530F+ Hyperprobe at the Smithsonian Institution. Trace elemental abundances were measured by laser ablation inductively coupled plasma mass spectrometry (LA ICP-MS) at the University of Maryland.

Results: All nine experiments produced consistent results, regardless of the run temperatures and durations, supporting equilibrium behavior was achieved during the experiments. Consequently, elemental partition coefficients (D) were determined from the average of the D values in each run weighted by the standard deviation of each determination. Figure 2 shows results for the partitioning of 22 elements between solid metal and liquid metal and between solid metal and troilite.

Our D(solid metal/liquid metal) coefficients were compared to predicted values calculated from model parameterizations based on previous experimental datasets [3]. Our new experimental D(solid metal/liquid metal) values showed good agreement with the values predicted from the parametrization, providing further support for equilibrium behavior in the runs. The only exception to the agreement was with Bi, which had limited previous data; we derived a new parameterization for Bi using our data along with the previously published values.

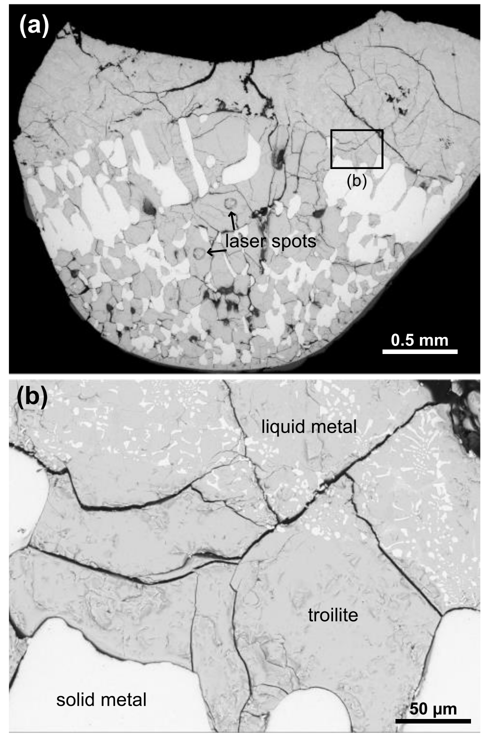

Fig 1. (a) Back-scattered electron image of typical run product. (b) Magnified portion depicting the different phases.

Previous experimental determinations of D(solid metal/troilite) are extremely limited, with values only reported for the five elements of Ni, Mo, Pd, Ag and Pb [4]. These limited data were a driving motivation for our current study, and our new results are consistent with these previously determined D values.

Discussion: When compared to the D(solid metal/liquid metal) values, it is clear that the presence of a troilite phase rather than a liquid metal phase has a noticeable influence on the partitioning behavior of many trace elements. As one might predict, the chalcophile elements of Bi, Pb, Ag, and Zn exhibit a

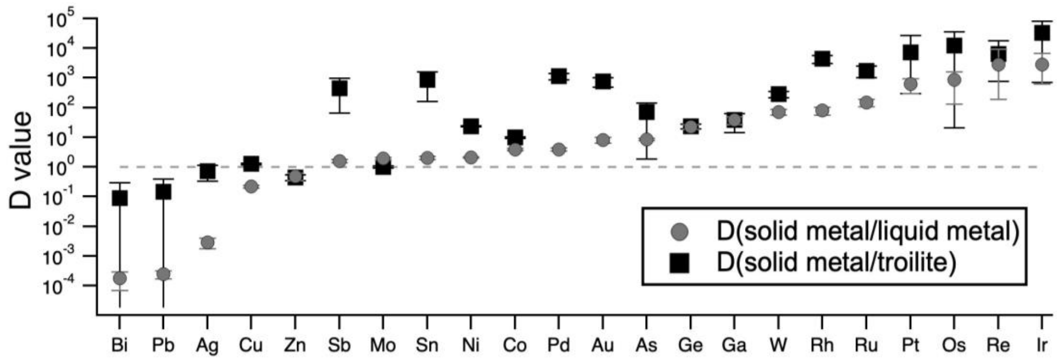

Fig. 2. Comparison of experimental partitioning into troilite and liquid metal, ordered by increasing D(solid metal/liquid metal). Errors are ±2σ.

preference for troilite over solid metal, with D(solid metal/troilite) values on Fig. 2 lower than one. The partitioning behavior of Cu is near unity, also consistent with its chalcophile nature.

For elements with siderophile behavior in the solid metal/liquid metal system, the majority of these elements have D(solid metal/troilite) values also greater than one. There is a noticeable difference for Sb and Sn, as shown on Fig. 2, which partition strongly into solid metal rather than troilite, but otherwise distribute almost evenly between solid and liquid metal. Additionally, Pd and Au partition significantly more into solid metal when troilite instead of liquid metal is present.

Among siderophile elements, Mo exhibits unusual behavior since it has a D(solid metal/troilite) value of about one. Thus, Mo would be more enriched in troilite compared to other siderophile elements, so Mo could serve as a chemical signature in iron meteorites which could provide insight into the crystallization conditions.

Figure 3 compares our experimental results to the limited measurements available of iron meteorites [5-8].

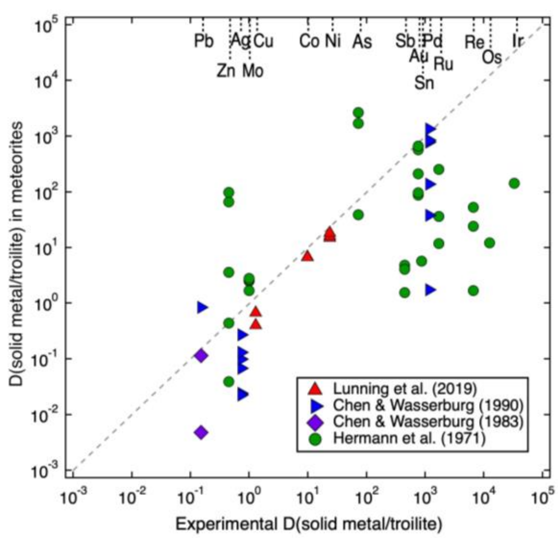

Fig. 3. Comparison of experimental D(solid metal/troilite) to meteorites [5-8].

D(solid metal/troilite) values for Cu, Co, and Ni from [5] are consistent with our experimental results, but partitioning coefficients derived from other studies vary widely [6-8], as shown in Fig. 3. It is unclear if chemical processes that occurred on iron meteorite parent bodies after the initial formation of troilite are responsible for the wide scatter reported in these studies, or if more precise measurements of these iron meteorites would resolve these inconsistencies.

The limited iron meteorite data available as shown in Fig. 3 highlights the need for additional measurements of trace elemental abundances in troilite in iron meteorites. Agreement of D(solid metal/troilite) between iron meteorites and our experimental results could be used to identify meteorites that are late-stage products of fractional crystallization, formed near the Fe-Ni-S coetectic composition, or it could be used to distinguish troilite that formed by trapped melt during crystallization. This work provides strong motivation to re-examine the trace element compositions of iron meteorites with troilite nodules to understand the late-stage crystallization of asteroidal cores.

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