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CALORIMETRIC THERMOMETRY OF METEORITIC TROILITE: PRELIMINARY THERMOMETER RELATIONSHIPS. Judith H. Allton[1], Susan J. Wentworth[1], and James L. Gooding[2]. [1]C23, Lockheed Engineering and Sciences Co., Houston, TX 77058. [2]SN2, NASA/Johnson Space Center, Houston, TX 77058 USA.

Summary. Thermodynamic properties of the α/β phase transformation in terrestrial troilite (FeS), as measured by differential scanning calorimetry (DSC), vary systematically with prior thermal history of the troilite, as imposed under laboratory conditions. Both the transition temperature and enthalpy change for the α/β transformation decrease with increasing maximum temperature of prior heat treatment. DSC measurements on troilite from various meteorites indicate clear differences in the α/β thermodynamic properties that are consistent with differences in the natural thermal histories of the meteorites.

Introduction. Our previous work [1,2] established the feasibility of DSC as a technique for measuring solid-state phases changes in troilite as possible indicators of troilite thermal histories. Here we report new data that confirm the separation of elemental compositions from thermal history as influences on DSC data for troilite. In addition, we present new evidence that thermal histories can be preserved in troilite samples that are stored at temperatures near 300 K.

Experimental Procedure. Individual samples of terrestrial troilite (from Del Norte County, California) were heated under Ar at 10 K/min and to various maximum temperatures up to the 1000 K operating limit of our DSC instrument [1,2]. After cooling at 10 K/min, each sample was re-heated at 10 K/min, under Ar, to the same maximum temperature as before; calorimetric data were collected and calibrated using temperature and enthalpy standards. Calibrated DSC analyses were performed on troilite extracted from the Mundrabilla (octahedrite) and PAT91501 (L7 chondrite) meteorites; DSC analyses were also made for bulk silicate powder of EET83213 (L3 chondrite). After heating, representative troilite samples were prepared as polished grain mounts and subjected to elemental analysis by electron microprobe.

Results and Interpretations. Troilite exhibits two solid-state phase transitions [1,2] but preliminary parameterization of data is based only on the stronger of the two, namely, the α/β transformation. Results for Del Norte clearly show systematic changes in the α/β transformation as a function of previous thermal history. Both the temperature and enthalpy change of the α/β transformation vary inversely with maximum temperature of prior heating (Fig. 1).

To test survivability of the α/β "memory" of thermal history, we analyzed a troilite sample that had been stored in air at about 300 K for more than one year

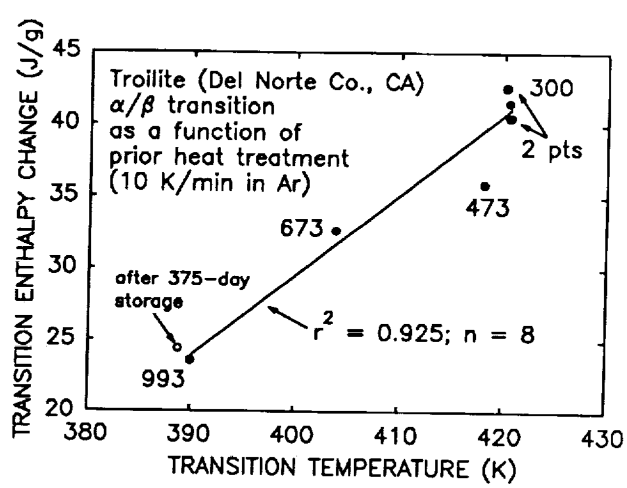

Figure 1. Thermometer relationship, based on the α/β phase transformation, determined for artificially heated samples of Del Norte troilite. The three-digit number by each point indicates the Kelvin temperature experienced during prior heat treatment of the sample. The cluster of points labelled "300" indicates scatter measured for replicate samples of the natural (unheated) troilite. Filled circles depict a series of samples that were analyzed within a few days of heat treatment; the open circle represents a sample analyzed more than one year after heat treatment.

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after it was artificially heated to 993 K. As shown in Fig. 1, the thermodynamic properties measured for the α/β transformation of previously heated troilite were essentially the same for a sample analyzed 375 days after heating compared with a separate sample analyzed only 6 days after heating to the same maximum temperature. Although a one-year baseline cannot be claimed as significant on the cosmic timescale, it at least demonstrates that troilite thermal memory does not rapidly degrade under mild storage conditions.

Results for meteoritic troilite show appreciable scatter for a given meteorite but, nonetheless, indicate systematic differences among individual meteorites (Fig. 2). Dissolved impurities might be expected to depress the temperatures and enthalpies of first-order phases changes, but the systematic differences in the troilite α/β transformations are not attributable simply to compositional differences. If trace elements controlled the α/β transformation, PAT91501 troilite, which is lowest in trace elements (Table 1), should probably not possess properties intermediate between those of Mundrabilla and Del Norte (Fig. 2). The Del Norte and Mundrabilla samples contain similar levels of trace elements (Table 1) but exhibit substantially different properties for the α/β transformation. Although trace-element chemistry probably plays a minor role, the systematic differences among the meteoritic troilites probably reflect separate, distinctive thermal histories.

Application of the preliminary Del Norte "thermometer" (Fig. 1) to the meteorite data (Fig. 2) suggests a trend of maximum planetary temperatures that decrease from Mundrabilla to PAT91501 to EET83213, which is qualitatively consistent with petrology. Iron meteorites probably cooled from 1800 K [3] but chondrites probably accreted at < 1000 K [4]. After further calibration, including possible effects of heating/cooling rates, more precise calorimetric thermometry of meteoritic troilite should become possible.

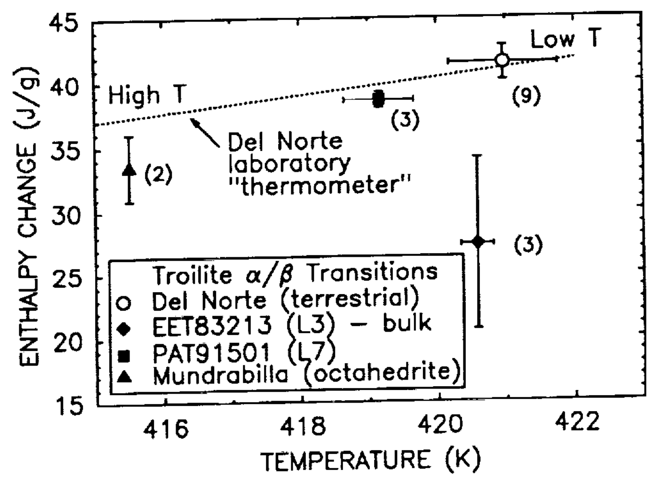

Figure 2. Thermodynamic properties of the α/β phase transformation in natural (not previously heated) troilite from various meteorites compared with the laboratory thermometer relationship determined for terrestrial troilite (Fig. 1). Each point represents the average result for the number of replicate samples shown in parentheses; error bars indicate one standard deviation of the mean. Results for EET83213, based on bulk samples of the meteorite, plot systematically low on the y-axis as a consequence of incomplete corrections for matrix effects.

Table 1. Trace-element compositions of troilite determined by electron microprobe (wt. %; 10-grain avg. ± 1 std. dev.)

	Ni	Cr	Mn
Del Norte	0.41 ± 0.17	0.01 ± 0.01	0.01 ± 0.01
Mundrabilla	0.04 ± 0.03	0.52 ± 0.27	0.07 ± 0.04
PAT91501	0.10 ± 0.04	0.06 ± 0.04	0.02 ± 0.01

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