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ENERGY LEVELS AND STRUCTURE OF LIGHT RARE-EARTH NUCLEI, $^{136,138,140}Sm$ and $^{132,134,136}Nd$, via BETA DECAY

B.D. Kern
University of Kentucky, Lexington, KY 40506
G.A. Leander, R.L. Mlekodaj, and H.K. Carter
UNISOR, Oak Ridge Associated Universities, Oak Ridge, TN 37831
M.O. Kortelahti and E.F. Zganjar
Lousiana State University, Baton Rouge, LA 70803
R.A. Braga , R.W. Fink, and C.P. Perez
School of Chemistry, Georgia Institute of Technology
Atlanta, GA 30332
P.B. Semmes+ and W. Nazarewicz‡
Joint Institute for Heavy-Ion Research,
Oak Ridge National Laboratory, Oak Ridge, TN 37831.

ABSTRACT

Levels in $^{136,138,140}Sm$ were populated by the beta decay of Eu, following (HI,pxn) reactions and on-line mass separation. Members of the γ band were observed in all three daughter nuclei. Spectroscopic calculations were made using the triaxial rotor model, with all parameters derived microsopically from a Woods-Saxon deformed shell model. Comparison with the data supports the characterization of these nuclei in terms of a triaxial intrinsic shape. Improved decay schemes for $^{132,134,136}Nd$ are given.

INTRODUCTION

A transition from spherical to deformed shape in increasingly neutron-deficient Sm and Nd isotopes with $N<82$ has long been predicted on the basis of elementary shell structure considerations and was borne out by recent systematic measurements of yrast level energies in these nuclei. The detailed nature of this shape transition is of special interest for the study of nuclear structure in view of the unusual nature of the analogous shape transition in the Sm isotopes at $N>82$. Deformed shell model calculations agree with the observation that experimentally available nuclear species with $50<N<82$ are softer with respect to triaxial gamma-deformation than their $N>82$ counterparts.

The tandem accelerator at the Holifield Heavy Ion Research Facility provided beams that were used to produce radioactive ions through the $^{92}Mo(^{46,48}Ti, ypxn)$ and $^{112}Sn(^{28}Si, ypxn)$ reactions at energies from 170 to 250 MeV. The radioactive ions were introduced into a high-temperature ion source and passed through the UNISOR mass separator. Also, in order to enhance the yields, He-jet measurements were carried out without mass separation. In both experimental

+On leave from TN Technological University, Cookeville, TN 38505.
‡On leave from Technical University, Pl-00-662, Warsaw, Poland.

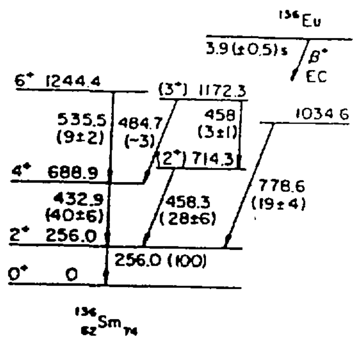

Fig. 1. Partial level diagram of ^{136}Sm.

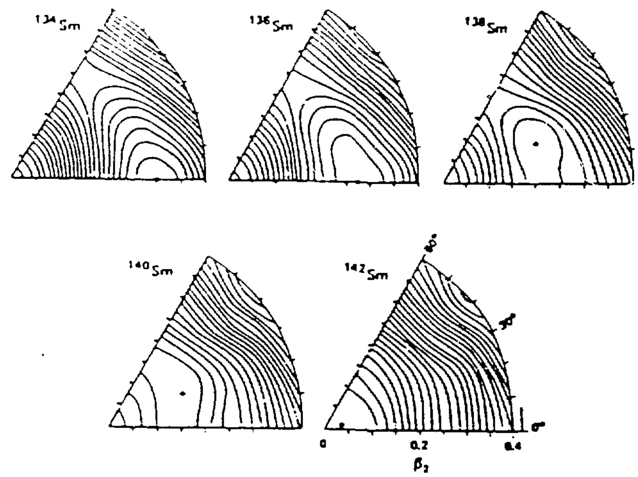

Fig. 2. Potential-energy surfaces in the β,γ quadrupole deformation plane.

arrangements, radioactive ions were transported on a continuous plastic tape from a collection point to a counting location which was situated between two Ge detectors. The counting time intervals were equal to the collection time intervals; these time intervals were varied from 5 s to 75 s.

