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Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

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ABSTRACT

The conversion electron spectrum following alpha decay of Am^{241} has been reinvestigated with 180° focusing beta-ray spectrographs at ~0.1% resolution. Multipolarity assignments for several gamma transitions are made, principally on the basis of relative L-subshell conversion coefficients. Energy-level spacings and relative transition probabilities are compared and discussed in terms of the Bohr-Mottelson model. The excellent agreement of energy-level spacings with the rotational formula and the general pattern of radiative transitions firmly establish the essentially rotational nature of these bands of levels. However, calculations involving M1 transition probabilities and magnetic moments lead to discrepancies with the simple theory, suggesting that intrinsic magnetic properties in Np^{237} may not be attributed simply to a single unpaired proton in a spheroidal well.

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INTRODUCTION

The decay properties of Am^{241} have recently been the subject of an extensive paper by Jaffe, Passell, Browne, and Perlman[1] in which experimental information on the alpha decay,[2] conversion electrons, gamma rays, and L x-rays is presented and correlated into a detailed disintegration scheme. The gamma-ray spectrum has also been examined with high precision by Day.[3] The conversion-electron spectrum has been studied by Milsted, Rosenblum, and Valadares[4] and by Wolfson;[5] more recently, Baranov and Shlyagin have published the results of an extensive beta-spectroscopic study.[6] A discussion of the excited states of Np^{237} in terms of the Bohr-Mottelson model has been given in various publications.[1,6,7]

The ground-state spin of Np^{237} has been measured as 5/2 by Tompkins.[8] Quite recently, Newton[9] has studied the excited states of Np^{237} that appear from Coulomb excitation experiments.

Figure 1 presents the energy-level scheme for Np^{237}, consistent with the above investigations.

Jaffe et al.[1] discuss the unusual properties of the 59.6-kev state in Np^{237}, which is populated by more than 99% of the Am^{241} disintegrations. They measured the total conversion coefficient of the 59.6-kev gamma ray to be 0.92, and concluded that the radiation is electric dipole. However, their observed $(L_I + L_{II})/L_{III}$ conversion ratio of 4.4 is more than twice that expected for an E1 transition according to the calculations of Rose,[10] and the total L-conversion coefficient is about twice the theoretical value. In addition, Beling, Newton, and Rose[11] have shown that the lifetime of this transition is more than 10^5 times that calculated for a single-proton transition.

Because in the work of Jaffe et al.[1] the L_I and L_{II} conversion electrons from this gamma ray were not completely resolved, one could not rule out

