motion of an electron. Let m be the magnetic quantum number referred to the magnetic field direction as axis. The interaction for each m-value with the atomic magnetic field leads to $(2J+1)$ equally spaced components of the nuclear energy level. Each component is then further shifted, if there is any anisotropy of inertia, by an amount $(\Delta M/M)\overline{T}\overline{P}_2$, where $\overline{T}$ is the average kinetic energy of the nucleon (of order 10 Mev, say) and $\overline{P}_2$ is a coefficient whose value depends on J, on $|m|$, and on the orientation of the magnetic field relative to the direction towards the Galactic center. For the nuclear ground state of Fe^{57} we have $J=1/2$ and $\overline{P}_2$ is zero. $J=3/2$ for the excited state at 14 kev and $\overline{P}_2$ is nonzero[6] for $|m|=3/2$, equal and opposite for $|m|=1/2$, and $\overline{P}_2$ changes sign as the magnetic field changes from a direction pointing towards (or away from) the Galactic center to a perpendicular direction.

The resonance absorption in the Mössbauer effect only compares the transition frequencies in the emitter and the absorber. If we neglect the magnetic moment of the Fe^{57} nuclear ground state (compared with that of the $J=3/2$ excited state), the observed pattern[3] consists of a central line plus three equally spaced satellites on each side. If the magnetic fields in the emitter and absorber are parallel to each other then the presence of anisotropy of inertia splits the first satellite into a symmetric triplet, the second satellite into a symmetric doublet, and leaves the central line and last satellite unsplit. If the two magnetic fields are perpendicular to each other, the central line is also split, into a symmetric doublet. In all cases these splittings are largest when the magnetic fields are parallel or perpendicular to the direction towards the Galactic center and vanish in between.

If the atomic magnetic fields are randomly oriented in the emitter and absorber, then the anisotropy of inertia merely contributes to the broadening of the lines. Experiments carried out so far[3,4] seem to limit this broadening to about 10^{-8} ev which already would put an upper limit of about 10^{-14} on $\Delta M/M$, the measure of the anisotropy. With small source-absorber distances the line shapes can be measured quite accurately and experiments carried out with aligned atomic magnetic fields with varying orientations relative to the Galactic center could improve the sensitivity for $\Delta M/M$ considerably.

Rather similar precision measurements will presumably be carried out by many workers in the future for quite different purposes. The present note is meant as a plea to these workers also to consider the effects mentioned above.

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*Supported in part by the joint contract of the Office of Naval Research and the U. S. Atomic Energy Commission.

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[6] $\overline{P}_2 = 1/5$ for a single $p_{3/2}$ nucleon.

POLARIZED SPECTRA AND HYPERFINE STRUCTURE IN Fe^{57}†

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(Received January 26, 1960)

The observation in this laboratory[1] of the polarization of the resonance radiation[2-5] emitted by the 14-kev level of Fe^{57} has led to a study of polarization in the hyperfine spectrum of the resonant absorption. The apparatus and the method of producing and detecting polarization were the same as used in reference 1 except that the source and the absorber were mounted on separate Alnico magnets. The magnet carrying the absorber was attached firmly to the bed of the lathe used in our previous work.[4] The other magnet holding the source was fastened securely to the carriage of the lathe. The detector of radiation (40-mil NaI) was mounted on the axis determined by the source and absorber and it was well shielded from magnetic fields.

The motion of the carriage provided uniform velocities of the source, and the polarized spectra were obtained by measuring the transmission, with crossed or parallel magnetizations in source and absorber, as a function of the velocity of the source. The operation of the lathe was made automatic so that the carriage (source) moved to and fro at a predetermined speed. During the "to" motions the pulses from the detector were recorded in the lower channels of a 256-channel analyzer; and during the "fro" motions they were accumulated in the upper channels of the analyzer. In a single run, therefore, the transmission was measured for a positive and for an equal negative velocity.

