knowledge of the branching ratio of $Zn^{62}$ decay where the decay might take place to two states separated by 41.8 kev. This would be difficult to determine without experimental knowledge of the conversion coefficient. The $Cu^{62}$ has a $f\tau_{\frac{1}{2}}$ value of $13.4\times10^4$ and $Zn^{62}$ has a $f\tau_{\frac{1}{2}}$ value of $5.3\times10^4$ (taking into account the decay by $K$-capture and positron emission) which classifies both spectra as allowed.

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[2] Miller, Thompson, Cunningham, Phys. Rev. **74**, 347 (1948).

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## The $Sn^{117}$ Isomeric Activity

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May 29, 1950

THE 14-day tin activity has recently been assigned to $Sn^{117}$ by Mihelich and Hill[1] and by Mallary and Poole[2] who activated electromagnetically enriched isotopes of tin with slow neutrons.

A sample of $Sn^{117}$ of high specific activity was prepared for observation in a magnetic lens spectrometer by bombarding a thick target of antimony with 100-Mev deuterons in the 184-inch Berkeley cyclotron. The $Sn^{117}$ activity was separated from the antimony target by selective precipitation as sulfides thus requiring the addition of a relatively large amount (5 mg) of tin carrier. A source was prepared by mounting the $SnS_2$ on a Formvar film backing so that the total source thickness was about 1 mg/cm². The observed spectrum is shown in Fig. 1. Two conversion peaks are present at 127.0 and 152.5 kev corresponding to the $K$ and $L$ conversion for a transition with an energy of $0.157\pm0.002$ Mev. This value is slightly smaller than the value of 0.159 Mev obtained by Mihelich and Hill.

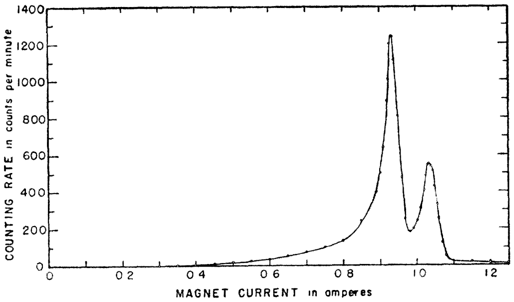

FIG. 1. The observed spectrum of conversion electrons from $Sn^{117}$ before correction for the finite resolution of the spectrometer.

From the half-life of 14 days and the energy of 0.157 Mev the transition corresponds to a transition of order five according to the classification of Axel and Dancoff.[3] The experimental ratio of the number of $K$ and $L$ conversion electrons is 2.2 taking into account the resolution of the spectrometer. With a value $l=5$ the theory of Hebb and Nelson[4] gives 0.95 as the theoretical $K/L$ ratio for electric transitions and 2.85 for magnetic transitions. With $l=4$ the theoretical $K/L$ ratio is 3.84 for magnetic transitions. Therefore in order to account for the experimental value of the $K/L$ ratio, a mixture of $2^5$ pole electric and $2^4$ pole magnetic radiation must be postulated.

The author wishes to thank Professor A. C. Helmholz for helpful discussions during the course of the experimental work described in this and the preceding letter and also to thank the Radiation Laboratory of the University of California for making some of their facilities available to him.

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[2] E. C. Mallary and M. L. Poole, Phys. Rev. **77**, 75 (1950).
[3] P. Axel and S. M. Dancoff, Phys. Rev. **76**, 892 (1949).
[4] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 436 (1940).

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## Magnetic Resonance in Antiferromagnetic Materials near the Curie Temperature*

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May 26, 1950

AN investigation[1,2] has been made of the magnetic resonance absorption of an antiferromagnetic material. $Cr_2O_3$ was selected for the initial experiments because it is a stable compound that has a Curie point at a convenient temperature. Honda and Sone[3] have reported a Curie temperature of 34°C for $Cr_2O_3$ while Foex and Graff[4] gave a higher value of 47°C.

The material was introduced into a rectangular cavity which formed one arm of a microwave bridge. The absorption was obtained by measuring the change of intensity of the reflection from the cavity which was slightly mismatched with respect to the line A d.c. magnetic field was set perpendicular to the microwave magnetic field. The procedure followed was to hold the frequency constant at 9300 Mc and sweep the d.c. magnetic field through the resonance peak at various temperatures, ranging from 150°C to liquid air temperature. A small field-dependent absorption has been eliminated from the data given below. We obtain, as a function of the temperature, the height of the absorption peak ($h$), and the value of the d.c. magnetic field ($H_0$) at the point of resonance.