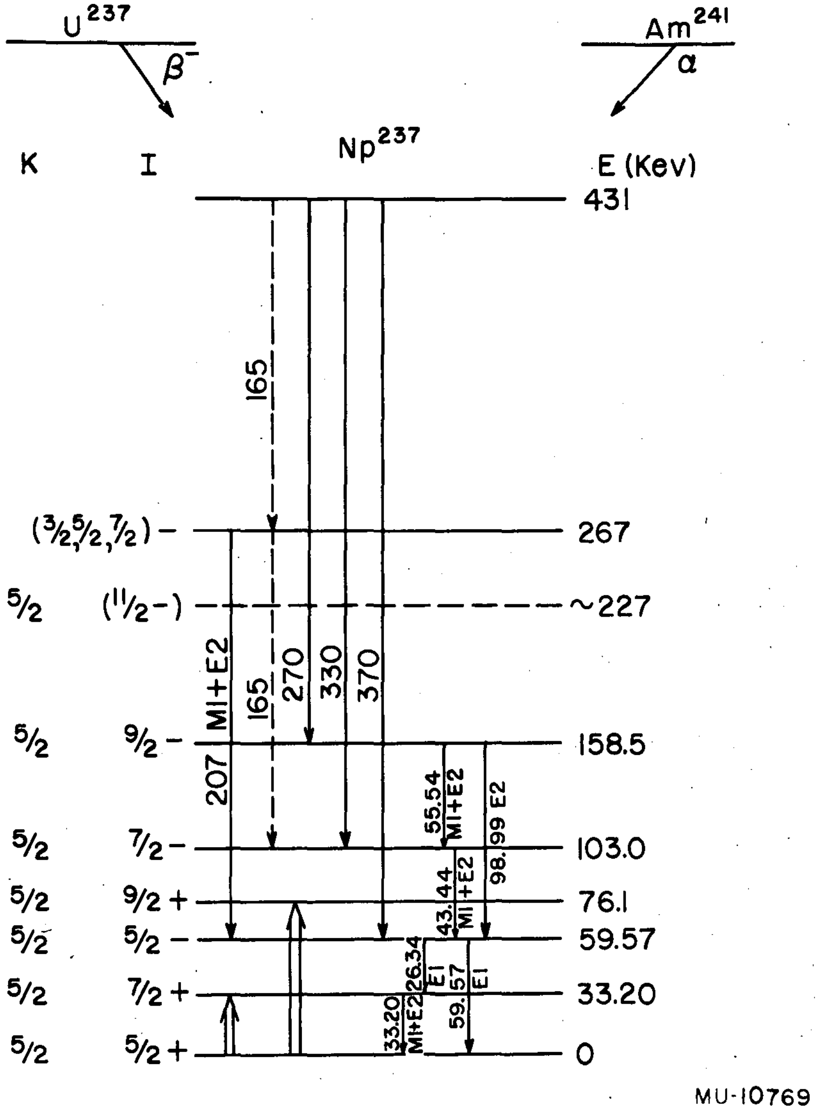

Fig. 1. The energy levels of Np^{237}.

the possibility of M2 admixture, which would contribute high L_I conversion and would therefore raise the $(L_I + L_{II})/L_{III}$ ratio over that expected for a pure E1 transition. We have therefore studied the subshell conversion ratios for this transition at higher resolution than that used previously, using two photographic recording 180° permanent-magnet spectrographs with resolution of approximately 0.1%. These spectrographs and the techniques of source preparation have been described previously.[12]

The low-lying levels of Np^{237} fall neatly into two rotational bands, an indication of the probable usefulness of the Bohr-Mottelson quasi-molecular model in the interpretation of level spacings and transition probabilities. In the latter part of this paper we make use of available data from several sources to test the model.

EXPERIMENTAL RESULTS

A total of 45 electron lines were identified, 40 of which could be assigned to known transitions in the Np^{237} nucleus. The energies of these lines were evaluated relative to those of the 59.57-, 43.46-, 33.20-, and 26.36-kev transitions whose absolute energies were measured by Day[3] with a curved-crystal diffraction spectrometer. The electron data are summarized in Table I. The electron-line intensities were measured with a recording densitometer by the method of Slätis.[13] A linear tracing of the densitometer plot of the lines of the 59.6-kev transition is shown in Fig. 2.

The 59.6-kev Transition

We have found the L-shell internal conversion ratios to be $L_I/L_{II}/L_{III}$ = 1.5/3.3/1.0 with an uncertainty of about ± 25% in each value. Jaffe et al.[1] found $(L_I + L_{II})/L_{III} = 4.4 \pm 1$, and Wolfson[5] obtained for the same ratio 6.4 ± 1.3. Milsted et al.[4] determined the L_I/L_{III} ratio to be 1/1.2; they did not determine the relative intensity of the L_{II} line because they believed that the M lines of the 43.4-kev transition would be superimposed on the 59.6-kev L_{II} line and the latter's intensity would be artificially high. In the work reported here the 43.4-kev M_I line was resolved from the 59.6-kev L_{II} line and the intensity of the former seemed to be very small compared with the latter so its contribution to the total line intensity can be neglected.

