Meteorite heat capacities: Results to date

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Heat capacity is an essential thermal property for modeling asteroid internal metamorphism or differentiation, and dynamical effects like YORP or Yarkovsky perturbations. We have developed a rapid, inexpensive, and non-destructive method for measuring the heat capacity of meteorites at low temperature [1]. A sample is introduced into a dewar of liquid nitrogen and an electronic scale measures the amount of nitrogen boiled away as the sample is cooled from the room temperature to the liquid nitrogen temperature; given the heat of vaporization of liquid nitrogen, one can then calculate the heat lost from the sample during the cooling process. Note that heat capacity in this temperature range is a strong function of temperature, but this functional relation is essentially the same for all materials; the values we determine are equivalent to the heat capacity of the sample at 175 K.

To correct for systematic errors, samples of laboratory-grade quartz are measured along with the meteorite samples. To date, more than 70 samples of more than 50 different meteorites have been measured in this way, including ordinary chondrites [1], irons [2], basaltic achondrites [3], and a limited number of carbonaceous chondrites [1]. In general, one can draw a number of important conclusions from these results. First, the heat capacity of a meteorite is a function of its mineral composition, independent of shock, metamorphism, or other physical state. Second, given this relation, heat capacity can be strongly altered by terrestrial weathering. Third, the measurement of heat capacity in small (less than 1 g) samples as done typically by commercial systems runs a serious risk of giving misleading results for samples that are heterogeneous on scales of tens of grams or more.

Finally, we demonstrate that heat capacity is a useful tool for determining and classifying a sample, especially if used in conjunction with other intrinsic variables such as grain density and magnetic susceptibility. We will present an updated list of our results, incorporating our latest corrections for a variety of small but measurable systematic errors, and new results for meteorites and meteorite types not previously measured or reported.

References: [1] Consolmagno G. J., Schaefer M. W., Schaefer B. E., Britt D. T., Macke R. J., Nolan M. C. and Howell E. S. (2013). The measurement of meteorite heat capacity at low temperatures using liquid nitrogen vaporization. Planet Space Sci. 87, 146–156. [2] Consolmagno G. J. and Britt D. T. (2013). Iron meteorite density and heat capacity. Meteorit. Planet Sci. 48, abstract 5128. [3] Macke R. J., Consolmagno G. J., and Britt D. T. (2014). Heat capacity measurements of HED meteorites from the Vatican collection. Lunar Planet. Sci. XLV, abstract 1929.