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The Directional Correlation of the γ Rays of A^{38}†

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The angular correlation of the γ rays in A^{38} following the β-decay of Cl^{38} has been measured. The correlation function is in agreement with that expected for the spin sequence $3(D)2(Q)0$ or possibly $1(D,Q)2(Q)0$ with a 2.5 percent quadrupole intensity (out of phase). Gamma-ray lifetime arguments strongly favor the $3-2-0$ spin sequence.

The β decay of Cl^{38} has been investigated in detail by Langer.[1] Hole and Siegbahn[2] have established the existence of two successive γ rays in A^{38} with energies of 1.60 and 2.15 Mev. Langer reported that the ground-state transition has the unique $\Delta I=2$, (yes) shape. Taking the ground-state spin of A^{38} as zero, this establishes the Cl^{38} ground state as a $2-$ level. The lowest-energy β transition to the 3.75-Mev level in A^{38} has a $\log ft=4.93$,[3] which suggests it has an allowed character. Hence the 3.75-Mev level would have odd parity. Inasmuch as the intensity of the crossover transition has been shown[4] to be less than 3×10^{-4}, Langer concluded that the spin of the upper level in A^{38} is most likely $3-$.

The angular correlation of the γ rays was measured by early investigators,[5] but the accuracy of their experiments prevented any definite conclusions. Later, Steffen[6] measured the angular correlation, and he interpreted his results as indicating that the spin of the levels were 3, 2, 0 with both γ rays quadrupole. The theoretical angular correlation for this assignment is shown in Fig. 1. From general considerations of transition probabilities, Steffen concluded that all three levels were of the same parity, in disagreement with the β-decay data.

The conclusions from the β-decay and angular correlation data could be consistent if the upper γ ray were $M2$. However, an upper limit of 4×10^{-10} sec has been placed on the half-life of the second excited state of A^{38}, which is of the order of 10 times less than would be expected for such an $M2$ transition on empirical grounds.[7] Because of these inconsistencies, it was decided to remeasure the angular correlation of the γ rays in A^{38}.

The experimental apparatus and method used have been described previously.[8] The counters had 1.2 cm of Lucite and 2.5 mm of Pb in front of them. In addition, the bias on each counter was set at about 600 kev to preclude counting any coincidences arising from annihilation radiation due to internally created pairs. The sources were prepared by irradiating LiCl in the Brookhaven reactor for 20 minutes. The active powder was dissolved in a small amount of water to form sources whose volume ranged from 0.05 to 0.25 ml. In order to correct for decay, the coincidence counts were normalized to the single counts of the movable counter. No deviation from a pure exponential decay was found in 7 half-lives. The uncorrected experimental points are shown in Figs. 1 and 2. The indicated errors are standard deviations. A least-squares fit of the data to the correlation function $W(\theta)=1+a_2\cos^2(\theta)$ yields a value of $a_2=-0.105\pm0.008$ when corrected for the angular resolution of the counters. The angular resolution function of our counters was determined by using a well-collimated beam of the γ rays of A^{38}. The magnitude of the geometrical correction is given by $Q_2/Q_0=0.954$ and $Q_4/Q_0=0.859$ in the notation of Lawson and Frauenfelder.[9]

The β-decay data of Langer[1] limits the spin of the

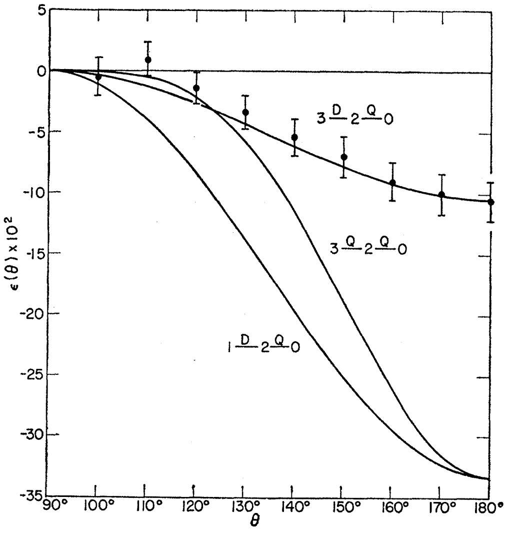

FIG. 1. Theoretical angular correlation curves for $3(D)2(Q)0$, $3(Q)2(Q)0$, and $1(D)2(Q)0$. The experimental points for A^{38} are drawn without angular resolution correction.

