Spin wave contribution to the specific heat of ferromagnetic terbium at low temperatures

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Abstract. The magnon contribution to the specific heat of ferromagnetic terbium is evaluated and the results are compared with the measurements from 90 K down to absolute zero.

Keywords. Spin wave contribution; specific heat; magnon contribution; ferromagnetic terbium.

Recently there has been a spurt in studies on heavy rare earth metals because of the magnon-phonon interactions observed in them. The phonon dispersion relations in terbium have been investigated by Houmann and Nicklow (1970) and by Menon and Rao (1972). The magnon dispersion relations have been measured by Moller *et al* (1968). In this paper we report the magnetic specific heat of terbium from 90° K down to absolute zero.

The total energy $U_m(T)$ of the spin waves which are excited at a temperature T is given by

$$U_m(T) = \int_0^{\infty} \frac{Eg(E)dE}{\text{Exp}(E/KT) - 1} \quad (1)$$

where $g(E)dE$ is the number of magnons in the energy interval E and $E + dE$. The energy density function has been obtained by making use of the measured dispersion relations of Moller *et al* (1968) and the normalized energy density function $g(E)$ has been divided into steps of 0.3 meV. The integration has been done using the numerical integration method on BESM-6 computer. A direct differentiation of (1) with respect to T will therefore yield the magnetic specific heat $C_m(T)$ of the material due to the excitation of the spin waves at that particular temperature. The resultant expression is used to evaluate the magnetic specific heat of terbium in the temperature range 0 to 90° K.

Figure 1 shows the temperature variation of the magnetic specific heat of terbium. The solid line is the theoretical curve and the dark circles are the experimental values obtained by Brooks *et al* (1968) from the experimental data of Jennings *et al* (1957). Upto 20 K, the agreement between the calculated and observed values is excellent. Between 20 K and 65 K the experimental values are consistently lower than the calculated ones. Between 75 K and 90 K the experimental values are higher than the present calculated values. The maximum discrepancy is found at 30 K where the deviation is about 28 %. The origin of the discrepancy between theoretical and the

Figure 1.

experimental results above $T = 20\text{ K}$ may be attributed to the assumptions made during the analysis of the experimental data.

It may be mentioned that in the analysis of the specific heat of many of the rare earths, previous workers (Lounasmaa 1966; Lounasmaa and Sundstrom 1966, 1967) had to make fairly drastic assumptions concerning the phonon contribution to the specific heat. As an approximation, they assumed that both the magnetic and the nonmagnetic heavy rare earths have the same lattice specific heat. Hence a thorough reanalysis of the specific heat data of the rare earths is useful.

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