Université Scientifique et Médicale de Grenoble

INSTITUT DES SCIENCES NUCLEAIRES
DE GRENOBLE

53, avenue des Martyrs - BP 257 ● 38044 Grenoble Cedex
Tél. 87 71 41

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EXCITATION OF HIGH SPIN LEVELS IN ^{129}Ba

J. GIZON and A. GIZON

Presented at the XXVI Conference on Nuclear Spectroscopy and Structure of the Atomic Nucleus, Baku, USSR, 3-6 February 1976

Laboratoire associé à l'Institut National de Physique Nucléaire
et de Physique des Particules

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The level structure of ^{129}Ba has been studied by the ^{120}Sn(^{12}C,3nγ) reaction. A set of negative-parity levels based upon a $9/2^-$ state is interpreted in terms of the rotation-alignment coupling of $h_{11/2}$ neutron holes to the triaxial core. A new band structure built upon a $7/2^+$ state is also observed. It could be due to the coupling of a $g_{7/2}$ neutron hole to the triaxial core.

A new kind of level structure was discovered by studies of La nuclei produced by (H.I.,xnγ) reactions[1] and was explained by the rotation-alignment model proposed by Stephens and Simon[2] . This model also describes the structure of odd-neutron deficient nuclei in the A ≈ 135 region and it was suggested[3] that quantitative deviations from the experimental results could be eliminated by considering asymmetric shape effects such as γ-distortion or softness. The influence of γ deformations has been extensively analyzed by Meyer-ter-Vehn who developed a very successfull model[4] for nuclei in the transitional regions.

To extend the systematics towards more neutron deficient nuclei, we present in this letter our results on the N = 73 barium isotope.

Very few data on ^{129}Ba were available[5] before our experiments although recently[6] some excited levels were identified in the ^{130}Ba(d,t)^{129}Ba reaction. In the triton spectra two strong peaks are associated by their angular distribution with $\ell = 0$ and $\ell = 5$ angular momentum transfers corresponding to the $1/2^+$ ground state and the $11/2^-$ excited levels at 277 keV respectively.

In order to further identify the ^{129}Ba properties we employed the techniques of classical in-beam nuclear spectroscopy. A target made of 3 mg/cm^2 ^{120}Sn on 1 mil lead was bombarded with the ^{12}C external beam of the Grenoble variable-energy cyclotron. The excitation functions of the γ-rays were measured at 45, 47, 49, 51 and 54 MeV. The maximum yield for the ^{120}Sn(^{12}C,3nγ)^{129}Ba reaction was found to occur at 51 MeV. The angular distributions of the γ-rays were obtained from measurements of in-beam spectra taken at -20°, 0°, 20°, 40°, 55°, 70° and 90° relative to the incident beam. The single spectra were recorded both during and between the beam bursts using a 2.5 cm^3 planar detector with a resolution of 1.0 keV FWHM at 100 keV and a 55 cm^3 coaxial detector. The prompt and delayed γ-γ coincidence events from two coaxial detectors of 77 and 55 cm^3 were recorded simultaneously. Half-lives of levels were deduced from the γ-RF coincidences.

It is known[3,7] that the odd-neutron nuclei in the $A \sim 130$ transitional region have an odd-parity band level structure. This is the case for Ba, Ce and Nd nuclei with 77 neutrons, all of which have a band built on an $I^\pi = 11/2^-$ isomeric state. In the $N = 75$ isotones, the "band head" is an $I^\pi = 9/2^-$ state. All these levels are generated from neutron hole-configurations in the $h_{11/2}$ shell and their energies and transitions probabilities are well reproduced by considering the coupling between neutron holes and a triaxial core[4].

In ^{129}Ba, such a band structure also exists. The positions of the levels relative to the $9/2^-$ and $11/2^-$ states are comparable to those in ^{131}Ba and ^{133}Ba. The level spacings decrease slightly when going down to $N = 73$ indicating a larger deformation for ^{129}Ba, in agreement with the trend observed in the even-even cores. Moreover, the intensities of the transitions and the branching ratios are similar to each other in all these three Ba nuclei.

Since the spin and the parity of the isomeric states have been unambiguously determined in ^{131}Ba and ^{133}Ba, we can assign $I^\pi = 9/2^-$ and $11/2^-$ to the first two members of the odd-parity band in ^{129}Ba.

