Gamma-Gamma Directional Correlation in Mg^{24}†

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The directional correlation between the 1.368-Mev gamma ray and the 2.75-Mev gamma ray of Mg^{24} was measured in an effort to strengthen the spin and parity assignment of the 4.12-Mev state. The data yield a least-squares solid-angle-corrected correlation function $W(\theta)=1+(0.102\pm0.003)P_2(\cos\theta)+(0.009\pm0.005)\times P_4(\cos\theta)$. This is consistent with the assignment (4+) for the 4.12-Mev state and analysis indicates that there can be at most 0.003% $M3$ radiation mixed with pure $E2$ radiation in the 2.75-Mev gamma ray transition.

I. INTRODUCTION

THE assignment of the 1.368-Mev state in Mg^{24} is well established as a (2+) state.[1–3] The assignment of the 4.12-Mev state is not so certain. Some of the internal pair production coefficient measurements imply that the 2.75-Mev gamma ray emitted in the transition from the 4.12- to the 1.368-Mev state could be either $E1$ or $E2$.[1–5] One measurement of the internal conversion coefficient of this transition implies a much higher multipolarity.[6] Since the ground state of Na^{24} is almost certainly (4+)[7,8] the analysis of the beta decay fixes the parity of the 4.12-Mev state as even but leaves some uncertainty in the spin assignment. Recent measurements on the polarization-direction correlation[9] infer a (4+) assignment but this in turn rests on the results of the older directional correlation work of Brady and Deutsch.[10] Since the collective nuclear model predicts a (4+) upper state for even-even Mg^{24} it seemed worthwhile to try to strengthen its assignment by directional correlation and to estimate the magnitude of mixing in the upper transition.

II. PROCEDURE

The gamma-ray spectrometer consisted of a pair of 1-in. by 1.5-in. diam NaI crystals optically coupled to DuMont K-1719 photomultiplier tubes. The crystals were unshielded so that the simplified correctons of Rose[11] for the finite solid angle could be determined and used to compare the raw data with the theory of angular correlation. The conventional fast-slow coincidence method was used. The slow channels were set to accept only the full-energy peak of the appropriate radiation. Corrections were made for chance coincidences by using the inchoherent source method to determine the resolving time of the fast coincidence circuit. The resolving time was 70 nsec for the pulse shapes used in this experiment. The angular settings were accurate to ±0.25°. The theory was compared with the experiment by modifying the theory to take account of the finite solid angle using the correction curves of Stanford and Rivers.[12] Care was taken to demonstrate that these corrections were appropriate for the spectrometer geometry.[13] A trial directional correlation experiment using the cascade gamma ray of Ni^{60} showed the over-all procedure to be satisfactory.

III. RESULTS

The results are shown in Fig. 1. A least-squares analysis of the data yields the directional correlation coefficients. These coefficients, when corrected for the finite solid angle of the detectors, lead to an experimental directional correlation function

$$W(\theta)=1+(0.102\pm0.003)P_2(\cos\theta)+(0.009\pm0.005)P_4(\cos\theta).$$

The indicated uncertainties are those calculated from

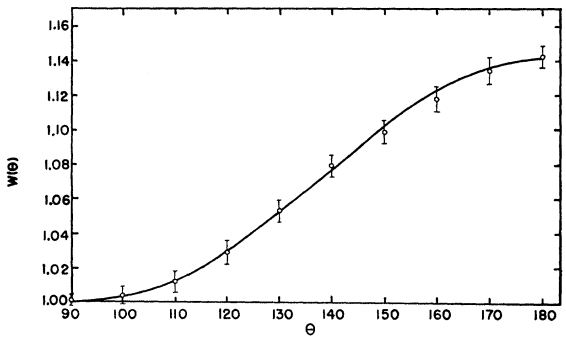

FIG. 1. The directional correlation of gamma rays in the decay of Mg^{24}. The experimental points are shown with statistical uncertainties only. The solid curve is the theoretical directional correlation function for a 4(2)2(2)0 cascade corrected for the finite solid angle subtended by the unshielded NaI detectors. θ is the angle between the spectrometer arms.

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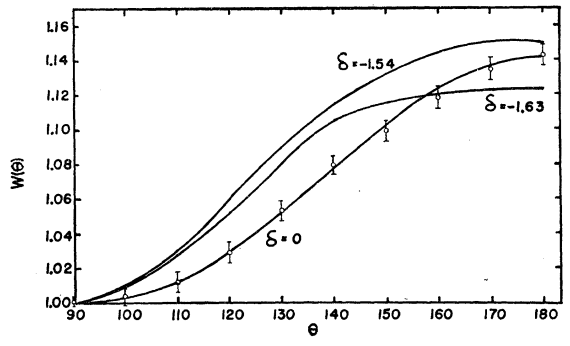

FIG. 2. Solid-angle-corrected, theoretical directional correlation functions for a 4(2)2-4(3)2 mixture compared with the experimental points. The mixing ratios $\delta=0$ and $\delta=-1.63$ are those consistent with the experimentally determined directional correlation function coefficients. The mixing ratios $\delta=0$ and $\delta=-1.54$ are those determined from the anisotropy. The octupole/quadrupole intensity ratio is given by δ^2.

counting statistics. The theoretical function for a pure 4(2)2(2)0 cascade is

$$W(\theta)=1+0.1020P_2(\cos\theta)+0.0091P_4(\cos\theta).$$

Because of the close agreement, any mixing of radiations in the cascade must be small. An estimate was made of the amount of mixed radiation that might be present in the upper transition. The lower transition was taken to be 2(2)0 and theoretical mixed directional correlation functions[14] were compared with the data for an upper transition consisting of a 3(1)2–3(2)2 mixture and a 4(2)2–4(3)2 mixture. These are the most likely possibilities consistent with the beta decay of Na^{24} which produces the upper Mg^{24} state, and with the conservation of angular momentum. The results clearly exclude the possibility of a spin 3 assignment for the upper state on the basis that there is no agreement with the experiment. Assuming that the 4.12-Mev state is (4+), $M3$-$E2$ mixing is expected to be very small. The results of trying a 4(2)2–4(3)2 mixture are shown in Fig. 2. The theory yields two values of the mixing ratio δ determined either by comparison with the measured, solid angle corrected correlation coefficients or by comparison with the measured, solid angle corrected anisotropy $W(180°)-1$. Although the mixing ratios $\delta=-1.63$ and $\delta=-1.54$ are not inconsistent with experiment at $\theta=180°$ the general disagreement over all angles excludes appreciable octupole-quadrupole mixing. On the other hand, the $\delta=0$ fit is sufficiently good so that if any octupole-quadrupole mixing is present, it must be less than 0.003% to be consistent with the statistical uncertainty in the experimental points. The conclusion then is that the upper state is almost certainly (4+). The method of directional correction is evidently a sensitive method of determining mixing in simple cascades.

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