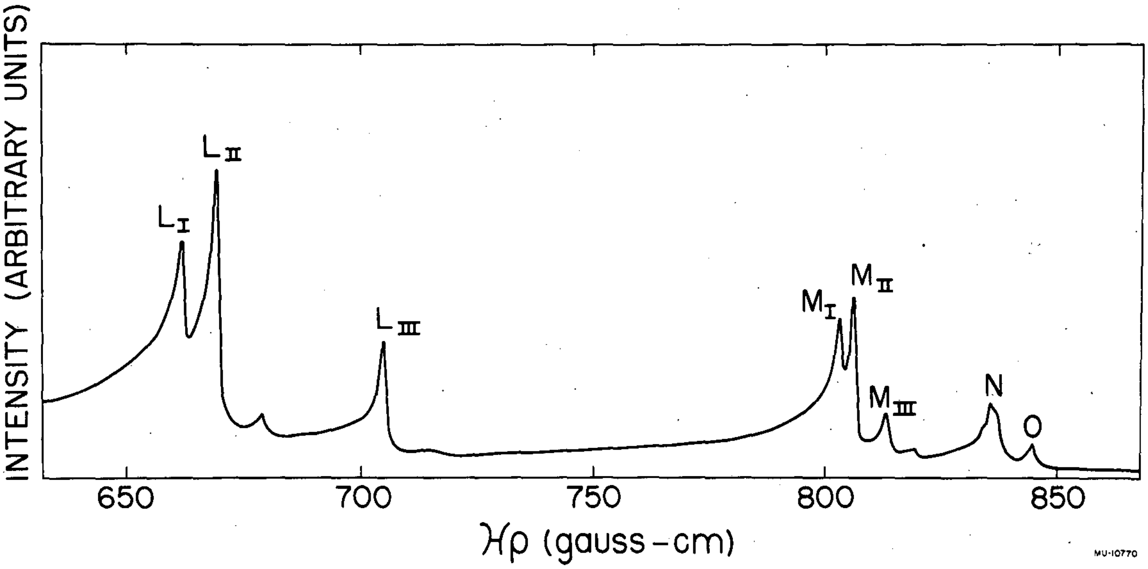

Fig. 2. Linear drawing of densitometer trace of conversion lines of 59.6-kev transition.

Table I

Electron energy	Shell	Relative abundance (visual estimate)*
26.36-kev transition		
20.61	M_I	vw
33.20-kev transition		
10.82	L_I	w
11.62	L_{II}	vvw
15.55	L_{III}	vvw
27.46	M_I	m
27.84	M_{II}	w
28.80	M_{III}	w
31.73	N_I	wm
31.92	N_{II}	vw
32.15	N_{III}	vw
32.45	$N_{IV}+N_V$	vvw
32.87	$O_I + O_{II}$	vw
43.46-kev transition		
21.05	L_I	m
21.87	L_{II}	m
25.85	L_{III}	m
37.71	M_I	w
- -	M_{II}	--
39.05	M_{III}	w
42.37	N_I, N_{II}, N_{III}	vw
43.20	O_I, O_{II}, O_{III}	vw
55.56-kev transition		
33.14	L_I	vw
33.99	L_{II}	w
--	L_{III}	--
49.78	M_I	vvw
50.23	M_{II}	vvw
51.14	M_{III}	vvw
59.57-kev transition		
37.16	L_{II}	s
37.98	L_{II}	vs
41.96	L_{III}	s
53.83	M_I	s
54.21	M_{II}	s
55.13	M_{III}	ms
55.74	M_{IV}	vw
55.87	M_V	vw
58.07	N_I	m
58.25	N_{II}	m
58.49	N_{III}	w
58.79	N_{IV}, N_V	vw
59.31	O_I, O_{II}	wm
59.53	P(?)	vvw
99.0-kev transition		
77.37	L_{II}	w
81.40	L_{III}	w
Unassigned lines		
12.22	L-Auger?	vvw
13.14	"	vvw
14.02	"	vvw
14.85	"	vvw
25.00	?	vw

* s = strong; m = moderate; w = weak; v = very —.

The recent results of Baranov and Shlyagin, $L_I/L_{II}/L_{III} = 1.5/3.3/0.7$, are in qualitative agreement with our data.

