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LETTER TO THE EDITOR

Low-lying positive-parity states of ^{151}Eu

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Abstract. The low-lying positive-parity states of ^{151}Eu are calculated by coupling single proton–hole motion to the quadrupole vibrations of the ^{152}Gd core. The energy levels and the B(E2) values are reproduced reasonably well; but the calculated and experimental spin assignments to some of the levels are in serious disagreement.

The stable europium isotopes ^{151}Eu and ^{153}Eu have received considerable attention from experimental workers for a long time. Although these two isotopes differ by only two neutrons, their nuclear properties differ greatly (Zavadil and Graetzer 1970, Thun and Miller 1972). The nucleus ^{153}Eu has a large static quadrupole moment and a ground state rotational band (Seaman *et al* 1967) characteristic of nuclei with spheroidal equilibrium shapes, whereas the ^{151}Eu nucleus shows a much more complicated level structure (Thun and Miller 1972). The level structure of ^{151}Eu has been studied recently from the decay of ^{151}Gd, using high-resolution Ge(Li) spectroscopy (Ford *et al* 1970) and by Coulomb excitation experiments (Zavadil and Graetzer 1970, Lewis and Graetzer 1971, Thun and Miller 1972). The energy levels revealed by the Coulomb excitation experiments below 600 keV are shown in figure 1 and the B(E2) ↑ values obtained for the different levels are given in table 1. Despite the considerable amount of experimental information, the spins and parities of most of the excited states of ^{151}Eu were not known prior to the work of Thun and Miller (1972). Thun and Miller (1972) have assigned spins and parities to some of the levels from the angular

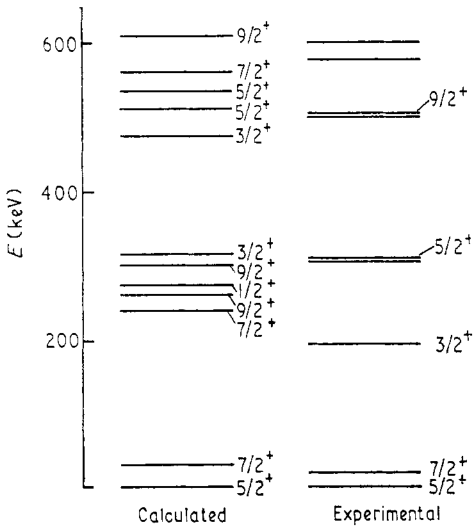

Figure 1. Calculated and experimental energy levels of ^{151}Eu.

Table 1. The calculated and experimental $B(\mathrm{E2})\uparrow$ values in ^{151}Eu

Calculated			Experimental				
Level (keV)	J^π	$B(\mathrm{E2})\uparrow$ (e^2b^2)	Level (keV)	J^π	$B(\mathrm{E2})\uparrow$ (e^2b^2) Thun and Miller (1972)	Lewis and Graetzer (1971)	Zavadil and Graetzer (1970)
30	7/2$^+$	0·043					
239	7/2$^+$	0·392					
263	9/2$^+$	0·070	196·45	3/2$^+$	0·090		
275	1/2$^+$	0·079	307·0		0·070		
302	9/2$^+$	0·301	307·45	5/2$^+$	0·470	0·540	0·540
317	3/2$^+$	0·017	499·6		0·020	0·030	
475	3/2$^+$	0·031	503·5	9/2$^+$	0·098	0·110	0·280
512	5/2$^+$	0·003	578·0			0·008	0·005
534	5/2$^+$	0·037	600·6			0·015	0·033
562	7/2$^+$	0·003					
608	9/2$^+$	0·0001					