In this work, level schemes for the N = 74-78 isotopes of Sm were established by observing γ rays following the β decay of $^{136,138,140}Eu$, and for the N = 72-76 isotopes of Nd, following the β decay of $^{132,134,136}Pm$. Gamma bands were observed in each nucleus. The level diagram of ^{136}Sm is shown in Fig. 1.

The potential energy of the β_2, γ and β_4 deformation was calculated using the triaxially deformed "Warsaw" Woods-Saxon potential[1]. The potential-energy surfaces shown in Fig. 2 were calculated with a square lattice of 0.05 and at steps of 0.04 in β_4. The contour line separation is 250 keV. Spectroscopic properties were calculated at the interpolated minima in β_2, γ, and β_4. Quadrupole transition moments, B(E2: $2^+ \rightarrow 0^+$) reduced transition rates, rotational moments of inertia with respect to the three principal axes, and the energy levels of $^{138,140}Sm$ were calculated. Details of these calculations will be available in a future publication[2].

RESULTS

The prediction of triaxiality in this region was made by several workers[2]. Here, in Fig. 2, the transition from a well-deformed prolate shape in ^{134}Sm to near-spherical shape in ^{142}Sm is seen to proceed <u>via</u> triaxial shapes in $^{138,140}Sm$.

The triaxial rotor Hamiltonian, without adjustment of parameters, reproduces the energies of levels of $^{138,140}Sm$ rather well (Fig. 3).

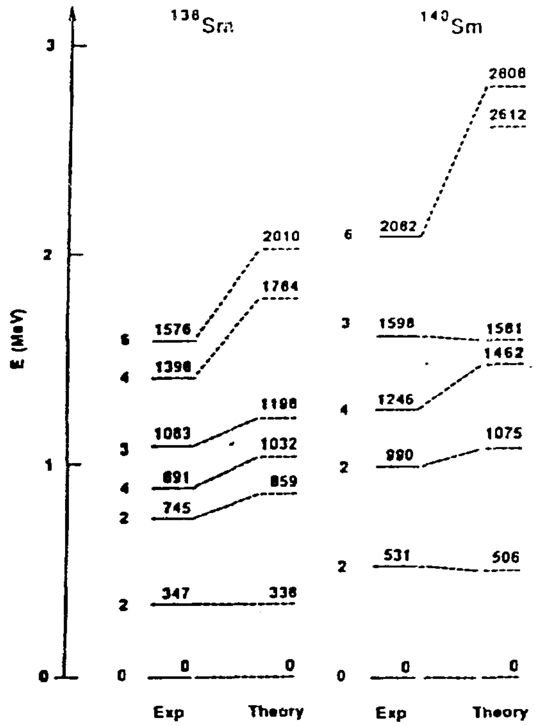

Fig. 3. Comparison between the experimental and calculated levels of the triaxial nuclei.

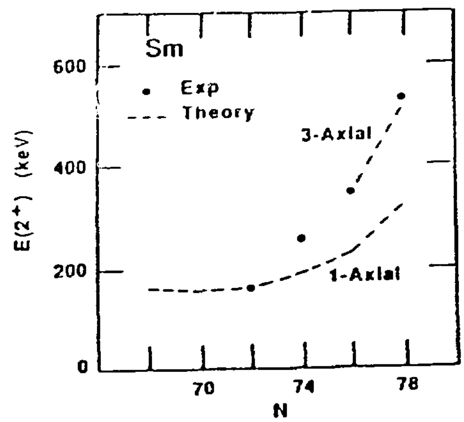

Fig. 4. Comparison between the experimental and calculated energies of the first 2^+ levels. The "1-axial" energies are those of a semiclassical rotor.

The experimental energies of the lowest 2^+ states are compared in Fig. 4 with the "1-axial" values which are for the shape which comes from a semiclassical treatment of the rotation, and with the "3-axial" values which were obtained from quantal triaxial rotation. The triaxial theory fits the ^{138,140}Sm energies and the axial symmetry theory fits the ^{134}Sm energy; the ^{136}Sm energy falls in between. The energies of the 2_2^+ and 3_1^+ members of the γ band are reasonable. The states of spin 4 and higher are systematically lower in experiment than in theory due to the variable moment of inertia effect.

Finally, it is noted that the large change in the energy of the 2_1^+ levels between ^{134}Sm (163 keV) and ^{140}Sm (531 keV) can be understood since the triaxial rotation tends to increase the 2_1^+ level energy of ^{140}Sm.