On the basis of the $(L_I + L_{II})/L_{III}$ ratio Jaffe et al.[1] suggested that the 59.6-kev transition might be an E1 + M2 mixture. It is now apparent, however, that no proportion of E1 and M2 mixing could reproduce the observed predominance of L_{II} conversion, since the theoretical screened relativistic conversion coefficients (extrapolated from the Rose's tables[10] for a transition of energy 0.12 mc^2 and $Z = 93$) are: E1, $L_I/L_{II}/L_{III} = 0.13/0.10/0.09$ and M2, $L_I/L_{II}/L_{III} = 480/35/190$. It thus appears that there is a real discrepancy between the experimental E1 conversion coefficients and the theoretical values of Rose.

We have also measured the relative M-subshell conversion coefficients for this transition. The ratios are $M_I/M_{II}/M_{III}/M_{IV+V} = 1.7/3.6/1.0/0.1$. Within the experimental error of approximately 25% in each value, the M-subshell ratios are the same as the L-subshell ratios; the similarity of L and M relative conversion coefficients has been noted previously for the 44.1-kev E2 transition in Pu^{238} and the 42.9-kev E2 transition in Pu^{240}.[12] Church and Monahan[14] have given theoretical estimates of threshold relative conversion coefficients for the M shell; for an E1 transition they obtain $M_I/M_{II+III}/M_{IV+V} \cong 1.6/4.6/5.3$. These calculations appear to overestimate the contribution of d-electron conversion in this situation by a factor of approximately 50.

The relative N-subshell coefficients were not determined quantitatively because of insufficient resolution, but visually the N_I and N_{II} lines were predominant, with N_{II} somewhat stronger than N_I.

The over-all conversion ratios were estimated to be $L_\Sigma/M_\Sigma/N_\Sigma/O_\Sigma = 1.0/0.3/0.1/\sim 0.03$.

The 33.2-kev Transition

Because of the poor efficiency of our photographic plates for electrons with energy under ~20 kev, we have no intensity data on the L-shell conversion lines of this gamma ray. However, the M-subshell conversion ratios were estimated as $M_I/M_{II}/M_{III} \approx 4/1/1$. These intensities are quite similar to the relative L-subshell ratios reported by Baranov and Shlyagin,[6] who found $L_I/L_{II}/L_{III} = 4.2/1.0/1.0$. On the basis of their L-subshell data, one would estimate from Rose's theoretical conversion coefficients[10] an approximate mixing ratio $M1/E2 \approx 50$ (for this mixing ratio the theoretical

L-subshell ratios are $L_I/L_{II}/L_{III}$ = 4.1/1.4/1.0).

The 26.4-kev Transition

Since the 59.6-kev transition is an E1 and the 33.2-kev transition is M1, the 26.4-kev gamma ray must be principally E1. Because of the low energy of the conversion electrons, we have no intensity data on this transition. Baranov and Shlyagin[6] quote the conversion ratio $L_I/L_{II}/L_{III} \approx 0.9/2.0/1.3$.

The Rotational Band: 59.6, 103.0, and 158.5 kev

The 103.0- and 158.5-kev levels are members of a rotational band based on the 59.6-kev level with I = 5/2.[7] One thus expects the de-excitation of the 158.5-kev level to take place with the emission of cascading M1-E2 mixed radiations and a pure E2 crossover gamma ray.

The cascading radiations from the 158.5-kev level are the 55.56- and 43.46-kev gamma rays. Our electron data on the 55.6-kev gamma ray are the following: L_I and L_{II} electrons are seen, in about equal intensity, whereas the L_{III} electron would be hidden under the much more intense L_{II} line of the 59.6-kev gamma ray. Also, M conversion is observed, with the M_I, M_{II}, and M_{III} lines visually estimated to be of equal intensity. Our L-electron data indicate an M1/E2 mixing ratio of ~4 (theoretical values[10] for this mixing ratio are $L_I/L_{II}/L_{III} \approx 1.1/1.0/0.8$.) Baranov and Shlyagin[6] report L_I/L_{II} = 1.4/1.0, which would indicate a mixing ratio M1/E2 ~6 (theoretical values are $L_I/L_{II}/L_{III} \approx 1.4/1.0/0.7$). The agreement between these two observations is satisfactory, considering the low intensity of this transition and the interference from the intense lines of the 59.6-kev transition.

