the continuum sum over the first variety is only of order $(1-S)^2$, the sum over the second variety is of order $(1-S)$.

A given spectroscopic factor, or sum of spectroscopic factors, will not therefore add to unity. It is quite possible for a spectroscopic factor of a single bound state to be significantly less than unity, without having to postulate the automatic existence of some second state.[4] Depending on the magnitude of the absorption effects in neutron scattering the continuum contributions to (12) can be large and in any such case a spectroscopic factor, or sum of spectroscopic factors, will be significantly less than unity. Conversely, if a spectroscopic factor is to be close to unity this must be associated with inhibition of neutron absorption in the continuum.

This latter question will be discussed in more detail in a later publication.

We are grateful to Dr. R. M. May and Professor N. Austern for helpful discussions. This work was supported in part by the Science Foundation within the University of Sydney and it is a pleasure to acknowledge the interest of its director, Professor H. Messel.

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SPIN AND LIFETIME OF THE 2797-keV LEVEL IN F^{19}†

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(Received 18 October 1968)

Correlation measurements have resulted in an unambiguous $\frac{9}{2}$ spin assignment to the level in F^{19} at 2797 keV. The lifetime of this level has been measured with the Doppler shift attenuation method to be 246 ± 44 fsec, which establishes its positive parity assignment.

A number of shell-model and collective-model calculations[1-5] have been made for the nuclei with $17 \leq A \leq 20$, in particular, for F^{19}. We have undertaken a re-examination of the reaction $N^{15}(\alpha,\gamma)F^{19}$ to obtain further evidence to support and distinguish between these models. In addition to other results to be discussed in a more extensive, future publication, we have succeeded in establishing the $\frac{9}{2}^+$ assignment to the 2797-keV level, an identification crucial to all the calculations of positive-parity levels. There have been several previous attempts[5-9] to establish an unambiguous spin assignment to the 2797-keV level in F^{19}, none of which has been successful.

In the present study, double and triple correlation measurements were performed on the transitions $5474 \rightarrow 2797$ and $2797 \rightarrow 197$ keV, hereafter referred to as the primary and secondary transitions, respectively. These result from the decay of the 5474-keV resonance level found at $E_\alpha = 1852$ keV, which was excited by the bombardment of thick TaN targets with the α-particle beam from the University of Kansas Van de Graaff accelerator. The double-correlation data were taken with a coaxial 15-cm^3 Ge(Li) detector. The intensities used in the analysis were those of the double escape peaks.

The analysis of the primary and secondary double-correlation measurements yielded the results shown in Tables I and II. In Table I are listed the A_2/A_0 and A_4/A_0 coefficients from a Legendre polynomial fit to the double-correlation data on the primary and secondary transitions and also on the transition $5474 \rightarrow 1347$ keV. The possibility of a $\frac{9}{2}$ spin assignment for the 5474-keV compound state was eliminated at the 0.1% confidence level by the analysis of the latter transition. The observed mixing ratios for the transition $2797 \rightarrow 197$ keV agree quite well with the recent measurements of Allen et al.[8] and Thomas et al.[9] The primary-decay mixing ratios shown in Table II are from the analysis of the

Table I. Coefficients of the Legendre polynomial fit to the double correlations of the transitions 5474→2797, 2797→197, and 5474→1347 keV. These are listed for reference only; the data points were used directly in a χ^2 analysis of the alternative spin assignments of the 5474- and 2797-keV levels, as shown in Table II.

Transition (keV)	A_2/A_0	A_4/A_0
5474→2797	-0.24 ± 0.09	-0.22 ± 0.11
2797→197	0.47 ± 0.07	-0.46 ± 0.11
5474→1347	-0.51 ± 0.06	

primary double correlations. The mixing ratios for the primary transition required by the analysis of the secondary double correlations are consistent with these values. Unfortunately, only the $\frac{3}{2}\to\frac{5}{2}\to\frac{5}{2}$ and $\frac{5}{2}\to\frac{5}{2}\to\frac{5}{2}$ spin sequences were eliminated by the double-correlation measurements on the cascade 5474→2797→197 keV. The possibility of a $\frac{3}{2}\to\frac{9}{2}\to\frac{5}{2}$ sequence was not given serious consideration since the resonance level does decay 65% to the 2797-keV state and only 30% to the $\frac{5}{2}^-$ level at 1347 keV, and also since the correlations contain obviously significant $P_4(\cos\theta)$ terms. The multipolarity mixing ratios[10] required by the double-correlation analysis were used to calculate the theoretical triple correlations (corrected for solid angle) of the primary and secondary transitions in the $A1$, $A2$, $C1$, $C2$, and D geometries.[11] On the basis of these predicted correlations the A geometry was selected as the most favorable for distinguishing between the alternative spin sequences. The correlation was, therefore, measured in this geometry, with the variable polar angle set alternately at 0° and 90° for a sequence of short data-taking periods to minimize the effects of any instabilities in the equipment. For this measurement, two 12.7-cm ×12.7-cm NaI detectors were used. The high voltage supplied to the photomultiplier tubes and the gains at which the amplifiers were set were adjusted to give an identical overall amplification to the pulses from each detector. A single-channel analyzer was used with each detector, with its window set to discriminate against voltage pulses corresponding to γ-ray energies greater than 2.97 MeV and to γ-ray energies below 1.95 MeV. Care was taken to ensure that the energy windows of the single-channel analyzers were equal. The gains and single-channel analyzer settings were checked at regular intervals during the experiment and corrected when necessary.