The spectra obtained in this way are shown in Fig. 1. Since no significant differences were observed for positive and negative velocities, the spectra have been folded about zero velocity. The spectrum obtained with source and absorber magnetized perpendicular to each other differs markedly from that obtained with parallel magnetizations. For comparison, a spectrum is shown for an unmagnetized source and absorber. It is seen that the hyperfine spectrum consists of six prominent lines instead of the four previously reported.[3,5] It is clear therefore that the earlier interpretation based on the existence of only four lines is incorrect.

The level diagram of Fe^{57} which seems to provide a satisfactory explanation of the spectra in Fig. 1 is shown on the left in Fig. 2. In the upper right are given the hyperfine components for $M1$ radiation. (We have found little need to introduce a significant amount of $E2$.) The intensities of the components are those appropriate to a random orientation of the internal magnetic fields at the nuclei. At the lower right are shown the components for the case in which the internal fields have been aligned. The intensities given are for radiations emitted perpendicular to the aligned field. The direction of polarization of each component relative to the direction of the aligned field is indicated by the symbol ∥ or ⊥.

If one takes a hyperfine pattern and moves it over itself, one obtains the hyperfine spectrum,

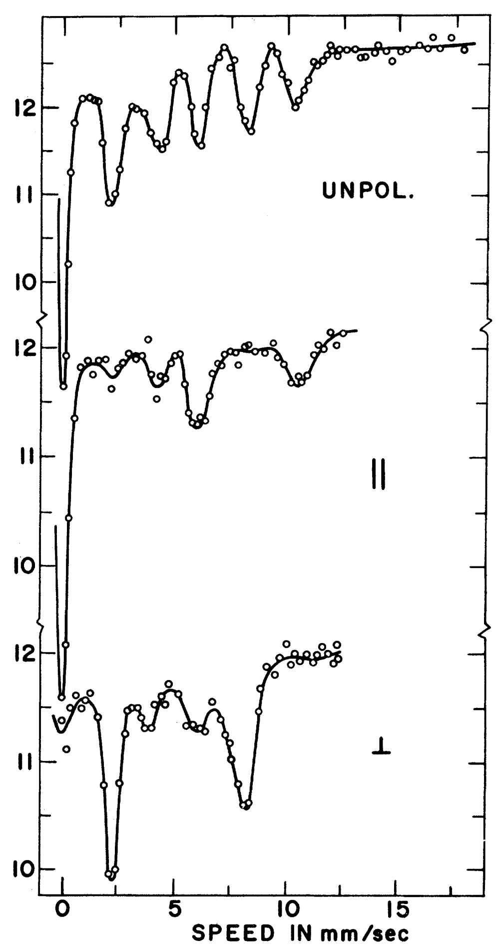

FIG. 1. Hyperfine spectra of Fe^{57}. Top: unpolarized. Middle: magnetization in source and absorber parallel. Bottom: magnetization in source and absorber perpendicular. The ordinate is in units of 2000.

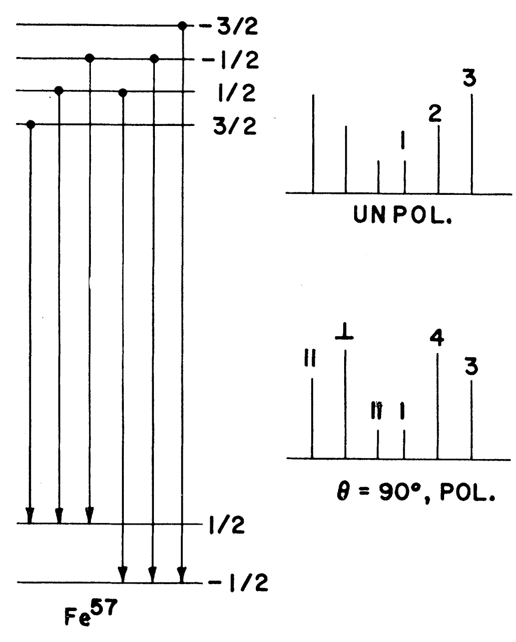

FIG. 2. Level diagram of Fe^{57} on which the discussion is based. Upper right: unpolarized hyperfine pattern. The numbers give the relative intensities. Lower right: polarized hyperfine pattern ($\theta = 90°$). The symbols ∥ and ⊥ stand for polarization parallel or perpendicular to the aligned field.