We have found that $h$ varies with the temperature of the powdered sample as shown by Fig. 1. It is noticed that $h$ decreases abruptly at about 38°C indicating a drastic change in the nature of the absorption. Through the paramagnetic range, $H_0$ was constant at approximately 3450 oersteds.

Magnetic susceptibility measurements[5] made on the sintered $Cr_2O_3$ used are shown in Fig. 2. It is noticed for this material that the Curie temperature is 38°C, close to the point where the break in the resonance absorption occurs. It is believed, therefore, that the sudden decrease in the resonance absorption can be attributed to the change of $Cr_2O_3$ from the paramagnetic to the antiferromagnetic state.

The amount of absorption occurring below the Curie temperature depended upon the nature of the material. When the $Cr_2O_3$ was in a powdered form two absorption peaks were found. $H_0$ for one peak was independent of temperature and equal to the value found in the paramagnetic region. $H_0$ for the second peak decreased as the temperature decreased as illustrated in Fig. 3. At −64°C the two peaks are well resolved, occurring at 3450 and 660 oersteds, respectively. When the $Cr_2O_3$ was prepared as

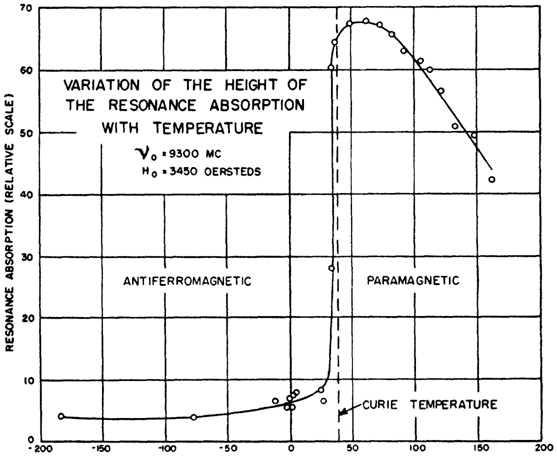

FIG. 1. Variation of the height of the peak ($h$) of the resonance absorption with temperature of powdered $Cr_2O_3$. The vertical broken line indicates the Curie point as determined by an independent measurement of the paramagnetic susceptibility on the sintered material investigated.

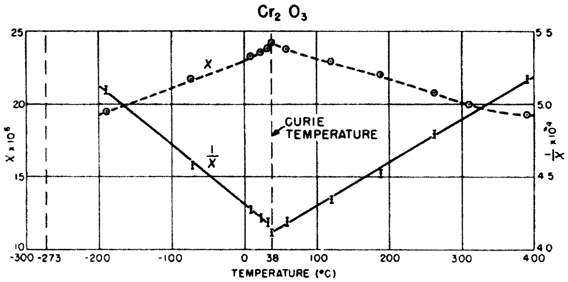

FIG. 2. Variation of paramagnetic susceptibility of sintered $Cr_2O_3$ with temperature.

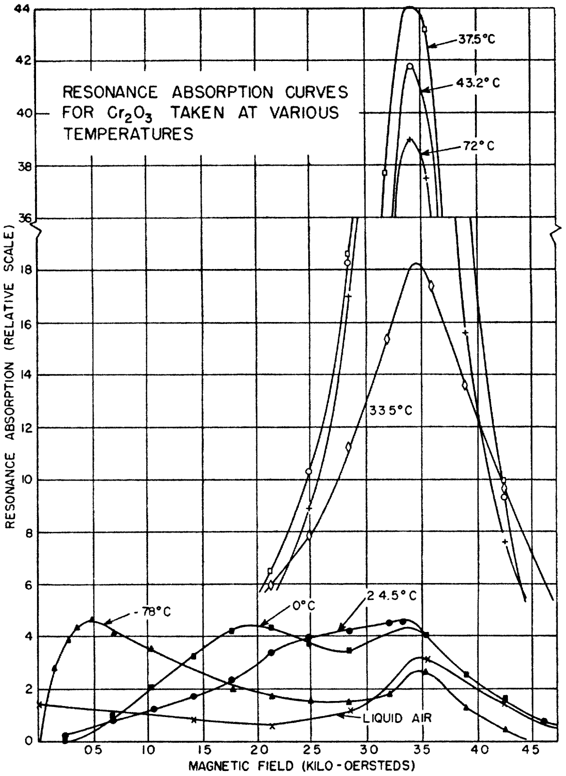

FIG. 3. Resonance absorption curves for powdered $Cr_2O_3$ taken at various temperatures below the Curie temperature.

sintered material the absorption decreased to zero below the Curie temperature.

