and electron-phonon induced attraction. If we use the expression given by Pines[10] to calculate the interaction energy, we obtain a value of 0.51 for that part of $N(0)V$ due to the electron-phonon interaction. Hence $N(0)V$ decreases by about 5×10^{-4}. Taking $T_c\approx4.5°K$, $N(0)V\approx0.25$ and the decrease in T_c is about 0.039°K. This is a little more than half the experimental value, so that the agreement is satisfactory considering the difficulty in estimating l and the simple nature of the calculation.

[10] D. Pines, Phys. Rev. **109**, 280 (1958).

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Specific Heat of Yttrium Iron Garnet from 1.5° to 4.2°K*

SAMUEL S. SHINOZAKI†
Department of Physics, University of California, Berkeley, California
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The specific heats of two samples of yttrium iron garnet have been measured between 1.5 and 4.2°K. The data have been analyzed into lattice- and spin-wave contributions characterized, respectively, by the Debye temperatures $\Theta_1=538°K$, $\Theta_2=567°K$, and by $D_1=0.81\times10^{-28}$ erg-cm^2, $D_2=0.85\times10^{-28}$ erg-cm^2, where D is defined by the dispersion relation for spin waves, $\hbar\omega=Dk^2$.

I. INTRODUCTION

THE low-temperature specific heat of yttrium iron garnet (YIG) is of interest in connection with the expected spin-wave contribution to the thermal properties. Recently, several specific-heat measurements have been reported, but the results are not in agreement with one another. In order to check the former results, measurements on two samples of YIG were carried out in the temperature range 1.5° to 4.2°K.

II. EXPERIMENTAL

In order to avoid errors associated with the desorption of exchange gas during the heating periods, a mechanical heat switch was used to cool the samples to 1.1°K. The switch consisted of two copper jaws connected to the helium bath by flexible copper wires. The jaws could be closed on a small copper sample holder which made thermal contact to the sample. The motion of the jaws was controlled by applying tension to a piano wire which went directly to the top of the apparatus and out into the atmosphere through a bellows. Half an hour was required to cool the sample from 77° to 4.2°K. When the switch was opened, a temperature increase in the sample was observed which corresponded to a heat input of between 10 ergs and 100 ergs. The sample was mounted rigidly in the cryostat with cotton thread.

The thermometer was an American Ohmite resistor ($\frac{1}{2}$ watt, 47 ohms), which was found to be more sensitive than the Allen-Bradley resistor. It was calibrated against the vapor pressure of the helium bath at 22 points between 1.5° and 4.2°K. During the calibration, power was supplied to the bottom of the bath at a rate of 0.04 watt and a correction for the hydrostatic

* Supported in part by the National Science Foundation.
† Present address: Ford Scientific Laboratory, Dearborn, Michigan.

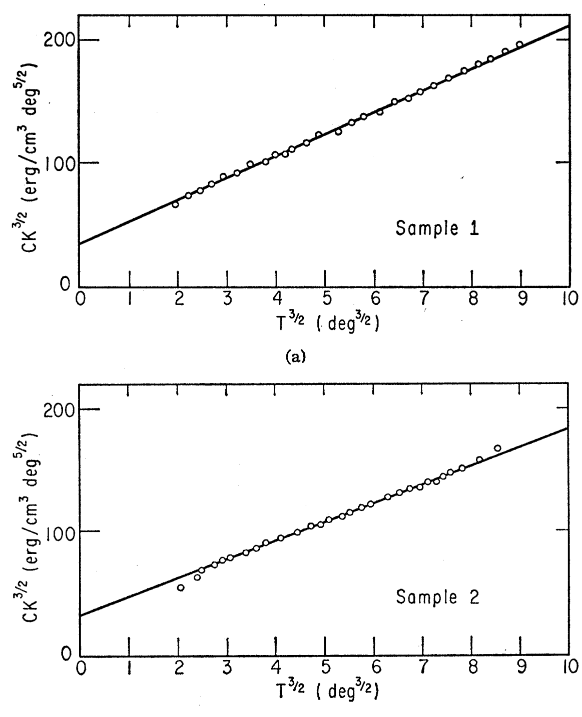

FIG. 1. The specific heat of the two YIG samples. The points for sample 1 give the results obtained in one experiment. The points for sample 2 give the results obtained in two separate experiments.

TABLE I. Comparison of experimental results for YIG. The values of a and b in the fourth and fifth rows were calculated using the x-ray density.[a]

	$C(\text{spin wave})=aT^{3/2}$			$C(\text{lattice})=bT^3$	
	a erg/cm³ deg$^{5/2}$	D erg/cm²	A erg/cm	b erg/cm³ deg⁴	Θ °K
Edmonds and Petersen	68.9	0.51×10^{-28}	0.27×10^{-6}	29.3	454
Meyer and Harris	75.7	0.48	0.25	12.8	599
Kunzler, Walker, and Galt	33.6	0.83	0.44	20.5	510
Shinozaki (1)	34.7	0.81	0.43	17.6	538
Shinozaki (2)	32.1	0.85	0.45	15.1	567
Calculated from sound velocity	···	···	···	15.2	566

[a] F. Bertant and F. Forrat, Compt. rend. **242**, 382 (1956).

head was made. At the end of the experiment exchange gas was introduced and several calibration points were checked. The resistance was measured with a 43-cps resistance bridge, together with a lock-in detector and dc galvanometer. Power dissipation in the thermometer was less than 3×10^{-8} watt. The rate of temperature drift of the sample was about 0.003 deg/min at 2°K.

III. RESULTS

Samples 1 and 2 were polycrystalline specimens of pure YIG weighing 10.34 and 22.25 g, respectively. Sample 1 was obtained from Bell Telephone Laboratories and was the sample used by Kunzler, Walker, and Galt.[1] The experimental results are presented in Fig. 1. The specific heat is analyzed into the spin wave ($T^{3/2}$) and lattice (T^3) parts by plotting $CT^{-3/2}$ vs $T^{3/2}$. Our results between 1.5°K and 4.2°K can be represented by $C=aT^{3/2}+bT^3$, with the values of a and b shown in Table I. Our experimental specific heats are considerably smaller than those measured by Edmonds and Petersen[2] and by Meyer and Harris,[3] but are in reasonable agreement with that of Kunzler, Walker, and Galt.[1] It has been suggested that the larger spin-wave specific heat is the result of magnetic impurities,[1,3] but this would not explain the discrepancies in the lattice term. It seems probable that the high values of the total specific heat observed by Edmonds and Petersen and by Meyer and Harris are associated with the absorption of exchange gas by the sintered samples.

The lattice contribution is in good agreement with that calculated from the sound-velocity measurements of McSkimin[4] on the assumption that YIG is isotropic.

On the assumption that the dispersion relation for spin waves is

$$\hbar\omega=Dk^2,$$

one can obtain the following equation for b:

$$b=(\tfrac{15}{32})(1.341\times\pi^{-3/2})k_B(k_B/D)^{3/2}=0.113k_B(k_B/D)^{3/2},$$

where the constant D may be expressed by the Landau-Lifschitz exchange constant A as[5]

$$D=2Ag(\mu_B/M_s).$$

k_B is the Boltzmann constant. We take $4\pi M_s=2449$ gauss,[6,7] μ_B is the Bohr magneton, and g is the spectroscopic splitting factor. Thus the constant D and Landau-Lifschitz exchange constant A can be evaluated as shown in Table I.

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