each line in the spectrum arising from the coincidence of hyperfine components in emission and absorption. At the top in Fig. 3 is shown the predicted spectrum of unpolarized radiation. In the middle is given the spectrum for the case in which the internal fields in source and absorber are aligned parallel to each other. In this case a line in the absorption spectrum will appear only if the respective hyperfine components have the same polarization. If, on the other hand, these polarizations are perpendicular, then the line will appear in the absorption spectrum only if the internal fields in source and absorber are aligned at right angles. The spectrum predicted for this case is shown at the bottom in Fig. 3. The intensities given in Fig. 3 are those nominally expected for a thin absorber. In addition it is assumed that a line which should appear only with one orientation of the fields will actually be present to the extent of about 10 % with the other orientation, because of incomplete alignment of the fields in source and absorber. The spectra in Fig. 3 are in good qualitative agreement with the observations in Fig. 1.

The hyperfine pattern of six components produces, in all, eight lines in the absorption spectrum. However, the splittings in the ground state and in the excited state are such that two doublets are formed which are not resolved in the unpolarized spectrum. The resolved peaks are numbered from one to six in Fig. 3. One member of the doublet in line 2 is too weak to affect the position of the peak. Thus, the spacings between line 1 and 2, 4 and 5, and 5 and 6 should be equal to the splitting of the ground state. The spacing between lines 2 and 4 gives the splitting of the ground state. Line 3 is a doublet, one member of which should appear in the spectrum with parallel fields, the other in the spectrum with crossed fields. The separation in the doublet is equal to $2g_1 - g_0$, where g_1 and g_0 are the splittings of the excited and ground level, respectively. We have measured this doublet separation with some care by observing the shift in line 3 in going from one polarized spectrum to the other. The separation is (0.5 ± 0.1) mm/sec. We have also measured the separation between lines 1 and 2 more carefully than shown in Fig. 1 and obtained $g_1 = (2.23 \pm 0.03)$ mm/sec. Hence $g_0 = (3.96 \pm 0.10)$ mm/sec.

Ludwig and Woodbury[6] have recently obtained an accurate determination of the magnetic moment of the ground state. If we use their value of $+(0.0903 \pm 0.0007)$ nm, the above measurements give $-(0.153 \pm 0.004)$ nm for the magnetic moment of the excited state, and a value of $(3.33 \pm 0.10) \times 10^5$ oersteds for the effective magnetic field at the iron nucleus. We note the opposite sign of the magnetic moment, which is an important feature of the above interpretation.