The L-subshell conversion ratios were determined for the 43.4-kev transition to be $L_I/L_{II}/L_{III}$ = 1.0/1.0/1.0, which corresponds to an M1/E2 mixing ratio of ~6 (the theoretical values[10] for this mixing ratio are $L_I/L_{II}/L_{III} \approx 1.0/1.0/0.7$). Milsted et al.[4] have reported $L_I/L_{II}/L_{III}$ = 0.9/1.0/1.0 and Baranov and Shlyagin[6] find $L_I/L_{II}/L_{III}$ = 1.2/1.0/0.8. These measurements all appear to be consistent within their experimental uncertainties.

Our data support the assignment of pure E2 character to the 99.0-kev transition, since L_{II} and L_{III} lines are observed (with L_{II} slightly more intense than L_{III}), and the L_I line is not seen. This is in agreement with the data of other investigators[4, 5, 6, 14].

Higher excited states than the 158.5-kev level have been observed from the decay of Am^{241} by Day,[3] from the decay of U^{237} by Wagner et al,[15] and from a study of both of these nuclides by Baranov and Shlyagin.[6] The existence of levels at ~270 kev and ~430 kev seems well established; in addition Baranov and Shlyagin[6] report a level at 227 kev, which would be the expected position for the $I = 11/2$ state based upon the 59.6-kev rotational band. Very little is known about the multipolarities of the gamma rays which de-excite these higher levels. Wagner et al.[15] have obtained a K conversion coefficient of 1.6 and a K/L ratio of 5 for the 207-kev gamma ray (which de-excites the 270-kev state to the base state of the 59.6-kev rotational band) but were unable to correlate these values with Rose's theoretical values[10] for any multipolarity. It might, however, be pointed out that the theoretical[10] values for a 50% - 50% M1 - E2 mixture are in qualitative agreement with the experimental results of Wagner et al.,[15] since for such a mixture $(\epsilon_K)_{theor} = 2.2$ and $(K/L)_{theor} = 3.5$.

ROTATIONAL SPACINGS AND MOMENTS OF INERTIA

The energies of rotational levels in odd-A nuclei are given by the equation[16] (valid except for $K = \Omega = 1/2$)

$$E_i = \frac{\hbar^2}{2\mathcal{J}} \left[I(I+1) - I_0 (I_0 + 1) \right],$$

where $\mathcal{J}$ = moment of inertia,
I = spin,
I_0 = spin of base level.

If we use Day's value,[3] 43.46 kev, for the energy difference between the 5/2 and 7/2 states, we calculate $\hbar^2/2\mathcal{J} = 6.21$ kev. Our value for the 7/2 – 9/2 difference, 55.56 kev, should also be quite accurate, since the conversion lines of this gamma ray fall among those of the 59.57-kev gamma ray, the energy of which is known to better than 0.1%. From the 7/2 – 9/2 difference we calculate $\hbar^2/2\mathcal{J} = 6.17$ kev. The average value for the rotational constant of the upper 5/2 band in Np^{237} illustrates the general behavior of odd-A nuclei in exhibiting slightly higher moments of inertia than neighboring even-even nuclei. For example, the ground-state rotational band in Pu^{238} has $\hbar^2/2\mathcal{J} = 7.37$ kev.[12] It is to be noted that the deviation of energies from the simple formula above is of the same sense as the deviations in even-even nuclei (i.e., a depression of the higher spin states of the band) and not, as Kerman[17] has noted in an odd-parity band in W^{182}, in the opposite sense.

Of great interest regarding effective moments of inertia are the recent Coulombic excitation results on Np^{237} by J. O. Newton.[9] He finds excitation of a rotational band which includes the known 33.2-kev level and a new level at 76 kev. The spacings agree with those expected for a normal $K = 5/2$ band with spins respectively 5/2, 7/2, and 9/2. The effective moment of inertia is by far the largest one known for a nuclear rotational band. The value of $\hbar^2/2\mathcal{J}$ is 4.75 kev, over 20% less than the corresponding value for the band based on the 59.6-kev level in the same nucleus.

