Measurement of the Magnetic Moments of the Microsecond-isomers in ^{73}As and ^{206}Pb [+]

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The isomeric state of ^{73}As (426 keV, 5.8 μsec) was produced and aligned by the reaction ^{71}Ga$(\alpha,2n)$ in a liquid metal target. The anisotropies of the depopulating γ-rays were measured vs. the dc magnetic field applied perpendicular to the beam-detector plane. From the attenuation and rotation, we obtain $g=+1.03\pm0.11$. Limits of $\delta^2<10^{-2}$ can be set to the multipole admixtures in both γ-transitions. The same technique was applied to the 123 μsec isomer of ^{206}Pb (2200 keV) produced by ^{204}Hg$(\alpha,2n)$. After estimating the relaxation time, $g=-(0.035\pm0.020)$ is obtained.

Considerable alignment is given to the low-energy, high-spin states populated by (α,xn) reactions. Without perturbation, the time integrated angular distribution of gamma radiation emitted by such states is described as $W(\Theta)=1+\sum A_k P_k(\cos\Theta)$, $k=2,4,\dots$. With $A_k=B_k F_k$, the coefficients B_k depend upon the degree of alignment, and the F_k are determined by the multipole character of the transition and by the spins involved. If one applies a static magnetic field $H_\perp$ perpendicular to the beam-detector plane, the angular distribution becomes [1]

$$W(H_\perp,\Theta)=1+\sum\frac{b_k/b_0}{1+(k\,\omega_\perp\,\tau)^2}\,[\cos k\,\Theta-k\,\omega_\perp\,\tau\sin k\,\Theta]\,;\quad k=2,4,\dots,\qquad(1)$$

where

$$b_0=1+(1/4)\,A_2+(9/64)\,A_4\dots,\quad b_2=(3/4)\,A_2+(5/16)\,A_4\dots,\quad b_4=(35/64)\,A_4\dots,$$

and

$$\omega_\perp=g\,\mu_n\,H_\perp/\hbar\,,\qquad g=\mu_I/I\,\mu_n\,.\qquad(2)$$

It is to be noted that a) no static interaction other than the one given by $H_\perp$ must be acting during the time of measurement; b) the time constant τ with which the anisotropic emission of the γ-rays decays has to be known.

The experiments were performed at the 88″ cyclotron at Berkeley using the reactions ^{71}Ga$(\alpha,2n)^{73}$As or ^{204}Hg$(\alpha,2n)^{206}$Pb and isotopically enriched liquid metal targets. The Ge(Li) detectors and the electronics used were very similar to the setup described in [2]. The variable field $H_\perp$ was known to about $\pm2\%$.

The ^{73}As isomer decays by two γ-rays in cascade, 360 keV ($9/2^+\rightarrow5/2^-$, E2) and 66 keV ($5/2^-\rightarrow3/2^-$, M1). From an angular distribution measurement ($H_\perp=0$), and from the data of Fig. 1 we get

$$A_2(360)=+0.34(4)\,;\quad A_4(360)=-0.05(5)\,;\quad A_2(66)=-0.20(5)\,.\qquad(3)$$

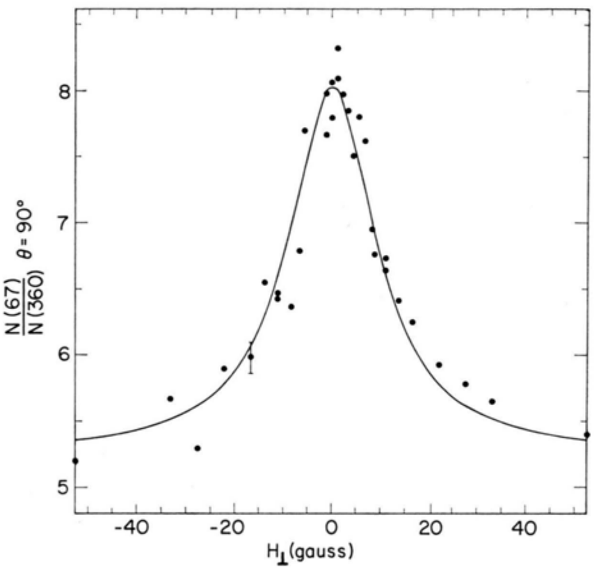

Fig. 1. Ratio of γ-ray intensities in the 90° detector vs. magnetic field $H_\perp$ for the ^{73}As 6 μsec isomer. The statistical error is indicated only once. The curve is from a least squares fit.

