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MAGNETIC MOMENT OF THE FIRST EXCITED STATE OF ^{114}Cd†

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The magnetic moment of the first 2^+ state at 558.5 keV in ^{114}Cd has been measured to be $|\mu_2| = 0.88 \pm 0.12\ \mu_N$ by the perturbed gamma-gamma angular correlation technique utilizing the internal hyperfine field in an Fe lattice.

The nucleus ^{114}Cd has played a significant role in nuclear physics as it has long been thought to exhibit every feature of a quadrupole-type vibrational spectrum.[1] However, the recent experimental determination[2] of the static quadrupole moment Q_2 of the 558.5-keV first excited 2^+ state of ^{114}Cd has shown a large value which is quite incompatible with that expected from a simple harmonic-quadrupole vibration of a spherical nucleus. The average experimental value $Q_2^{\mathrm{expt}} = -0.50 \pm 0.25$ b can be obtained if ^{114}Cd is assumed to be a rotational nucleus; however, other spectroscopic properties of at least the low-lying states are well described as the characteristic quadrupole vibrations of a spherical nucleus. Tamura and Udagawa[3] have recently shown that reasonable models of vibrational nuclei can be constructed which can explain the large observed Q_2. In their phenomenological model (model A), where the first 2^+ state is assumed to be an orthogonal linear combination of one-phonon and two-phonon harmonic vibrational 2^+ states, they predict $|Q_2| = 0.58$ b, the sign depending on the details of the mixing interaction. On the other hand, in their microscopic model (model B) they predict $Q_2 = -0.511$ b for $e_{\mathrm{eff}} = 1$. Thus both models seem to explain the large Q_2 while retaining the vibrational character of the nucleus. However, the predictions of these two models for the magnetic moment, μ_2, of this state are widely different. Model A predicts $\mu_2^{(A)} = 0.86\ \mu_N$, whereas model B predicts $\mu_2^{(B)} = 2.38\ \mu_N$. Thus a measurement of μ_2 can decide which of the two models is more appropriate in explaining most of the low-lying nuclear properties of the ^{114}Cd nucleus.

The present note describes our experimental results on the determination of the g factor of the 558.5-keV 2^+ state utilizing the integral–reversed-field method of the perturbed gamma-gamma angular correlation technique.[4] The mean life of this state is known to be $\tau = (1.32 \pm 0.09) \times 10^{-11}$ sec from the measured $B(E2)$ values following Coulomb excitation.[5] In order to measure the g factor of such a short-lived state, we employed the large hyperfine magnetic field available at the site of the Cd nuclei when they are introduced in very dilute form into an Fe lattice.[6] The known field H_{int} at Cd in Fe lattice is $|H| = 348 \pm 10$ kG. The activity utilized in this experiment is the 49-day ^{114m}In, which decays by electron capture[7] (branching ratio of 3.5 % of the total activity) to the 1278-keV state which in turn decays to the ground state of ^{114}Cd via the (722-558.5)-keV gamma-gamma cascade. The angular correlation coefficients for this cascade have been measured by Steffen[8] to be $A_2 = 0.099 \pm 0.005$, $A_4 = 0.01 \pm 0.07$ and also by Kawamura[9] to be $A_2 = 0.091 \pm 0.006$, $A_4 = 0.030 \pm 0.009$; thus this cascade is believed to be $4^+(E2)2^+(E2)0^+$.

Indium metal, enriched to 96.4 % in ^{113}In as obtained from Oak Ridge National Laboratory, was irradiated for 7 days at a flux of 2×10^{14} n/cm^2 sec to produce the ^{114m}In activity. 0.15 mg of active In was sealed in vacuum in an Fe container (purity 99.999 %) weighing 1 g and was then melted in an induction furnance employing a levitating Ag boat. The molten alloy (about 0.015 % In by weight) was rapidly cooled to room temperature and later was coined into a cylinder of 5-mm diameter and 6-mm height. Two such sources were prepared (source 1 and source 2). After an initial measurement with an unannealed source 1, the sample was annealed for 4 hours at a temperature of 1050°C in vacuum, the surface was cleaned with concentrated HCl and washed, and the experiments were repeated. No activity was found to be lost in the annealing process. Source 2 was annealed for about 2 hours in vacuum at 850°C.

The 722- and 558.5-keV gamma rays were detected in 1.5-in. diam × 3-in. thick NaI(Tl) crystals coupled to magnetically shielded 56AVP photomultiplier tubes.

In order to minimize the stray magnetic-field effects on the photomultipliers a completely enclosed toroidal H magnet was constructed. The source samples were fitted between the pole tips of the magnet and the magnet current needed to saturate the source sample was determined by measuring its B-H curve. The gamma rays reached the detectors (each at 5 cm distant from source axis) after passing through the $\frac{1}{8}$-in thick Armco flux-return path of the magnet and a 2-mm Pb absorber; this amount of absorber reduced the intense 192-keV isomeric gamma intensity to a tolerable level. A compensating coil wound around the equatorial plane of the magnet enabled us to reduce the stray field to less than 0.005 G. In this way the effect of field reversal on singles counting rates was reduced to less than 0.01%.

