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EVIDENCE FOR ROTATIONAL-LIKE STRUCTURE IN $^{117}_{51}Sb$

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In the last years some cases of rotational-like structure in nuclei near closed shells attracted interest because such phenomena seem to be a puzzle in mass regions, where nuclei are assumed to be spherical. For instance in ^{115}In and ^{117}In, having one proton less than the magic number, some excited states have been interpreted as members of rotational bands[1-3]. The results of newer investigations, however, make these interpretations doubtful[4,5].

Already in 1969 a highly excited isomeric state in ^{117}Sb with a half-life of 340 μs has been observed[6]. The experiments were performed with a pulsed α-beam of 27 MeV at the 120 cm cyclotron. After determination of the γ-energies and γ-intensities in the prompt and delayed spectra the decay scheme was constructed and proved by the results of coincidence measurements.

In order to give spin and parity assignments for the levels populated in the isomeric decay, the investigations were continued by the following methods: (i) γ-ray angular distribution measurements, (ii) conversion electron measurements by means of a transport-solenoid Si(Li) spectrometer[7] up to 1.3 MeV and (iii) excitation studies of the levels in ^{117}Sb in different reactions using protons, deuterons and α-particles as projectiles and by variation of the α-particle energy. The information gathered by these methods gives rise to an exact determination of spins and parities, shown in the level scheme of fig. 1. Details about the experimental methods and results will be published in ref.[8].

The decay of the isomeric state can be interpreted as following two branches. In comparison to the states on the left-hand side of fig. I the levels with $J^{\pi} = 9/2^+$, $II/2^+$, $I3/2^+$, $I5/2^+$ and $I7/2^+$ are much more populated in direct feeding than in the isomeric decay. The regular spin sequence together with the behaviour of the level spacings and the existence of crossover transitions lead to the assumption of a rotational -like structure in this branch as already mentioned by Peker and Volmyansky /9/. This conception has been tested by the measured cascade/crossover intensity ratios R_J for the three subsequent levels given in table I. From the experimental values one can calculate $\left|(g_K-g_R)/Q_o\right|$. In our case these values are nearly constant, supporting the assumption of a similar intrinsic structure of the levels considered.

From the R_J values one can compute the mixing ratios δ^2 of the cascade transitions. The measured angular distribution anisotropy coefficients A_2 for the mixed MI/E2 cascade transitions are reproduced within the limits of error only for positive sign of δ (see table I). Using the convension signδ = sign $(g_K-g_R)/Q_o$ one gets a quadrupole moment Q_o= +3.44 b and the related deformation ε = +0.22. The g_K value was taken from the $9/2^+[404]$ band expected in the Nilsson diagram /IO/ for Z = 5I and prolate deformation and g_R was assumed as usually to be Z/A. A unified model calculation reproduces the R_J values under the assumption of the $9/2^+[404]$ band in an excellent manner. So the properties of this band are well explained in the framework of the Nilsson model.

The level distances show the behaviour of a quasirotational band (see for comparison ^{43}Sc /II/) and cannot be explained by the I(I+I) formula. On the other hand, calculations

with projected angular momentum wave functions, using a parametrization of the spectrum /I2/, reproduce the level energies within a mean deviation of less than IO keV. It should be mentioned, however, that the larger distance between the $II/2^+$ and the $9/2^+$ states (374 keV) in comparison to the spacings of the following levels (336, 367 and 387 keV) should be explained by the influence of the 9/2 state at I3IO keV, lowering the bandhead energy.

A further argument for the different level structures in the two branches are the high hindrance factors ($\sim IO^5$) of the two EI transitions (250.4 and I63.I keV) feeding levels of the rotational band in the isomeric decay.

For the validity of the assumptions the equilibrium deformation in ^{II7}Sb is of interest. Summing the Nilsson single particle energies and the Coulomb energy one gets the $5/2^+[4I3]$ state (which may stay for the ground state) at slight oblate and $9/2^+[404]$ state at prolate deformation with the deformation value of ε = +0.23 and the excitation energy of $(E_{9/2} - E_{5/2})$ = I.2 MeV, as shown in fig. 2a. For such a simple approach this is a surprisingly good accordance to the experimental findings. In fig. 2b the results are compared with more detailed computations, in which the shell correction method of Strutinsky /I3/ is used. A short description and an application of this method can be found in ref. /I4/. The calculations deliver the energy minima for the $5/2^+$ and $7/2^+$ states at slight oblate deformation, while the $I/2^+$ and $3/2^+$ states (not populated in the isomeric decay) are obtained at slight prolate deformation. The $9/2^+$ state reproduces the experimental findings very well.

In this picture the II/2⁻ state has even larger oblate deformation. Therefore it is questionable to assume that the levels populated in the main decay branch are typical spherical states. The broad valley for the minimum energy, shown in fig. 2b, accounts for the softness of the ^{117}Sb nucleus against deformation. If this would be a general property in this mass region, rotational-like phenomena should be expected also in neighbouring nuclei.

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Table I

Analysis of the cascade/crossover intensity ratios R_J

J^{π}	R_J experimental	R_J reproduction for $9/2^+[404]$ (Q_o=3.44 b)	$\left\lvert\frac{g_K-g_R}{Q_o}\right\rvert$	$\frac{I}{\delta^2}$	A_2 experimental	A_2 reproduction for positive δ
$13/2^+$	5.03(58)	5.00	.276	31.5	.061(12)	.047
$15/2^+$	4.01(47)	4.25	.267	33.5	.078(20)	.058
$17/2^+$	2.99(22)	2.86	.282	43.1	.031(21)	.015

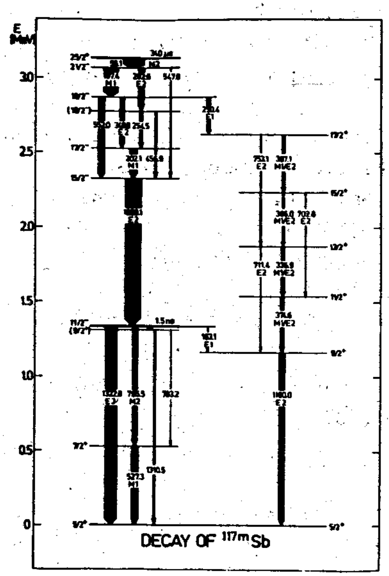

Fig. I. Decay of ^{117m}Sb drawn in a way to show the two different deexcitation branches.

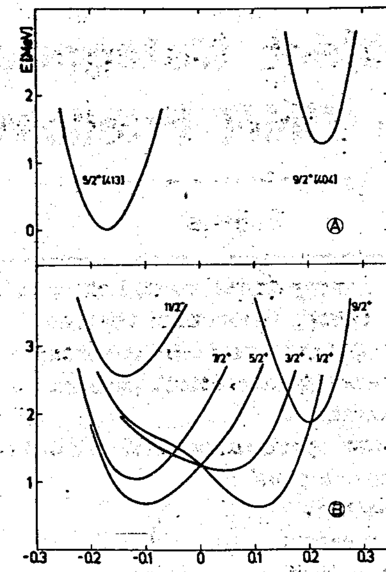

Fig. 2. Equilibrium deformation energies in ^{117}Sb

A) Summation of the Nilsson single particle energies.

B) Calculations using the shell correction method.

The energies in A) are given as differences to the $5/2^+$ state, in B) the numbers stand for the total deformation energy.