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second excited state of A^{38} to 3, 2, or 1. The spin of the first excited state is limited to 2 or 1 on γ-ray lifetime arguments. With these spin limitations and assuming a zero spin for the A^{38} ground state, the value we obtain for a_2 is compatible with the following cascades:

(a) 2–1–0 with either ~4 percent or ~79 percent quadrupole intensity (in phase).[10]

(b) 1–1–0 with either ~99 percent or ~1.3 percent quadrupole intensity (out of phase).

(c) 3–2–0 with <0.02 percent (in phase) or <0.01 percent (out of phase) quadrupole intensity.

In addition, a least-squares fit of the data to the correlation function $W(\theta)=1+a_2\cos^2\theta+a_4\cos^4\theta$, after the angular resolution correction described above, yields $a_2=-0.024\pm0.037$ and $a_4=-0.094\pm0.042$. These coefficients are compatible only with the 1–2–0 cascade with a 2.5 percent quadrupole intensity (out of phase). We should point out that the errors attached to the a_2 and a_4 coefficients are purely statistical. We therefore cannot definitely state whether the a_4 coefficient is zero or nonvanishing. It is worth noting that a small spurious coincidence rate (≤ 1 percent) arising from scattering or from some other unknown cause can account completely for the possible presence of an a_4 term in the angular correlation.

The four possible cascades compatible with the experimental data can be reduced to two if the well-founded empirical rule,[11] that the first excited state of an even-even nucleus has spin 2 and even parity, is valid in this case. We may then consider only the cascades $3(D,Q)2(Q)0$ and $1(D,Q)2(Q)0$. The latter would seem unreasonable in view of the fact that the crossover transition has not been seen experimentally.[4] (Its intensity would be less than 3×10^{-4} of the cascade intensity.) It may be noted here that for the 1–2–0 levels of Nd^{144} the dipole crossover transition occurs with ~3 times the intensity of the cascade transition.[12] The degree to which the crossover transition has been excluded in A^{38} is consistent with empirical lifetime-energy relations for $E3$ transitions and the known upper limit on the lifetime of the 3.75-Mev state. We therefore feel the spin assignments 3−, 2+, and 0+ for the levels of A^{38} are most consistent with all available experimental information, although the accuracy of our angular correlation data cannot by itself exclude the $1(D,Q)2(Q)0$. If the cascade is the $3(D,Q)2(Q)0$ cascade, then within our experimental error, the first transition in the cascade is pure dipole. The decay scheme is shown in Fig. 2.

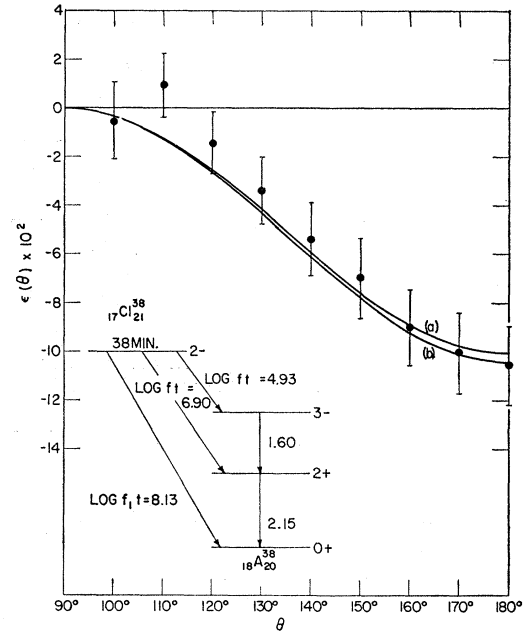

FIG. 2. Angular correlation curves for A^{38} and proposed decay scheme. Curve (a) is a least-squares fit of $1+a_2\cos^2\theta$ to the experimental points shown. Curve (b) is the theoretical correlation for a $3(D)2(Q)0$ cascade. The geometry-corrected least-squares fit is for practical purposes indistinguishable from curve (b).

It is of interest to note that the assignment of odd parity to the level of spin 3 is in agreement with the conclusions of Glaubman[13] and Talmi[14] regarding the parity of odd spin states of even-even nuclei.

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