distribution measurements in their Coulomb excitation work. Zavadil and Graetzer (1970) have tentatively suggested that the strongly excited levels in ^{151}Eu result from 2^+ phonon excitation of the even-mass core coupled to the single-proton or proton–hole, ground state. Thun and Miller (1972) have observed that the sum of the B(E2) of the five levels at 196·45, 307·0, 307·45, 499·6 and 503·5 keV agrees well with the B(E2) of the ^{150}Sm core. Apart from these tentative suggestions, no detailed theoretical calculations of the level properties of ^{151}Eu have so far been reported. In the present work, the properties of the low-lying positive-parity states of ^{151}Eu have been calculated by coupling single proton–hole motion in the $2d_{5/2}$ and $1g_{7/2}$ orbitals to the quadrupole vibrations of the ^{152}Gd core. Core states up to three quadrupole phonon excitations have been considered. As the technique of this core–particle coupling calculation is well known and the mathematical formalisms used in the present work have already been discussed in detail in earlier publications (Sen and Sinha 1970, Sen 1972), we shall discuss only the results of the calculation. The proton–hole picture has been preferred to the particle picture because of the positive sign of the ground state and first excited state quadrupole moments of ^{151}Eu (Cohen 1969). There are two parameters in this calculation: namely, the single-hole energy difference between the $1g_{7/2}$ and $2d_{5/2}$ orbitals ($\epsilon_{7/2}$) and the hole–core interaction strength X_2 (Sen and Sinha 1970, Sen 1972). The energy levels calculated with the parameter values $\epsilon_{7/2} = 0{\cdot}05$ MeV and $X_2 = 0{\cdot}30$ MeV are shown in figure 1. The quadrupole phonon energy $\hbar\omega_2$ is taken from the experimental excitation energy of the first 2^+ state of ^{152}Gd. In calculating the B(E2) values, there are two parameters, namely, e_{eff} and $eZ(\hbar\omega_2/2C_2)^{1/2}$, whose values are to be fixed. It has been found that the ground state and first excited state quadrupole moments can be fitted with $e_{\mathrm{eff}} = 2e_{\mathrm{p}}$ and $eZ(\hbar\omega_2/2C_2)^{1/2} = 7\,e_{\mathrm{p}}$. The value of $eZ(\hbar\omega_2/2C_2)^{1/2} = 7\,e_{\mathrm{p}}$ is consistent with the C_2 value deduced from the experimental excitation energy and the B(E2) value for the first 2^+ state of ^{152}Gd (Wong 1968). The $B(\mathrm{E2})\uparrow$ values calculated for the different levels with these parameter values are listed in table 1.

On the basis of the excitation energies and the B(E2) values, an attempt can be made to identify the calculated energy levels with the experimental ones. The calculated 275 keV $1/2^+$ level may be identified with the 196·45 keV level in the experimental spectrum. Thun and Miller (1972) have assigned spin and parity $3/2^+$ to this level. However, Zavadil and Graetzer (1970) have not excluded the possibility of $1/2^+$ assignment to the 196·45 keV level. Though the calculated excitation energy is somewhat higher, preliminary calculations, including the $2d_{3/2}$ and $3s_{1/2}$ orbitals have shown that even if we take somewhat higher values for the single-particle energies of these two orbitals, the calculated $1/2^+$ and $3/2^+$ levels are depressed considerably. The calculated 263 keV $9/2^+$ state may be identified with the 307 keV level in the experimental spectrum on the basis of the B(E2) values. The calculated levels at 239 and 302 keV have very large $B(E2)\uparrow$ values and the 307·5 keV level, most strongly excited in Coulomb excitation work, may correspond to any one of them. But in that case, it is very difficult to explain how the other level with large B(E2) value can be missed in Coulomb excitation work. The other possibility may be that these two levels could not be resolved in experimental investigations. However, it should be mentioned that Thun and Miller (1972) have assigned spin and parity $5/2^+$ to the 307·5 keV level. Earlier workers (Zavadil and Graetzer 1970) have excluded $J = 9/2$ for this level whereas both the calculated levels have high spin values (7/2 and 9/2). On the basis of the B(E2) values, the levels at 475, 534 and 562 keV may be associated with the three levels at 499, 503 and 578 keV in the experimental spectrum. Thun and Miller (1972) have assigned $J = 9/2$ for the 503 keV level whereas the calculated $9/2^+$ level in this region has a very small B(E2) value. In summary, it may be said that this simple calculation can reproduce energy levels and B(E2) values but the calculated and experimental spin assignments for some of the levels are in serious disagreement. If the spin assignments by Thun and Miller (1972) are taken to be conclusive then it appears that this model cannot explain the level structure of ^{151}Eu. However, in view of the complexity of the experimental spectrum, the results of this simple calculation may be of some interest to the experimental workers.

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