^{132,134,136}Nd

Recently acquired data has enabled improved decay schemes of ^{132,134,136}Nd[3] (Fig. 5-7). Not shown, but available elsewhere[2], are the β_2, γ and β_4 calculated values for the Nd isotopes. They show that at ^{132}Nd there is a trend toward a stiffly prolate shape; experimentally this is indicated by the increase in energy of the 2_γ^+ level as it moves above that of the 4_1^+ level.

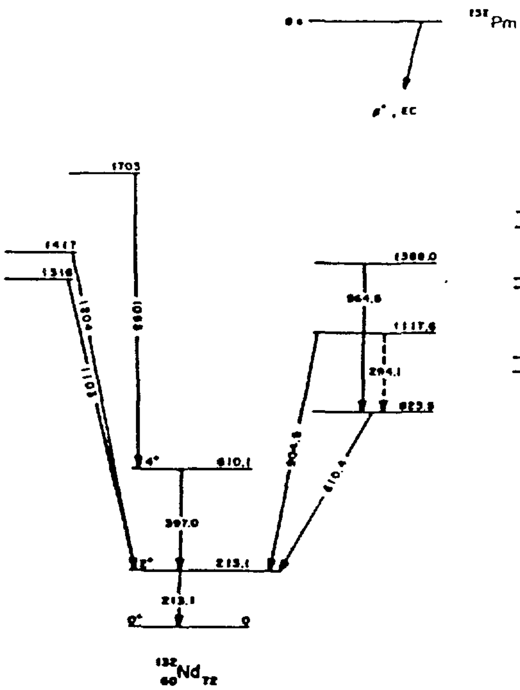

Fig. 5. Partial decay scheme of ^{132}Nd. The level at 823.5 keV is assumed to be the 2^+ of the γ band.

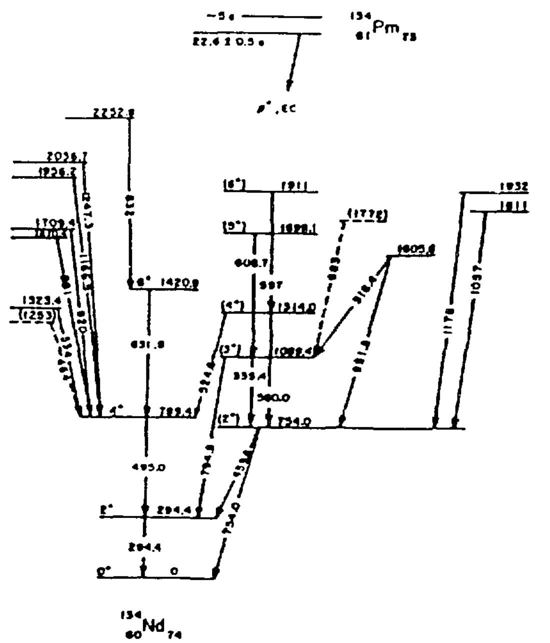

Fig. 6. Partial decay scheme of ^{134}Nd.

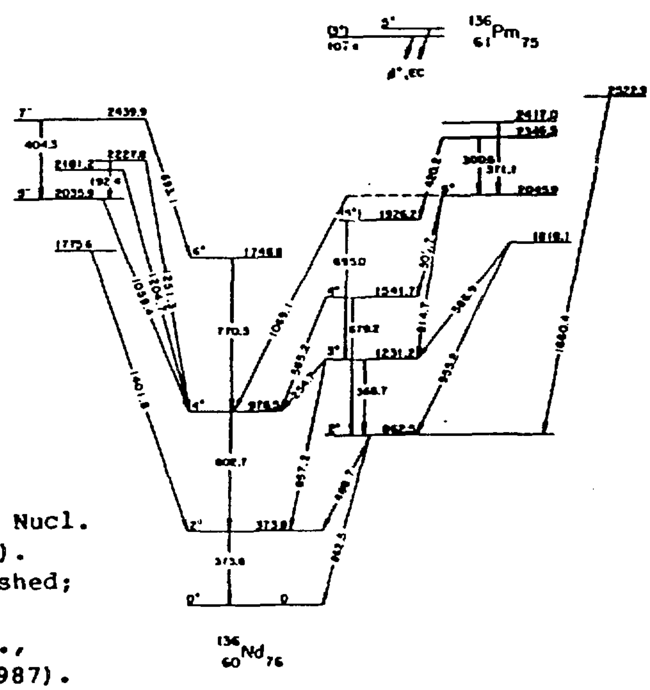

Fig. 7. Partial decay scheme of ^{136}Nd.

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