In order to accomodate high counting rates and still obtain a small coincidence resolving time, each of the anode pulses was split into a high- and a low-frequency component; a low-level trigger accepting the high-frequency signal was gated on only when the low-frequency signal exceeded a certain threshold. With such an arrangement we obtained a resolving time (full width at half-maximum) of 1.5 nsec, leading to a 10% random-to-true ratio with about 200 000 counts per second in each of the detectors. The photopeaks corresponding to each of the gamma rays were selected in each of the counters by single-channel analyzers. Each slow channel was equipped with a peak-stabilizing system, so that the long-term singles counting-rate shift was always less than 0.5%. The time spectrum was stored in subsections of a 400-channel RIDL analyzer according to the direction of the aligning field and slow coincidence requirements. In this way the field effect on the coincidence counting rate, defined as

$$R(\theta)=2[W(\theta,B)-W(\theta,-B)]/[W(\theta,B)+W(\theta,-B)],$$

was simultaneously measured at 135° and 225° during each run. As a check on instrumental asymmetry $R(\theta)$ was determined for the random background of the time differential spectrum. The angle between the two counters was alternated between 135° and 225° on successive days. This procedure has the effect of reversing the role of the two counters, and leads to the cancellation of certain systematic errors. As a further check $R(180°)$ was measured. The results are summarized in Table I. The an-

Table I. Summary of results; values of $R(\theta)$ are given in percent.

Nature of Source	$R(135°)$ (%)	$R(225°)$ (%)	$R(180°)$ (%)	R(Random) (%)
Source I unannealed	-0.208 ± 0.068	$+0.278\pm0.068$		
Source I annealed	-0.224 ± 0.060	$+0.253\pm0.060$	$+0.042\pm0.050$	
Source II annealed	-0.230 ± 0.066	$+0.251\pm0.066$		
Weighted average	-0.221 ± 0.037	$+0.260\pm0.038$	$+0.042\pm0.050$	$+0.031\pm0.016$
Weighted average of 135° and 225° data	$\lvert R\rvert=(0.240\pm0.026)\,\%$			
Angular correlation coefficients, uncorrected for geometry	$A_2=0.0843\pm0.0014$; $A_4=0.001\pm0.003$			
$\omega\tau=\frac{R}{3}\left(\frac{1}{A_2}+0.25\right)$[a]	$-(9.69\pm1.06)\times10^{-3}$ rad[b]			

[a]Assuming $A_4\approx0$.

[b]Error is statistical.

gular correlation coefficients A_2 and A_4 were determined in the same geometry.

From the experimental value of $\omega\tau = -(9.69 \pm 1.06)\times 10^{-3}$ rad, assuming $\tau = 13.2$ psec and $|H_{\text{int}}| = 348$ kG, we obtain

$$|g| = 0.44 \pm 0.06 \text{ corresponding to}$$

$$|\mu_2| = 0.88 \pm 0.12\ \mu_N.$$

If we assume the sign of the internal field H_{int} of Cd in Fe to be negative in accord with systematics,[6] then the g factor is positive.

Our experimental value of μ_2 agrees very well with the prediction of the phonon-mixing model (model A) of Tamura and Udagawa[3] which is essentially the hydrodynamical model predicting $g = Z/A = 0.42$; but our result disagrees with the prediction of their microscopic model (model B), even though the latter model seems[3] to explain most of the other experimentally determined quantities in ^{114}Cd nucleus better than the phenomenological model.

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SUPERMULTIPLET STRUCTURE RESULTING FROM THE EXISTENCE OF Q_K

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We examine the possibility of combining SU(3) with U(1)(Q_K) to obtain a nontrivial compact local Lie group whose algebra contains a maximal Abelian subalgebra spanned by I_Z, Y, and Q_K. If the simple Lie groups are ruled out (on physical grounds), it is shown that the only possibility remaining is a direct product SU(3) and a group containing U(1)(Q_K). Thus, the Q_K and SU(3) assignments are not linked by the group and no nontrivial supermultiplet structures ensues.

The attempts to find a compact internal-symmetry group larger than and containing SU(3) as a subgroup were motivated in part by the desire to explain the existence and degeneracy of certain SU(3) multiplets. For example, the adjoint representations of A_3, B_3, and C_3 contain an octet and a singlet SU(3) multiplet which would remain degenerate in the presence of a small breaking of this supposed larger symmetry. The experiments indicating a CP nonconservation in K_2^0 decay led Lee[1] to suggest the possible existence of a part of the electric charge (Q_K) which commutes with the particle-antiparticle conjugation operator (C_{St}) for the strongly interacting particles. In a recent work,[2] the author has attempted to build a simple Lie group of rank three using as the third conserved quantity that conjectured part