The striking correlation of the decrease in peak absorption with the Curie temperature suggests the possibility of interpreting these results in terms of the large local fields associated with the spontaneous magnetization. In the ferromagnetic case the applied torque, in the classical sense, is independent of the internal field arising from the exchange integral because the exchange field and the magnetization vectors are parallel. The effective field required for resonance is then determined by the applied field which is independent of temperature. In contrast to the ferromagnetic case, the spontaneous magnetization for an antiferromagnetic material need not be parallel to the total magnetic moment.[6] On the basis of this simplified microscopic picture, it has been suggested[2] that the cross product of the magnetization and the exchange field is not always zero, making the resultant torque depend on the combined internal and external fields. Kittel,[7] however, has indicated that even in the case of antiferromagnetic resonance absorption the spin systems precess together and the exchange torques mutually cancel.

The small absorption remaining below the Curie temperature for the powdered material is described above as consisting of two parts, one which indicates the growth of an internal field with decreasing temperature. This field is of the order of magnitude of a magnetic dipole field.

Antiferromagnetic resonance is being investigated for NiO, MnO, CoO, and $\alpha Fe_2O_3$ and will be included in a forthcoming paper.

The writers are indebted to Dr. J. W. Beams of the University of Virginia for suggesting that the nature of the internal field of antiferromagnetic materials might be studied by microwave resonance absorption and to Dr. J. Samuel Smart for his interest and helpful discussions.

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[*] Supported in part by the ONR.

[1] Trounson, Bleil, and Maxwell, Phys. Rev. **79**, 226 (1950).

[2] D. F. Bleil and R. K. Wangsness, Phys. Rev. **79**, 227 (1950).

[3] K. Honda and T. Sone, Sci. Rep. Tohoku Imp. Univ. **3**, 223 (1914).

[4] G. Foex and M. Graff, Comptes Rendus **209**, 160 (1939).

[5] The data given here were kindly furnished by Dr. T. R. McGuire of the Naval Ordnance Laboratory.

[6] J. H. Van Vleck, J. Chem. Phys. **9**, 85 (1941).

[7] C. Kittel (private communication, May 1, 1950).

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## Single Synthetic Zinc Sulfide Crystals

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June 14, 1950

SINGLE synthetic zinc sulfide crystals have been grown under pressure in a hydrogen sulfide atmosphere. Chemically pure zinc sulfide powder was distributed in a quartz tube over a length of 2½ inches. After inserting the quartz tube in the combustion furnace, the tube was evacuated and hydrogen sulfide gas was passed into the system until a pressure of 6 p.s.i. was obtained. The tube was then heated to a temperature of 1150°C for a period of 48 to 96 hours.

An attempt was made previously to grow zinc sulfide crystals in vacuum; however, no satisfactory crystals were produced and as

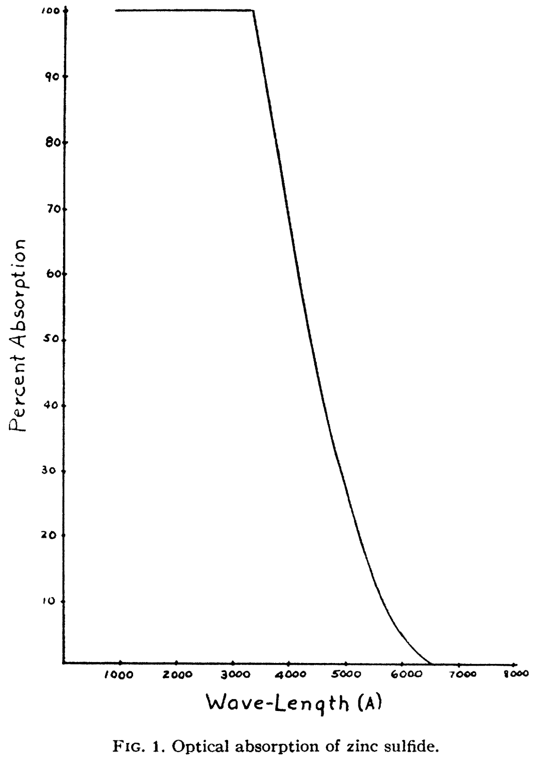

FIG. 1. Optical absorption of zinc sulfide.