and

$$\mu_{Cu^{65}} = 2.3847 \pm 0.0030.$$

The unusual intensity of the copper lines is probably caused by a cupric impurity in the sample. Since the cupric ion is electronically paramagnetic, and since electronic paramagnetic relaxation occurs rapidly,[6] compared with the frequency of the nuclear lines in the present experiment, a fluctuating local field would result having an intensity much larger than in crystals not having a paramagnetic impurity. Therefore, the relaxation time $T_1$ of the nuclei of the cuprous ions would be considerably shortened. A similar effect has been observed for the protons in $CuSO_4 \cdot 5H_2O$ by Bloembergen.[7] A shortened relaxation time gives rise to relatively intense lines under the conditions of operation of the spectrometer because partial saturation is common for most crystalline samples.

The widths of the two lines as recorded, about 5 gauss or 5 kc/sec. between maxima and minima, are determined partly by inhomogeneity of the magnetic field. The magnet used for these experiments has poles only $3\frac{3}{4}$ in. in diameter and a $1\frac{5}{8}$-in. gap, while the sample was about $\frac{3}{4}$ in. long by $\frac{1}{2}$ in. in diameter. Computation of the r.m.s. line width from the spin-spin interactions in the crystal, using a formula developed elsewhere,[8] gives about 2 kc/sec., if an average is taken over all directions of the crystal axes, with respect to the field. The observed line breadth sets a lower limit on the spin-lattice relaxation time $T_1$ of about $10^{-4}$ second.

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## Conductivity Pulses Induced in Single Crystals of Zinc Sulfide by Alpha-Particle Bombardment

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CONDUCTIVITY pulses similar to those observed in diamond[1] have been observed with specimens of single crystals of zinc sulfide when they are bombarded with alpha-particles from polonium.

The types of electrodes used were the same as in the diamond experiments. With electrodes separated by a 0.003-cm gap on the crystal surface, pulses were observed when a potential of 30 volts was applied. Pulses were also observed when a potential of 100 volts was applied between electrodes on opposite sides of specimens about 0.050-in. thick. Pulses were observed both when polished surfaces and cleaved surfaces were used. Pulses were observed with all of the limited number of specimens tested. The response both in numbers of pulses and pulse height is substantially less than that from the best diamond.

The specimens* used were natural crystals of sphalerite which is the cubic form of zinc sulfide. A qualitative spectrochemical analysis of one of the specimens showed an impurity content of the order of 0.1 percent, chiefly germanium. Similarly, the other specimens exhibited impurity contents in the neighborhood of 0.01 percent of one or more of the elements gallium, mercury, cadmium, and manganese. The appearance of pulses in zinc sulfide with this relatively high impurity content contrasts strikingly with the absence of pulses in some diamonds where the impurity content is known to be much smaller.

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* Some of the specimens were obtained through the courtesy of Dr. Keith Boyer, Massachusetts Institute of Technology, and others from Dr. M. F. Distad, Naval Research Laboratory.

## A Note on Relativistic Quantum Mechanics

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THE usual method for obtaining a Hamiltonian for systems of interacting particles and fields is by the use of a Lorentz invariant Lagrangian or an equivalent method. An alternative method is the direct examination of the transformation properties of an assumed form for a Hamiltonian. This note reports the results of such an examination for the following example. Suppose the Hamiltonian, $H$, of a system may be written in the form

$$H = \int e_{\mathbf{k}} dn_{\mathbf{k}} + \int \epsilon_{\mathbf{K}} dN_{\mathbf{K}} + \int V(\mathbf{k}, \mathbf{k}', \mathbf{K}) d\alpha_{\mathbf{k}}^{+} d\alpha_{\mathbf{k}'} da_{\mathbf{K}}, + \int V^{*}(\mathbf{k}, \mathbf{k}', \mathbf{K}) d\alpha_{\mathbf{k}'}^{+} d\alpha_{\mathbf{k}} da_{\mathbf{K}}^{+}$$

and the total momentum, $\mathbf{P}$, may be written

$$\mathbf{P} = \int \mathbf{k} dn_{\mathbf{k}} + \int \mathbf{K} dN_{\mathbf{K}}.$$

In the above equations $d\alpha_{\mathbf{k}}^{+}$ are creation operators and $d\alpha_{\mathbf{k}}$ are annihilation operators for Fermi particles and satisfy the commutation relations $d\alpha_{\mathbf{k}}^{+} d\alpha_{\mathbf{k}'} + d\alpha_{\mathbf{k}'} d\alpha_{\mathbf{k}}^{+} = 0$ if $\mathbf{k} \neq \mathbf{k}'$ and $= d\mathbf{k}$ if $\mathbf{k} = \mathbf{k}'$, and $dn_{\mathbf{k}} = d\alpha_{\mathbf{k}}^{+} d\alpha_{\mathbf{k}}/d\mathbf{k}$. Also, $da_{\mathbf{K}}^{+}$ is a creation operator and $da_{\mathbf{K}}^{+}$ is an annihilation operator for Bose particles and satisfy $da_{\mathbf{K}} da_{\mathbf{K}'}^{+} - da_{\mathbf{K}'}^{+} da_{\mathbf{K}} = 0$ if $\mathbf{K} \neq \mathbf{K}'$ and $= d\mathbf{K}$ if $\mathbf{K} = \mathbf{K}'$, and $dN_{\mathbf{K}} = da_{\mathbf{K}}^{+} da_{\mathbf{K}}/d\mathbf{K}$.

The requirement that $H$, $\mathbf{P}$ constitute a four vector with respect to homogeneous Lorentz transformations gives the following results. First, $e_{\mathbf{k}} = \pm (M^2 + \mathbf{k}^2)^{\frac{1}{2}}$ in which the constant $M$ may be identified with the mechanical mass of the Fermi particle. Second, $\epsilon_{\mathbf{K}} = \pm (u^2 + \mathbf{K}^2)^{\frac{1}{2}}$ in which the constant $u$ is the mechanical mass of the Bose particle. Third,

$$V(\mathbf{k}, \mathbf{k}', \mathbf{K}) = U_0 \delta(\mathbf{k} - \mathbf{k}' - \mathbf{K}) \exp\{2g(\mathbf{k}) - 2g(\mathbf{k}') - 2f(\mathbf{K})\}$$

in which $U_0$ is a constant, $f$ and $g$ are real functions of their arguments, and $\delta(\mathbf{k} - \mathbf{k}' - \mathbf{K})$ is the Dirac $\delta$-function. This particular Hamiltonian does not give convergent results. Other forms for Hamiltonians are being examined at the present time.