Too little is known about higher rotational bands than these in Np^{237} at attempt any detailed analysis of the effects of rotational perturbations from higher bands in the manner of Kerman[17] for W^{183}. It seems likely, however, on the basis of the M1-E2 mixed character of the 207-kev gamma that the level at 270 kev is the base state of a band interacting with the band based at 59.6 kev.

We should like to propose tentatively that the difference in rotational spacings between the ground-state and 59.6-kev bands might be qualitatively explained in terms of the rotation-particle-coupling interaction as follows: We would suggest that the parity of the ground band is even and that of the 59.6-kev band is odd. The $\Omega = 5/2$* even-parity orbitals available to the odd proton in the region of $Z = 93$ are of predominantly $i_{13/2}$ nature, although the large spheroidal deformation introduces some admixture of other j values, (cf. wave function tables of Nilsson.)[18] The possible $\Omega = 5/2$ odd-parity orbitals in this region are mixtures of components, with j ranging between 1/2 and 9/2. The RPC interaction matrix elements are increasing functions of j; hence, the interactions tending to decrease rotational band spacings in Np^{237} will be larger for the even-parity than for

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* Ω is the component of total nucleonic angular momentum along the nuclear symmetry axis. K is the component of total angular momentum along the symmetry axis and is expected to be equal to Ω for low-lying states.

the odd-parity band, and rotational spacings will be smaller, provided the energies of the perturbing higher bands are comparable.

TRANSITION-PROBABILITY CALCULATIONS WITH THE BOHR-MOTTELSON MODEL

The Bohr-Mottelson rotational model for strongly deformed nuclei[16, 19] has found striking success in correlating relative reduced transition probabilities of beta or gamma transitions which have a common initial state and have final states within a single rotational band. These relative probabilities are usually in the simple ratio of squares of Clebsch-Gordan coefficients involving the spins I_i and I_f, the multipolarity L, and the K-quantum numbers K_i and K_f. Alaga, Alder, Bohr, and Mottelson[20] have listed several examples, and others have been listed elsewhere.[16, 21, 22] Kerman[17] has interpreted the gamma transition data of Murray et al.[23] for W^{183} by taking into account interactions mixing the zero-order Bohr-Mottelson wave functions. Several examples[20, 21, 22] of the operation of K-selection rules have been given, these rules following from the fact that the Clebsch-Gordan coefficients vanish identically when ΔK exceeds L, the multipolarity. The above-mentioned branching ratio tests are essentially checks on the separability of rotational motion from intrinsic nucleonic motion in the rotating frame of reference; such separation introduces the K quantum numbers. These checks do not directly test the details of intrinsic nucleonic structure except when $K = \Omega = 1/2$.

With the present data from alpha decay of Am^{241} one can make the following simple branching-ratio test: The relative reduced transition probabilities for the two E1 transitions should be, from theory,

$$\frac{B_{5/2 \xrightarrow{E1} 5/2}}{B_{5/2 \xrightarrow{E1} 7/2}} = \frac{(5/2\ 1\ 5/2\ 0 \mid 5/2\ 1\ 5/2\ 5/2)^2}{(5/2\ 1\ 5/2\ 0 \mid 5/2\ 1\ 7/2\ 5/2)^2} = 2.50. \qquad (1)$$

Experimentally, from the proportional counter studies of Beling, Newton, and Rose,[24] the relative photon intensities of 59.57- and 26.36-kev transitions are 1 to 0.075 ± 0.008, and from Day,[3] 1 to 0.082. Taking an average value and removing the energy dependence, one finds

$$B_{59.6} / B_{26.4} = (1/0.08)\ (26.4/59.6)^3 = 1.1. \qquad (2)$$

The theoretical and experimental values do not agree, and this failure of the branching-ratio test for the E1 gammas would be explained within the framework of the rotational model by contributions from one or more admixed configurations with $K \neq 5/2$. It is difficult at present to estimate from this evidence the magnitude of these admixtures, in view of the erratic and large retardations[11,25,26] of E1 transitions in the heavy region (i.e., a relatively small wave-function component with $K \neq 5/2$ might give large contributions to the E1 intensities).

