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THE PARTITIONING OF SIDEROPHILE ELEMENTS BETWEEN KAMACITE AND COHENITE.

A. Gangopadhyay[1,2], M. Humayun[1,2], and R. E. Goddard[1], [1]National High Magnetic Field Laboratory, 1800 E Paul Dirac Dr., Tallahassee, FL 32310, USA (amitava@magnet.fsu.edu), [2]Department of Geological Sciences, Florida State University, 108 Carraway Building, Tallahassee, FL 32306, USA.

Introduction: Iron meteorites are asteroidal fragments that crystallized from Fe-Ni-X liquids, where X = S, C, and/or P. It is well known that the partitioning of siderophile (iron-loving) elements in iron metal is strongly influenced by the amount of S in the liquid (e.g., [1]). Chabot et al. [2] have recently shown that the presence of C in the liquid increases the compatibility of most siderophile elements, with the notable exception of Cr, Re and W. The D values of these three elements were found to decrease with increasing C in the liquid and hence were termed “anthracophile” (Greek, carbon-loving: [2]). Further, Chabot et al. [2] found that available kamacite-cohenite partitioning studies in natural irons showed the same general partitioning behavior as solid metal-liquid Fe-Ni-C indicating that anthracophile preferences are a fundamental feature of the Fe-Ni-C system. The data used by Chabot et al. [2] came from unpublished studies [3, 4], and pooled data from Odessa [3] with that from Canyon Diablo [4] to obtain D’s for 13 elements. Because of the importance of this anthracophile effect, we have conducted a comprehensive set of measurements of kamacite-cohenite pairs. Here we present our estimates of partition coefficients of 19 elements between cohenite and kamacite [D(cohenite/ kamacite)], including 15 of the elements determined by [2].

Samples and Analytical Techniques: The concentrations of 19 elements in cohenite and host kamacite in Canyon Diablo and Odessa were determined, using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). These two samples were selected because of their high C contents (up to ~10 mg/g: [5]) and abundant large crystals of cohenite (up to ~ 1 mm) that facilitated relatively precise determination of concentrations of these elements.

Polished meteorite slabs were imaged by environmental scanning electron microscopy using an ElectroScan E-3 ESEM, and cohenite was identified via quantitative analysis of Fe and Ni. Large cohenite crystals (up to ~1mm) were selected for LA-ICP-MS analyses. A CETAC LSX-200™ 266 nm frequency-quadrupled Nd-YAG UV laser ablation system coupled to a Finnigan Element™ ICP mass spectrometer was used for the analyses. A 10 Hz pulsed laser beam with a diameter of ~ 50 µm, scanned over the surface at 10 µm/s, was used to ablate the sample, and the aerosol was transported to the Element™ via Ar gas. A line scan of ~1-2 mm length was performed for each analysis of a cohenite-kamacite pair. The peaks ^{31}P, ^{53}Cr, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{69}Ga, ^{74}Ge, ^{75}As, ^{97}Mo, ^{102}Ru, ^{103}Rh, ^{106}Pd, ^{182}W, ^{185}Re, ^{192}Os, ^{193}Ir, ^{195}Pt and ^{197}Au were monitored during each analysis. Standardization was accomplished via analyses of two natural iron meteorites (Hoba and Filomena), using concentration values reported in [6].

Results: The Fe, CI-normalized concentrations of 17 siderophile elements in kamacite from Canyon Diablo and Odessa, along with the bulk compositions of both meteorites [7], are plotted in Fig. 1(a). Phosphorus and Cr are not shown.

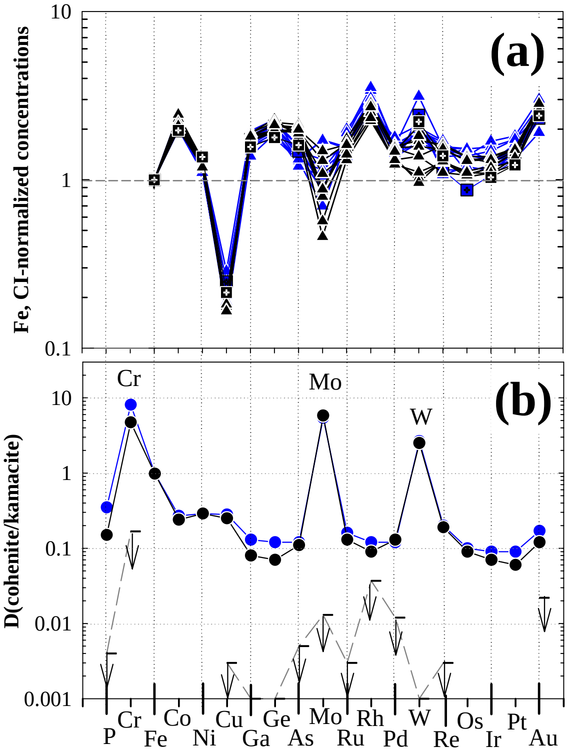

Fig. 1. (a) Plot of Fe and CI-normalized concentrations of siderophile elements (excluding P and Cr) in kamacite grains in Canyon Diablo (blue triangles) and Odessa (black triangles). The blue and black squares with cross hairs are the bulk compositions of Canyon Diablo and Odessa [7], respectively. **(b)** Plot of measured partition coefficients, D(cohenite/kamacite), determined for Canyon Diablo and Odessa. The dashed line connects the estimated detection limits (arrows).

