SHORT COMMUNICATIONS

A STUDY OF THE 3·00 MeV LEVEL OF ^{27}Al VIA ^{24}Mg(α, pγ)^{27}Al†

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It is at present considered (Thankappan 1966) that the weak-coupling model is more appropriate to the ^{27}Al nucleus than the strong-coupling (Nilsson) model, which has been applied with some success to ^{25}Mg, ^{25}Al, and other lighter nuclei in the 2s–1d shell (Gove 1960). Thankappan (1966) has interpreted the low-lying $J = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, and $\frac{9}{2}$ levels as a multiplet formed by the coupling of a $1d_{5/2}$ proton hole to the first excited (2$^+$) state of ^{28}Si. This model is able to fit simultaneously the level positions and many of the γ-ray transition rates. The proton inelastic scattering cross sections (Crawley and Garvey 1965) are also in better agreement with this model than with the strong-coupling model. The 3·00 MeV level has for some time been regarded as the low-lying $J^\pi = \frac{9}{2}^+$ state predicted by Thankappan's excited-core model, but the experimental evidence is somewhat contradictory. Towle and Gilboy (1962) claimed an unambiguous assignment of $J = \frac{9}{2}$ from inelastic neutron scattering; the γ-ray correlation results of Lawergren (1964) are consistent with this assignment. Wakatsuki and Kern (1966) used γ-ray correlation methods to make a firm assignment of $J = \frac{7}{2}$, but it is not obvious that the data used to exclude a $J = \frac{9}{2}$ assignment were free of contributions from the 2·98 MeV level. In addition, those authors made the dubious assumption that the reaction proceeds through an isolated level of the compound nucleus, and the mixing ratio obtained for the 3·00 to 0 transition is inconsistent with a recent lifetime measurement (Broude, Smulders, and Sharpey-Schafer 1967). Sheppard and van der Leun (1967), using a Ge(Li) γ-ray spectrometer, have measured gamma–gamma correlations in the ^{26}Mg(p, $\gamma\gamma$)^{27}Al reaction and claim a definite assignment of $J = \frac{9}{2}$. Gove *et al.* (1967*a*, 1967*b*) have performed a D.W.B.A. analysis of the angular distributions in the ^{28}Si(d, ^{3}He)^{27}Al reaction using a magnetic spectrograph to resolve the 2·98 and 3·00 MeV levels; they conclude that the 3·00 MeV level has $J = \frac{3}{2}$ or $\frac{5}{2}$. This raises the possibility that the 3·00 MeV "level" is, in fact, a doublet, one member of which has $J = \frac{9}{2}$ and the other, populated in the (d, ^{3}He) reaction, $J = \frac{3}{2}$ or $\frac{5}{2}$.

Since the presence of a low-lying $J = \frac{9}{2}$ level is essential to the excited-core model of the ^{27}Al nucleus (and not readily explicable with the simple Nilsson model), we have used the ^{24}Mg(α, pγ)^{27}Al reaction to investigate the spin of the 3·00 MeV level and the possibility that it is a doublet.

A thin, enriched ^{24}Mg target was bombarded with 9·025 MeV α-particles. The angular correlation of γ-rays in coincidence with protons populating the 3·00 MeV

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level was measured using a 12·7 cm by 10·2 cm NaI(Tl) crystal 20 cm from the target in conjunction with a double-focusing magnetic spectrometer (Elliott, Carter, and Spear 1968) set at 0° to the beam direction. Particle groups to the 2·98 and 3·00 MeV levels were adequately resolved. The collinear geometry ensures that only the m $= \pm\frac{1}{2}$ magnetic substates of the final nucleus are populated, so simplifying the correlation function (Litherland and Ferguson 1961).

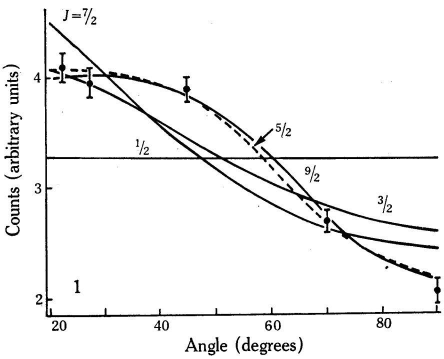

Fig. 1.—Experimental angular correlation for the 3·00 to 0 transition with best fits for various possible spins of the 3·00 MeV level.