With regard to the retarded E1 transitions it appears from calculations of Strominger and Rasmussen[27] that this retardation may be a natural and general consequence of using single-particle wave functions in a spheroidal well. In these calculations single-proton E1 transition probabilities were calculated by use of the wave functions of Nilsson[18] for various degrees of prolate deformation and for various combinations of initial and final states. A large, though variable, retardation from ordinary single-particle lifetime formulas was always found.

Interesting tests of the detailed single-particle assumptions of the Bohr-Mottelson model may be made where the M1/E2 mixing ratio of a cascade transition within a single rotational band is known together with the magnetic moment for the base level of the band. E2 transition probabilities are proportional to the square of the intrinsic quadrupole moment, a quantity that may be estimated from Coulomb excitation cross sections.[28] M1 transition probabilities are theoretically proportional to $(g_\Omega - g_R)^2$, where g_Ω is the g factor appropriate to the odd-nucleon wave function and g_R is the g factor for the collective rotational motion -- commonly assumed[16] to be of the order of Z/A. The magnetic moment of the base state of a rotational band is given[16] as

$$\mu = \frac{I_0^2}{I_0+1} g_\Omega + \frac{I_0}{I_0+1} g_R . \qquad (3)$$

Knowing μ and the M1/E2 ratio of a transition in the band and knowing or assuming Q_0, one can solve separately for g_Ω and g_R. Alaga et al.[20] mention similar tests on the Ta^{181} ground rotational band. They found the data consistent with the model predictions, at least within the uncertainty of the magnetic moment determination. Mottelson and Nilsson[29] likewise have found good results in Tm^{169}, assuming the intrinsic structure to be a single proton in a particular orbital of the deformed well.

We are able to make checks in both rotational bands of Np^{237}. The ground-state magnetic moment has been measured as 6.0 ± 2.5 nuclear magnetons by Bleaney et al.,[30] and Novey, Krohn, and Raboy[31] have measured a g factor of $g = +0.8 \pm 0.2$ for the 59.6-kev state by measuring the attenuation of the alpha-gamma angular anisotropy in an applied magnetic field. With the spin value of 5/2 assigned[7] to the 59.6-kev level the μ value is 2.0 ± 0.5 nuclear magnetons.

For the ground-state band, if we take the experimental M1/E2 ratio for the 33.2-kev transition of approximately 50 and apply the appropriate gamma transition equations,[16] we calculate $(g_{\Omega} = g_R) / Q_0 = \pm 0.065 \text{ barn}^{-1}$.

Temmer[32] has calculated from absolute Coulomb excitation cross sections the $|Q_0|$ values of 9 barns for Th^{232} and 8 barns for U^{238}. For the present purposes it would be most desirable to have a direct determination of $|Q_0|$ for Np^{237} itself, but we do not have this information. We might estimate as a reasonable value 12 barns, with perhaps a 40% uncertainty. With this assumption we calculate $g_{\Omega} - g_R = \pm 0.8$ for the ground-state band.

Though we lack direct evidence on the M1/E2 ratio of the cascade gamma from the 76-kev level, it is still possible to make an independent determination of $(g_{\Omega} - g_R)/Q_0$ for the ground band by using the relative intensities of cascade and crossover photon radiation from the 76-kev state as determined by Newton.[9] Newton's ratio of crossover to cascade photons is $0.052 \begin{smallmatrix} +0.016 \\ -0.026 \end{smallmatrix}$ to 0.45 ± 0.05. Assuming E2 radiation from the 76-kev level to divide between crossover and cascade according to a relation similar to Eq. (1), we calculate a probable M1/E2 ratio for the upper cascade transition (42.9 kev) of about 50 to 1. Carrying through the theoretical calculation as for the 33.2-kev transition we obtain $(g_{\Omega} - g_R)/Q_0 = \pm 0.064 \text{ barn}^{-1}$, an answer in fortuitously good agreement with the other determination. This agreement supports the idea that the Bohr-Mottelson separation of rotational and intrinsic motion is a reasonably good approximation in the ground band.