The concentrations of these 17 siderophile elements are generally very similar in the two meteorites. Both Mo and W are depleted in kamacite relative to neighboring siderophile elements and to the bulk compositions, indicating the importance of cohenite as a significant host of these elements. Although Cr is exceedingly depleted in kamacite (~0.001xCI), the weight fractions of cohenite in these meteorites is too low to account for this depletion, and other hosts (e.g., chromite and sulfides [5]) are needed. The concentrations of the rest of the elements show very limited ranges in kamacite and are generally close to their bulk concentrations.

The measured D(cohenite/kamacite) of the 19 siderophile elements are similar in the two meteorites (Fig. 1b; Table 1). Our results show that Cr, Mo and W exhibit relatively strong anthracophile behavior (in that order) in solid state partitioning between cohenite and kamacite. Rhenium in these meteorites is at best weakly anthracophile, with D(Re)~2xD(Os)<1. Except for Mo (which was not included in the study of [2]), no other anthracophile elements have been identified among the siderophile elements, although we have not yet measured Sn and Sb. The influence of carbon on the partitioning of Cr, Mo and W, three elements of the same group in the periodic table (VIB), is now confirmed. It should be noted that Re belongs to an adjacent group in the periodic table that also includes Tc (an extinct radionuclide in iron meteorites).

Table 1: Average D, with1σ standard deviation (no. of cohenite-kamacite pairs)

	Canyon Diablo (11)		**Odessa (10)**	
	D	1 σ	D	1 σ
P	0.2	0.1	0.4	0.2
Cr	5	2	8	3
Fe	0.98	0.01	0.98	0.01
Co	0.24	0.05	0.27	0.04
Ni	0.29	0.05	0.29	0.03
Cu	0.3	0.1	0.28	0.08
Ga	0.08	0.06	0.13	0.05
Ge	0.07	0.06	0.12	0.03
As	0.11	0.06	0.12	0.04
Mo	5.8	2.0	5.4	2.0
Ru	0.13	0.06	0.16	0.04
Rh	0.09	0.06	0.12	0.06
Pd	0.13	0.06	0.12	0.04
W	2.5	0.7	2.7	0.7
Re	0.19	0.09	0.20	0.07
Os	0.09	0.05	0.10	0.04
Ir	0.07	0.05	0.09	0.03
Pt	0.06	0.05	0.09	0.03
Au	0.12	0.07	0.17	0.06

Discussion: The comparisons between the D (cohenite/kamacite: this study) and D (liq. metal/solid metal at 1200°C and 3.8 wt.% C in the liquid: [2]) show that there is a broad positive correlation between these two distinct measures of anthracophile tendency for siderophile elements (Fig. 2). A significant difference between this study and the equivalent figure in [2] is that Os, Ir and Pt are about 10-fold higher in cohenite in this study. The origin of the discrepancy is under examination. The addition of As introduces another anomaly. Arsenic is incompatible in solid metal in the experiments of [2], whereas it preferentially partitions into kamacite in the IAB irons. The incompatible behavior of As in Fe-Ni-C is thus of importance to the study of siderophile element fractionation in C-rich iron meteorites [7], where Au (normally equally incompatible) becomes compatible with increasing C contents in the liquid. The [D(Au)-1]/[D(As)-1] ratio may, therefore, be useful as an indicator of the C contents of natural metallic liquids parental to iron meteorites. Our results thus extend the experimental results of [2] to the solid state and down to lower temperatures (<1200°C) for the Fe-Ni-C system. We anticipate that fractionations of Re/Os (and, by analogy, Tc/Ru) in cohenite relative to kamacite in iron meteorites may prove useful for future geochronological studies.

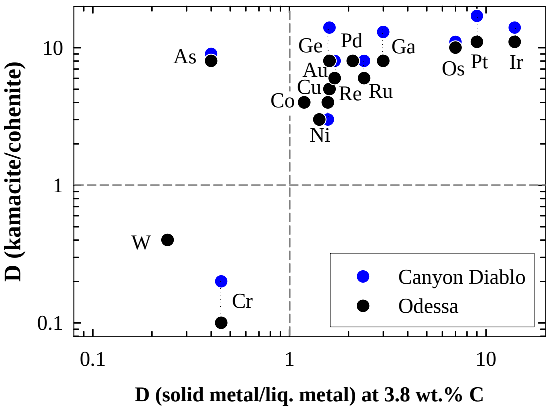

Fig. 2. Plot of D(kamacite/cohenite) in the IAB iron meteorites (this study) vs. D(solid metal/liquid metal [2]). The dotted tie lines connect the D values for each element for Canyon Diablo and Odessa meteorites. Note that the D values in Fig. 1b [D(cohenite/ kamacite)] are reversed in Fig. 2 [D (kamacite/cohenite)].

References: [1] Willis, J., and Goldstein, J. I. (1982), J. Geophys. Res., 87, A435-A445. [2] Chabot et al., Geochim. Cosmochim. Acta, in press. [3] Campbell, A. J, and Humayun, M. (1999), LPSC, XXX, #1974. [4] McDonough et al. (1999), LPSC, XXX, #2062. [5] Buchwald (1975), Handbook of Iron Meteorites, Univ. of California Press. [6] Campbell et al. (2002) Geochim. Cosmochim. Acta, 66, 647-660. [7] Wasson, J. T., and Kallemeyn, G. W. (2002), Geochim. Cosmochim. Acta, 66, 2445-2473.