

Bridge You and Nano

Specific Heat Capacity of Refractory Material

Temperature is a measure of the average kinetic energy of a substance. As a substance absorbs energy, the atoms and molecules become excited. Specific heat, C_p , is a measure of a substance's ability to absorb heat and is expressed as the amount of energy required to change the temperature of one unit mass of the substance by one degree Kelvin.

For quantum mechanical reasons, as a substance absorbs heat and becomes hotter, more degrees of freedom are available for the constituent molecules. As these degrees of freedom become available, the substance is able to absorb more energy per degree of temperature change.

Specific heat measurements using Differential Scanning Calorimetry (DSC) require three separate test runs to obtain accurate data. The first test run must be performed using two empty crucibles to establish baseline performance of the instrument. The second test run is performed using a specific heat standard, typically high purity sapphire, that has a very well defined heat capacity over the full temperature range of the specific heat measurement. The third test is performed with the sample being measured. The specific heat is then determined via Equations 1 and 2.

Eq. 1

$$C_{p} = \frac{Signal(Sample - Baseline)}{Mass(Sample) \cdot Heating Rate \cdot Sensitivity}$$

Eq. 2
$$Sensitivity = \frac{Signal(Sapphire - Baseline)}{Mass(Sapphire) \cdot Heating Rate \cdot Theoretical C_p(Sapphire)}$$

Specific heat capacity is an important property to consider for a variety of different applications. While specific heat values for individual elements are well known, they are less so for multicomponent systems such as alloys and composites. Understanding how these materials store heat energy is vital in heat transfer applications.

One such application for C_p measurements is nanostructured materials. These materials tend to show atypical values for specific heat, in some cases as much as 50% higher than that of the coarse-grained material.

Another application is furnace materials. Refractory materials that line a furnace should have low heat capacity so that less energy is drawn away from the furnace and stock material. Due to their chemical stability, high melting temperature and low specific heat, bricks made partly from Aluminum Oxide (Al_2O_3) are frequently used to build the interior wall of high temperature furnaces.



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The specific heat of Aluminum Oxide (Al_2O_3) was measured in Ebatco's NAT Lab using a Netzsch Simultaneous TGA/DSC Apparatus STA 449 F3 Jupiter (Germany). The STA is capable of performing specific heat measurements between room temperature and 1500°C with a stated accuracy of $\pm 5\%$. The measurement results are presented in Figure 1. The average deviation of the experimental data from the published data is only 0.78%.



Figure 1. Specific heat measurement results for Aluminum Oxide.

Reference:

Sarge, Stefan M., Eberhard Gmelin, Günther W.H. Höhne, Heiko K. Cammenga, Wolfgang Hemminger, and Walter Eysel. "The Caloric Calibration of Scanning Calorimeters." *Thermochimica Acta* 247.2 (1994): 129-68. ISSN 0040-6031, 10.1016/0040-6031(94)80118-5.