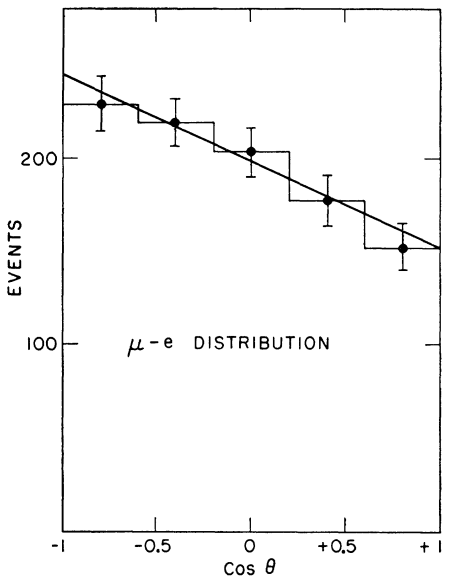

FIG. 1. The electron angular distribution from μ^+ decay. A least squares fit gives $dN/d\Omega \propto 1-(0.25\pm0.045)\cos\theta$. The errors represent standard deviations.

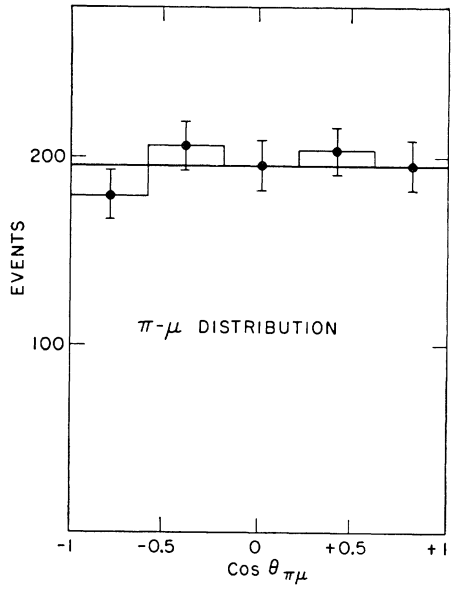

FIG. 2. The μ^+ angular distribution from π^+ decay. The distribution is evidently consistent with an isotropic decay. A least squares fit gives $dN/d\Omega \propto 1+(0.043\pm0.045)\cos\theta_{\pi\mu}$. [The errors represent standard deviations.]

chamber and their precession in the field will tend to destroy angular correlations. Therefore a degaussing coil was placed around the chamber which reduced the field in the chamber to less than 0.25 gauss.

Figure 1 shows the $\mu-e$ angular distributions derived from 980 events. A similar plot of the $\pi-\mu$ angles shown in Fig. 2 is consistent with the spherical symmetry to be expected from this decay. Since the μ range of about 1.1 cm is small compared with the dimensions of the chamber, and since the μ directions are isotropic, it seems unlikely that any scanning or measuring bias affects the measured distributions appreciably.

According to Lee and Yang[1] the measured values of the Michel parameter, ρ, indicate that the decay process is probably $\mu^+\rightarrow e^+ + \nu + \bar{\nu}$. For a simple nonderivative coupling theory the normalized electron distribution was found by Lee and Yang to have the form

$$dN = 2x[(3x-2x^2)+\xi(x-2x^2)\cos\theta]dxd\Omega/4\pi, \quad (1)$$

where x is the ratio of the electron momentum to the maximum electron momentum, θ is the angle between the directions of emission of the μ and electron, and

$$\xi = (f_V f_A^* + f_A f_V^*)/(|f_V|^2+|f_A|^2), \quad (2)$$

where f_V and f_A are the usual vector and axial vector coupling constants, respectively. Integrating over all x, we get

$$4\pi(dN/d\Omega) = 1-\tfrac{1}{3}\xi\cos\theta. \quad (3)$$

Our value of 0.25 ± 0.045 for the coefficient of $\cos\theta$ leads to a value for ξ of 0.75 ± 0.14, if depolarization is negligible. If there is appreciable depolarization, ξ must be nearly equal to its maximum possible value of one.

Lee and Yang[4] have discussed gradient coupling terms though these are not important in nuclear beta decay. These can lead to values of the coefficient of $\cos\theta$ greater than $\frac{1}{3}$ for the integrated spectrum as well as a different energy dependence than indicated by Eq. (1). Our result does not require the introduction of a gradient coupling.

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† National Science Foundation Predoctoral Fellow.
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Odd-Odd Isotope Having Zero Spin*

J. C. HUBBS, W. A. NIERENBERG, H. A. SHUGART, AND J. L. WORCESTER

Radiation Laboratory and Department of Physics, University of California, Berkeley, California

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THE nuclear angular momenta of two neutron-deficient isotopes of gallium have been determined by the atomic-beam magnetic-resonance method. The results are that for 9.4-hr Ga^{66}, $I=0$, subject to the qualification below, and that for 78-hr Ga^{67}, $I=\frac{3}{2}$. The two isotopes are produced by alpha-particle bom-