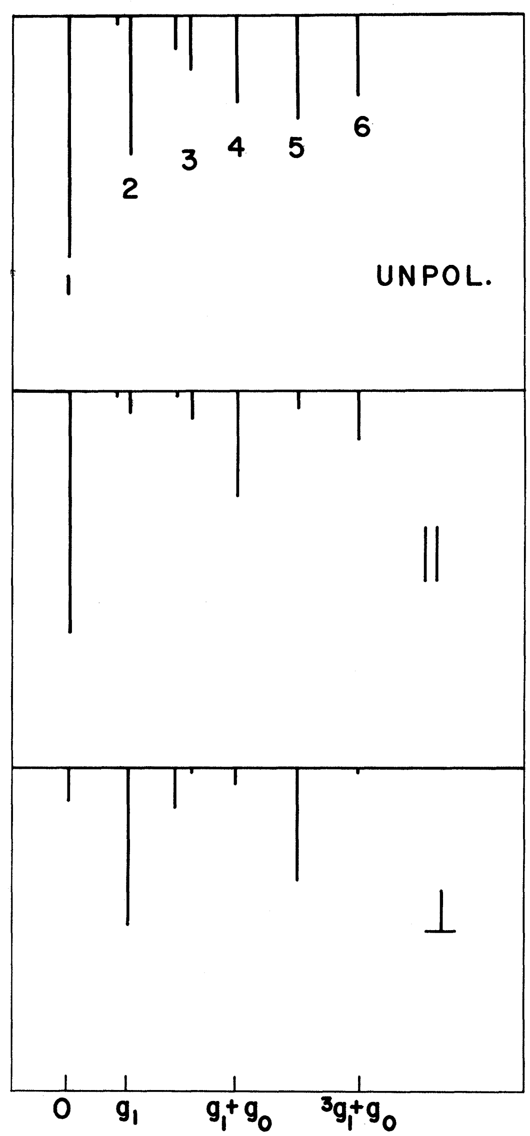

FIG. 3. Spectra predicted by the scheme in Fig. 2. Top: unpolarized. Middle: magnetizations parallel. Bottom: magnetizations perpendicular. The main peaks are numbered from one to six. The symbols g_0 and g_1 represent the gyromagnetic ratios of ground and excited levels, respectively.

We would like to thank B. F. Martinka and H. W. Ostrander for generous assistance in the mechanical aspects of our work. We are grateful to

G. W. Ludwig and H. H. Woodbury for communicating their results to us.

†Work performed under the auspices of the U. S. Atomic Energy Commission.

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GAMMA WIDTH IN Be^8 PERTINENT TO A TEST OF THE CONSERVED VECTOR CURRENT THEORY*

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(Received January 21, 1960)

In a recent experimental test[1] of the conserved vector current theory of β decay it was found that the predicted $(\beta - \alpha)$ angular correlations are not observed in nuclei of mass 8. The only way this might happen and still be consistent with the theory is for the $M1$ transition width Γ_{M1} to be anomalously small between the states $(J=2, T=1)$ and $(J=2, T=0)$ in the nucleus Be^8.

The quantity Γ_{M1} enters into the predicted asymmetry coefficient for the $(\beta - \alpha)$ correlation in the form $(\Gamma_{M1})^{1/2}$. Since the $(J=2, T=1)$ level decays by α emission rather than γ emission, Γ_{M1} is not known experimentally. In the prediction[2] of the $(\beta - \alpha)$ asymmetry, a probable width of $\Gamma_{M1} = 0.15$ Weisskopf unit ≈ 8 ev was assumed.

In those cases in which a comparison has been made between experiment and calculations with the intermediate-coupling model, it is found that the computed $M1$ widths are fairly reliable. The results of calculating the Γ_{M1} pertinent to the present experiment with intermediate-coupling functions are given in Table I. Since other evidence[3] suggests that for Be^8 the intermediate-coupling parameter (a/K) lies between 2.0 and 2.5, the calculation indicates that

$$\Gamma_{M1} \approx 3 \text{ to } 5 \text{ ev.}$$

Table I. Gamma transition width Γ_{M1} for the $(J=2, T=1)$ to $(J=2, T=0)$ transition in Be^8 as a function of the relative strength of spin-orbit coupling, a/K.

a/K	0	1.5	3.0	4.5	6.0
Γ_{M1} (ev)	0	2.0	7.4	14.8	23.4

Such a value would multiply the predicted asymmetry in the $(\beta - \alpha)$ correlation by about 0.7, and thereby give a theoretical estimate of about +0.10, where the sign is determined by the positive sign of the computed matrix element. The experimental result[1] is $+0.02 \pm 0.04$. Therefore the present calculation indicates that the discrepancy between experiment and the conserved vector current theory of β decay is real.

*Work performed under the auspices of the U. S. Atomic Energy Commission.

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