One can go a step further and test the validity of assuming that the intrinsic magnetic properties are attributable to a single unpaired proton with good quantum number Ω. We use Eq. (3) for the single-particle Bohr-Mottelson magnetic moment, and solve for g_R from the quantities

μ = +6 and $g_{\Omega} - g_R = \pm 0.8$. We find an apparent $g_R \approx 1.8$ or 3.0 (depending on the choice of sign). Both of these values seem quite incompatible with the expected value $g_R \approx Z/A = 0.39$. (Recent theoretical K-conversion coefficients calculated by Sliv[31a] are, for Ml transitions, as much as a factor of two lower than those of Rose[10]. In view of a possible extension of this discrepancy to the L-shell coefficients, perhaps the uncertainty of our calculated Ml/E2 photon ratios should be greater than the experimental uncertainty in the electron relative intensities. Solving for values at the extreme limits of error μ = +3.5 and Ml/E2 = 100 one finds that the lower value of g_R has come down only to 0.6, still in disagreement with Z/A).

Similar calculations on the upper band from data on the 43.4-kev transition (Ml/E2 = 6) yield $(g_{\Omega}' - g_R')/Q_0' = \pm 0.030$ barn^{-1}. Calculations using an average mixing ratio for the 55.6-kev transition in this band (Ml/E2$\approx$5) yield $(g_{\Omega}' - g_R')/Q_0' = \pm 0.026$ barn^{-1}. The agreement is satisfactory, and the assumption of 12 barns for Q_0' leads to $g_{\Omega}' - g_R' = \pm 0.34$. Combining these data with the experimental value +2.0 nuclear magnetons for the magnetic moment of the 59.6-kev state, and using the theoretical Bohr-Mottelson relations as before, we get $g_R' = 0.56$ or 1.0. Substituting values at the extreme error limits (μ = +1.5, $(\mathrm{Ml/E2})_{43.4} = 10$) we get $g_R' \approx 0.26$ as the lower value. Thus for the upper band the theoretical estimate $g_R \approx Z/A = 0.39$ is well within the limits of error.

To summarize our present ideas on the lowest two bands in Np^{237}: the agreement of rotational energy spacings with simple theory and the agreement of two independent calculations of $(g_{\Omega} - g_R)/Q_0$ for each band from experimental data support the idea that the Bohr-Mottelson quasi-molecular separation of rotational from intrinsic motion is quite valid in each band, hence that K is at least a moderately good quantum number. As stated earlier, the failure to secure agreement on the branching ratio of the El gammas means some but not necessarily a large admixture of configurations with K $\neq$ 5/2 in initial or final states. Regarding the details of the intrinsic nucleonic structure within the spheroidal well, it appears that the magnetic moment* and the cascade Ml transition probabilities can be explained for

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* Theoretical magnetic moment calculations[33] for the various possible Ω = 5/2 orbitals in Nilsson's [18]scheme in no case yield moments in excess of +3 nuclear magnetons. The largest moment corresponds to an even-parity orbital. Configuration mixing of Ω = 3/2 and Ω = 7/2 single-particle wave functions may increase the magnetic moment further, but do not seem sufficient to bring it near the experimental +6 nuclear magnetons.

the upper but not for the lower band simply by an extreme single-particle configuration where all nucleons are assumed paired except for the odd proton whose total angular momentum along the symmetry axis (Ω) is a good constant of the motion. The disagreement with the extreme single-proton assumption in the lower band does not necessarily mean that the single-particle picture is not qualitatively correct here, for nuclear magnetic properties such as the magnetic moment are known often to be quite sensitive to small amounts of configuration mixing (for example, see the work of Blin-Stoyle and Perks[34] on the influence of configuration interaction on the magnetic moment of Bi^{209}). Among various interactions that might be responsible for configuration mixing in Np^{237} are the RPC (rotation-particle coupling)[17] and residual specific nucleon-nucleon forces[35] which are responsible for pairing energies. Both these interactions might be especially large for the even-parity band, where the odd proton wave function has a particularly high average amount of orbital angular momentum.

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