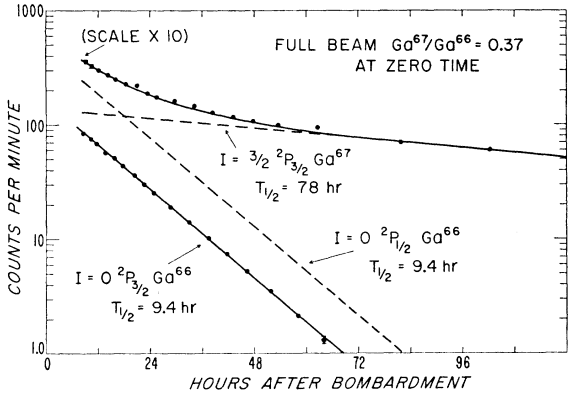

FIG. 1. Decay of gallium spin samples. Decay curve of a spin-0 sample and a spin-$\frac{3}{2}$ sample. The decay serves to identify the specific even-A and odd-A isotopes as Ga^{66} and Ga^{67}, respectively.

bardment of copper in the Berkeley 60-inch cyclotron, and identification made from a half-life analysis of beam exposures taken at appropriate values of radio-frequency and magnetic field (Fig. 1). The observed decay is in good agreement with assignments in the literature.[1-5]

The ground-state fine structure of gallium is 826 cm^{-1}, and the beam temperature 1100°C; therefore, both the $4p\ ^2P_{\frac{3}{2}}$ and $^2P_{\frac{1}{2}}$ levels are appreciably populated. Gallium 66 and 67 resonances have been observed in both levels. Because of a coincidence between the Zeeman frequencies for spin $\frac{3}{2}$ in the $^2P_{\frac{3}{2}}$ state and spin 0 in the $^2P_{\frac{1}{2}}$ state, exposures taken at this position show a compound decay. Two special runs were therefore made, one for which the 9.4-hr component was allowed to decay before the run was begun, the other for which the 9.4-hr component was selectively produced by differential bombardment. In each case the appropriate resonances were considerably enhanced.

Gross results of spin searches are shown in Fig. 2.

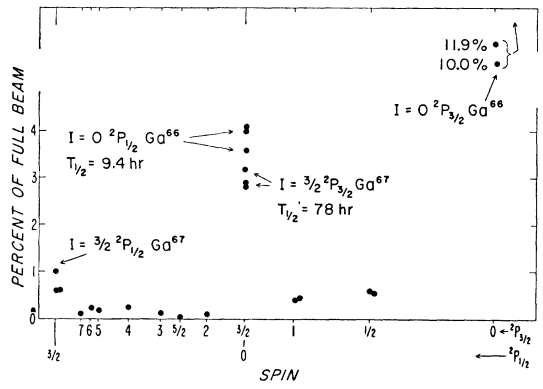

FIG. 2. Comparison of spin samples of Ga^{66} and Ga^{67}. Results of spin searches are indicated by points at various values of frequencies corresponding to specific spins. The experimental points are extrapolated to a time shortly after cyclotron bombardment, and the observed resonances are normalized by the component of the appropriate isotope in the full beam. All possible resonances corresponding to an even-A isotope, $I=0$, and an odd-A isotope, $I=\frac{3}{2}$, were observed.

The atomic-beam method is unfortunately incapable of giving an unequivocal spin-zero assignment, because interactions between the electronic and nuclear systems may be too small for observation. It can, however, give an upper limit to the interaction. Observations on the Ga^{66} resonance in the $^2P_{\frac{1}{2}}$ state have been made at three values of magnetic field and from the observed data one can set a conservative upper limit to the magnetic dipole moment of 10^{-3} nuclear magnetons. It is therefore highly probable that the spin of Ga^{66} is zero.

Work on gallium is continuing; a new upper limit to the magnetic moment of Ga^{66} and the hyperfine structure of Ga^{67} will be published later.

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Magnetic Moment and Spin of $_{40}Zr_{51}^{91}$

E. BRUN, J. OESER, AND H. H. STAUB
University of Zurich, Zurich, Switzerland
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THE optical hyperfine structure of Zr I which was studied by Arroe and Mack[1] yielded a nuclear spin of 5/2 for Zr^{91}. Suwa,[2] using the same method, determined the magnetic moment to be $\mu(Zr^{91})=-1.3\pm0.3$ nm. Murakawa[3] corrected the result of Suwa and determined the magnetic moment to be $\mu(Zr^{91})=-1.9\pm0.2$ nm.

Using a Bloch-type nuclear resonance spectrometer, a nuclear induction signal of Zr^{91} has been observed in a saturated solution of $(NH_4)_2ZrF_6$ in D_2O. A comparison of the signal with the corresponding one of O^{17} indicates a negative magnetic moment. The ratio of resonance frequencies of Zr^{91} and D^2 in the same magnetic field and the same sample was measured as

$$\nu(Zr^{91})/\nu(D^2)=0.60557\pm0.00001.$$

In order to determine the spin of Zr^{91}, differentiated n-mode signals of Cl^{35} (abundance $f=75.4\%$, $I=3/2$, $\mu=0.8209$) and Zr^{91} (abundance $f=11.2\%$) in appropriate solutions of well-defined molarities ($m=1.97$ and 0.7, respectively) were compared at the same resonance frequency and consequently nearly the same magnetic field. The height of these signals was measured as a function of the amplitude H_m of the modulating magnetic field. The ratio of signals S with maximum height was determined to be

$$S(Cl^{35})/S(Zr^{91})=0.93\pm0.04.$$