MASTER

MAGNETIC FIELD DEPENDENCE OF THE THERMAL CONDUCTIVITY OF COBALT CHLORIDE THIOUREA.* C. Ni and H. Weinstock. Department of Physics, Illinois Institute of Technology, Chicago, Ill. 60616 USA

The thermal conductivity of $\text{Co}[(\text{NH}_2)_2\text{CS}]_4\text{Cl}_2$ has been measured in the temperature range from 0.4°K to 4.0°K and in magnetic fields up to 27.7 kilogauss. In every case reported, heat flowed in the $[001]$ direction and, with but one exception the magnetic field was applied parallel to this same direction.

Figure 1 is a detailed plot of the data obtained for both a zero and a 20 kilogauss externally applied field. Figure 2 shows a sequence of six curves which approximate the actual data points taken in various external fields.

The zero field data are in agreement with previous measurements⁽¹⁾ carried out over a more limited temperature range from 0.4°K to 1.5°K . Because of this limited range, it appeared that conductivity

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:
 A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
 B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.
 As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

below the Néel temperature of $(0.92 \pm 0.02)^\circ\text{K}^{(2)}$ was enhanced, possibly due to magnon conductivity. The currently reported work indicates that the conductivity in the vicinity of the Néel temperature undergoes a relatively sharp depression. It is now believed that this anomalous behavior is associated with critical scattering of phonons due to critical fluctuation of the spin energy density, as suggested by Kawasaki.⁽³⁾

Interpretation of the data obtained in the presence of an applied field is facilitated by re-evaluating it as the change in thermal resistivity relative to the zero field resistivity ($\Delta W/W_0$). This quantity is then plotted in Figure 3 as a function of applied field for a temperature of 1.8°K . In Figure 4 ($\Delta W/W_0$) is plotted as a function of temperature at various fields. Attention is called to

the unusual behavior near 1°K exhibited in all but the 27.7 kilogauss data. This is seen as a manifestation of the critical scattering of the phonons by paramagnons exhibiting short range

order just above the Néel temperature. As the magnetic field is increased, the Néel temperature is shifted to lower values and hence the critical scattering becomes less of a factor above 1°K.

The gross features of Figures 3 and 4 may be interpretable as due to a coupling of the phonons to the Zeeman splitting of the cobalt ions. Huber⁽⁴⁾ has treated this interaction for a two-level paramagnetic spin system (which can be applied here even though the cobalt system is multi-leveled). His resultant expression when reworked in terms of $(\Delta W/W_0)$ is

$$\frac{\Delta W}{W_0} = - \left[1 - \frac{A 2\pi^2 v^2 k T^5}{\hbar^2 (\Delta\omega) L \omega_0} \exp(-\hbar\omega_0/kT) \times \left(\exp(\hbar\omega_0/kT) - 1 \right)^2 \right]^{-1} \quad (1)$$

where AT^3 is the conductivity without spin-phonon interaction, $\hbar\omega_0$ is the Zeeman splitting, L is on the order of specimen thickness, and $\Delta\omega$ is the phonon bandwidth for those phonons with mean free paths less than L . When $(\Delta W/W_0)$ vs. H is plotted according to equation (1), a peaked function with quadratic rise for small H is obtained, the peak falling in the region of $\hbar\omega_0 = 4kT$. Similarly, plotting $(\Delta W/W_0)$ vs. T , one obtains another peaked function, the peak falling in the region of $\hbar\omega_0 = 5kT$. Assuming a spectroscopic splitting factor of $g = 2$ for cobalt, it is found that the curve in Figure 3 is in qualitative agreement with equation (1). Since at the highest field used, $\hbar\omega_0/kT = 2.0$, no peak is observed. More significantly, in Figure 4 a peak is observed for each curve. It is rather difficult to evaluate these curves in light of equation (1) because of the anomalous phonon scattering in the region above the Néel temperature. This effect causes the peaks in the curves to be shifted to higher temperatures, with the shifts decreasing at higher fields. Unfortunately, this tends to obscure the prediction of equation (1) that the peak should shift to higher temperatures at higher fields. Further, the appearance of the 27.7

kilogauss peak at about 1.7°K would indicate a g value of about 3 to 4. Such an assumption would still not invalidate the analysis of Figure 3. Although no measurements of g exist for this crystal, work by Narath⁽⁵⁾ on $\text{CoCl}_2 \cdot 2\text{H}_2\text{O}$ (a system in which the chlorine coordination of the cobalt is similar) yields values for g of this magnitude. The behavior of the lowest three curves in Figure 4 may be due to the excitation of electrons to higher Zeeman levels.

Preliminary measurements in which the magnetic field is perpendicular to the heat flow, yield values of $(\Delta W/W_0)$ for a given field which are less than the corresponding values for the parallel field case. This would imply that either g and/or the phonon-spin coupling are anisotropic.

The authors wish to thank Professor H. N. Spector of IIT and Dr. F. Mueller of Argonne National Laboratory for valuable discussion.

* Supported by the U. S. Atomic Energy Commission under contract AT(11-1) 1629.

- (1) H. Weinstock, Phys. Letters 26A, 117 (1968).
- (2) H. Forstat, N. Love, H. McElearn and H. Weinstock, Phys. Rev. 145, 406 (1966).
- (3) K. Kawasaki, Prog. Theor. Phys. 29, 801 (1963).
- (4) D. L. Huber, Phys. Letters 20, 230 (1966).
- (5) A. Narath, Phys. Rev. 140A, 552 (1965).