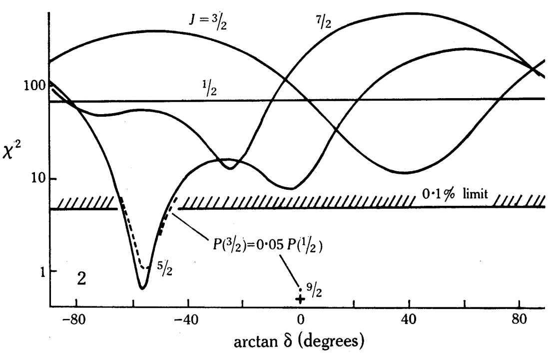

Fig. 2.—Plots of χ^2 versus the amplitude mixing ratio for the 3·00 to 0 angular correlation. Also shown is the effect on the fits for $J = {}^5/_2$ and ${}^9/_2$ of a 5% population of the m $= \pm{}^3/_2$ substates.

The measured correlations of the 3·00 to 0 and 3·00 to 2·21 γ-ray transitions were analysed assuming $J = \frac{5}{2}$ for the ground state (Endt and van der Leun 1962) and $\frac{7}{2}$ for the 2·21 MeV level (Ophel and Lawergren 1964; Sheppard and van der Leun 1967). The 3·00 to 0 correlation could only be fitted within the 0·1% confidence limit (see Figs. 1 and 2) for $J(3\cdot00) = \frac{9}{2}$ with δ (= M3/E2) = 0 and for $J(3\cdot00) = \frac{5}{2}$ with $-2\cdot00 < \delta$ (= E2/M1) $< -1\cdot07$. The 3·00 to 2·21 correlation could be fitted for $J = \frac{9}{2}$ with $|\delta| < 0\cdot1$ and for $J = \frac{5}{2}$ with $-0\cdot29 < \delta < 0\cdot03$ or $\delta < -8\cdot1$ or $\delta > 6\cdot3$. The last two possibilities can be eliminated since such large mixing ratios, when coupled with a recent lifetime measurement (Broude, Smulders, and Sharpey-Schafer 1967) of $(8\cdot3\pm0\cdot7)\times10^{-13}$ sec, imply an enhancement of the E2 width by a factor of about 1000 over the single-particle estimate.

For both transitions the mixing ratios obtained for $J = \frac{9}{2}$ are in agreement with the results of Lawergren (1964) and Sheppard and van der Leun (1967). It is noteworthy that for the 3·00 to 0 transition, the mixing ratio obtained from the present data if $J(3\cdot00) = \frac{5}{2}$ (i.e. $-2\cdot00 < \delta < -1\cdot07$) agrees with the value that Sheppard and van der Leun found to give a satisfactory fit at two of the resonances studied; their $J = \frac{9}{2}$ assignment was based on the fact that at a third resonance $J = \frac{5}{2}$ gave a solution that, although next best to $J = \frac{9}{2}$, fell outside the 0·1% limit.

The branching ratios extracted from the $^{24}Mg(\alpha, p\gamma)^{27}Al$ correlation data are compared in Table 1 with those obtained using (p, p′) and (p, γ) reactions. The close agreement implies that, if we are in fact dealing with a doublet, either the two members are populated in the same ratio in all three reactions or they have almost identical decay schemes. It is therefore very improbable that the 3·00 MeV level is a doublet.

Table 1

Branching ratios of 3·00 MeV level of ^{27}Al

Reaction	Branching (%) 3·00 → 0	Branching (%) 3·00 → 2·21	Reference
$^{27}Al(p, p')$	84±6	16±6	Lawergren (1964)
$^{27}Al(p, p')$	93±4	7±4	Elliott, Ophel, and Spear (to be published)
$^{26}Mg(p, \gamma)$	91±3	9±3	Sheppard and van der Leun (1967)
$^{24}Mg(\alpha, p)$	90±3	10±3	Present work

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