Table II. Results of double-correlation analysis of the transitions 5474→2797 and 2797→197 keV. J_R is the assumed spin of the 5474-keV level and J_I is the assumed spin of the level at 2797 keV. The 0.1% and 10% confidence limits occur at the values of χ^2 of 4.6 and 1.9, respectively, for the primary transition and 5.5 and 2.1, respectively, for the secondary transition.

		Primary transition		Secondary transition	
J_R	J_I	Mixing ratio	χ^2	Mixing ratio	χ^2
$\frac{7}{2}$	$\frac{9}{2}$	-0.13 ± 0.04	1.4	0.06 ± 0.05	1.6
$\frac{7}{2}$	$\frac{5}{2}$	0.01 ± 0.02	1.3	-1.74 ± 0.32	2.5
$\frac{5}{2}$	$\frac{9}{2}$	-0.45 ± 0.04	0.8	0.05 ± 0.11	3.3
$\frac{5}{2}$	$\frac{5}{2}$	0.75 ± 0.06	0.6	-1.31 ± 0.72	5.8
$\frac{3}{2}$	$\frac{5}{2}$	-0.24 ± 0.06	1.9	-1.44 ± 0.75	6.2

Coincidence ($2\tau=50$ nsec) was then required of the logic pulses from each of the single-channel analyzers. The coincidence counting rate was the sum of the counting rates for the correlations in the $A1$ and $A2$ geometries. This procedure was used because of the low yield of the reaction, which made the use of NaI detectors imperative, and the inability of these detectors to resolve the primary and secondary decay γ rays.

An anisotropy, defined by

$$\epsilon=\frac{\{W^{A1}(0)-W^{A1}(90)+W^{A2}(0)-W^{A2}(90)\}}{\{W^{A1}(0)+W^{A1}(90)+W^{A2}(0)+W^{A2}(90)\}},$$

was calculated, where $W^{A1}(0)$ is the theoretical angular correlation function in the $A1$ geometry at 0°, etc. This number was then compared with the difference divided by the sum of the coincidences obtained at 0° and 90°. The results are shown in Table III. The column "Probability of occurrence" lists the probability that the experimental result will deviate as much as observed

Table III. Comparison of the observed anisotropy of the cascade 5474→2797→197 keV and that predicted for the alternative spin sequences which were not eliminated by the double-correlation results. The anisotropy was determined in the A geometry defined in Ref. 10, as discussed in the text.

Spin sequence	Predicted anisotropy	Observed ansiotropy	Probability of occurrence (%)
$\frac{7}{2}\to\frac{9}{2}\to\frac{5}{2}$	0.313	0.270 ± 0.040	10.0
$\frac{7}{2}\to\frac{5}{2}\to\frac{5}{2}$	0.151	⋯	0.19
$\frac{5}{2}\to\frac{9}{2}\to\frac{5}{2}$	-0.157	⋯	$<10^{-10}$

from the theoretical value if the corresponding spin sequence is correct.[12] Briefly, these are based on the statistical error in the measured anisotropy and on the internal error of the "best" values of the primary and secondary transition mixing parameters. They are pessimistic estimates in that they are based on the internal errors, rather than the much smaller external errors, and in that they do not take account of the preference indicated in Table II for a $\frac{9}{2}$, rather than a $\frac{5}{2}$, assignment for the 2797-keV level. Clearly only the sequence $\frac{7}{2}\rightarrow\frac{9}{2}\rightarrow\frac{5}{2}$ yields reasonable agreement with the experimental result.

The measured Doppler shifts have been used to calculate the lifetime of the 2797-keV level following the technique outlined by Blaugrund.[13] The specific energy loss functions calculated by Lindhard[14] for both electronic and nuclear collisions were used in the evaluation of the attenuation factor versus lifetime relationship. The nuclear energy loss was approximated by the functional form employed by Engelbertink, Lindeman, and Jacobs.[15] Corrections were included for the effect of the finite solid angle subtended by the Ge(Li) detector. A correction for the systematic difference between experimental and empirical values of the electronic stopping, based on the measurements of Ormrod, MacDonald, and Duckworth,[16] was also included.

The centroids of the peaks were determined from the spectra taken at 0° and 90° with respect to the beam direction. The observed shifts in the centroids were 5.5 ± 0.6 keV for the secondary transition and 18.0 ± 0.6 keV for the primary, while the calculated unattenuated shifts are 17.3 and 17.8 keV, respectively. These latter values for the unattenuated shifts are based on a recoil energy of the F^{19} nucleus of 390 keV. The lifetime of the 2797-keV state was determined to be 246 ± 44 fsec, based on the attenuation curve, calculated as described above, for a stopping material of TaN. This result is in slight disagreement with the upper limit of 190 fsec reported recently by Robinson and Bent.[17]

The decay probability in Weisskopf units for the 2797-keV level is 9.1 for $E2$ radiation and 210 for $M2$ radiation. This unreasonably large value for $M2$ radiation, together with the positive parity of the 197-keV level, confirms the positive parity of the 2797-keV level.

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†Work supported in part by the U. S. Atomic Energy Commission.

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