Fig. 1 shows the change of the γ-intensities with $H_\perp$. From this measurement and one with one of the detectors at 54°, we obtain through Eq. (1)

$$g=+1.03(11)\,,\qquad(4)$$

using the average [3, 4] $T_{1/2}=5.8(5)$ μsec. This gives the sign for and agrees with the more precise value

$$|g|=1.146(7)$$

obtained later [5].

An estimate of the possible combinations of F_2, F_4 can be derived for a particular gamma transition from the observed coefficients A_2 and A_4, if no perturbations occur in the decaying state. This is because for $k=2$ and $k=4$, the factors [6] α_k describing the loss of alignment during the neutron- and γ-emission turn out to be approximately related as $\alpha_4\approx(\alpha_2)^3$, when $\alpha_2>0.5$. Together with the limits on the mixing parameters δ

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given in Ref. [3] and Ref. [7], we thus obtain the region of possible values $\delta(360)$ and $\delta(66)$ which is displayed in Fig. 2.

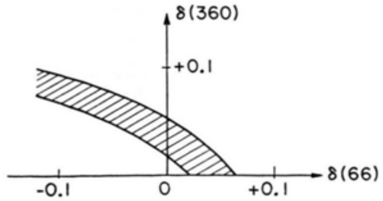

Fig. 2. Mixing ratios $\delta(360)$ and $\delta(66)$ for the two γ-rays depopulating the 6 μsec isomer in ^{73}As ($9/2^+ \rightarrow 5/2^-$, predominantly E2 and $5/2^- \rightarrow 3/2^-$, predominantly M1, respectively).

For the isomeric state in ^{206}Pb, the change of the γ-ray intensities with $H_\perp$ is displayed in Fig. 3. A least squares fit of Eq. (1) to these data, neglecting the A_4 and higher terms, gave

$$g \cdot \tau = -(3.0 \pm 1.0) \cdot 10^{-6} \text{ sec.} \tag{5}$$

For each of the γ-transitions, the value of A_2 is reduced to about 0.5 of the value for maximum alignment and lowest possible multipole character in all transitions.

For ^{206}Pb, relaxation in the isomeric state may reduce the time during which the interaction $g \mu_n H_\perp$ is effectively observed below the nuclear lifetime [8]

$$\tau = 177.9(1.6)\ \mu\text{sec.}$$

To estimate this effect, we assume an effective relaxation time T_r for the P_2 term; the coefficients A_2 are then reduced by the factor $T_r/(\tau + T_r)$, and so is the g factor entering Eq. (2). We find magnetic relaxation negligible (see [9]), $T_r \gtrsim \tau$, and

$$g = -0.035(20). \tag{6}$$

The g factor was calculated for a $p_{1/2}\, i_{13/2}$ neutron hole configuration as $g = -0.06$, using the g factors of the ^{207}Pb and ^{197}Hg ground states (-0.20 with the Schmidt values). The use of more accurate wave functions [10] does not improve the agreement with experiment, giving $g = -0.08$.

The magnetic moment of the ^{206}Pb-isomer is being determined more precisely by MAIER et al. using the stroboscopic observation of the Larmor precession [11].

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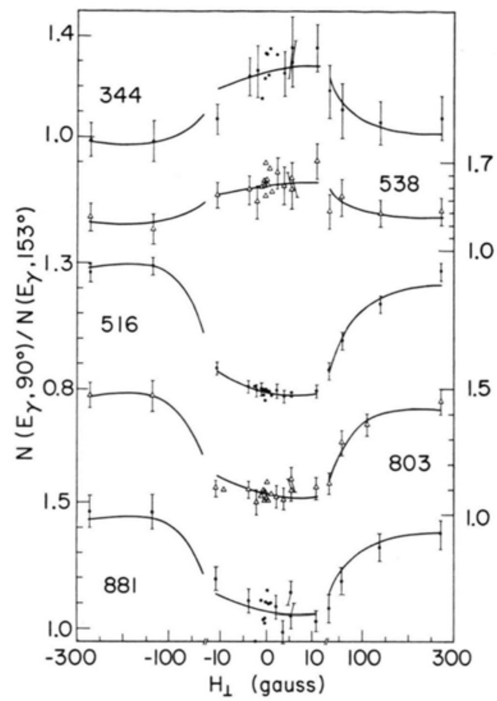

Fig. 3. Ratio of γ-ray intensities vs. magnetic field for the ^{206}Pb 123 μsec isomer. The γ-energies (in keV) are given between the data and the ordinate scale applicable. Note the changes in abscissa scale. The points in the region $H_\perp \approx 0$ have nearly the same errors as the points farther out. The curves are from a least squares fit.

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