All the transitions shown in the level scheme of figure 1 are seen in the γ-γ coincidences spectra. The assignments of levels are deduced from the multipolarities of the transitions.

A calculation of the energies and transition probabilities has been made with the computer code of Meyer-ter-Vehn for a static, triaxial rotor plus particle model. The energies are well fitted with a deformation parameter $\beta = .23$ and an asymmetry $\gamma = 20°$. The experimental and theoretical transition probabilities are also in good agreement.

Using the approximate classification of Meyer-ter-Vehn[4], it is possible to distinguish between two sets of odd-parity levels. The first one is built on the $\overline{\Omega} = 11/2$ state. It contains the yrast cascade, made of very strong E2 transitions, and two other parallel cascades ending at the $(13/2^-)_1$ and $(15/2^-)_2$ levels. The yrast levels have a dominant $\Omega = 11/2$ component and can be considered as $(\overline{K},\vec{\Omega})$ band-heads on which a $\Delta I = 1$ spin sequence is built. In the second set based on the $\overline{\Omega} = 9/2$ state, appear the $\overline{K} = 9/2^-$ and $13/2^-$ states. Because of a smaller feeding, only a few levels are observed there.

A new set of strongly populated levels is observed in addition to the odd-parity band. It consists essentially of two cascades of stretched E2 transitions which feed levels connected by weak $\Delta I = 1$ transitions. The level spacings of the cascades are similar to those of yrast cascade ending at the $11/2^-$ state. We have not observed a transition depopulating to lowest level and there is only one connection between this band structure and the negative parity system.

This new level structure can be identified considering the strong 173.5 keV γ-ray which desexcites the $9/2^-$ state. The Legendre polynomial coefficients of this γ-ray are $A_2 = -0.212 \pm 0.035$ and $A_4 = 0.027 \pm 0.037$ which are characteristic of a pure L = 1 transition. Thus the state fed by this transition has a spin I = 7/2 or 11/2. Since in the N = 73 region, the only 11/2 negative parity state is the one generated from the $h_{11/2}$ shell, the only odd-parity reasonable remaining level could be the 7/2 level from this $h_{11/2}$ shell. If so, the 173.5 keV γ-ray would be fast. This γ-ray appears in the out-of-beam spectra and a lifetime $T_{1/2} \approx 18$ ns has been measured for the $9/2^-$ state. Such a large value is impossible between two states from the same $h_{11/2}$ shell. Therefore the assignment of an E1 multipolarity to the 173 keV γ-ray remains as the only possibility which yields an hindrance factor $F \approx 3.5\ 10^5$ and justifies assigning $7/2^+$ to this state.

Our results appear to contradict the $^{130}Ba(d,t)^{129}Ba$ pickup results where Griffioen and Sheline[6] found a strongly excited $11/2^-$ level but never observed a peak corresponding to a $7/2^+$ hole state. The $11/2^-$ level of the $h_{11/2}$ band-structure that we observe can unambiguously be assigned as the $11/2^-$ ($\ell = 5$) level at 277.1 keV [ref. [6]]. Then, choosing this energy value as a reference, the $7/2^+$ state of our level scheme is only 7 keV above the $1/2^+$ ground state, i.e. the $\ell = 4$ triton peak might be hidden by the stronger, unresolved $\ell = 0$ ground state peak. This is not in contradiction with an energy resolution greater than 15 keV. Moreover, standard DWBA calculations of the differential cross-sections σ_j for the $\ell = 0$ and $\ell = 4$ angular momentum transfers show that the $\sigma_{\ell=0,j=1/2}(\theta)$ cross-sections are always 3 or 4 times greater than $\sigma_{\ell=4,j=7/2}(\theta)$ in the angular region measured by Griffioen and Sheline. Thus we believe that the (d,t) experiment could not observe the $7/2^+$ state at 7 keV which we identify by in-beam spectroscopy.

Up to now, there is no obvious interpretation for the even-parity structure. A possibility is given by the coupling of a $g_{7/2}$ neutron-hole to the triaxial core. Indeed, the first calculations performed indicate that the energies of the levels are in very good agreement with the one calculated using a triaxial core (β = .27 and γ = 21°) coupled to a $g_{7/2}$ neutron hole.

These band-structures observed in this triaxial nucleus ^{129}Ba are also well developped in ^{125}Ba, ^{127}Ba, ^{129}Ce and ^{131}Ce [8].

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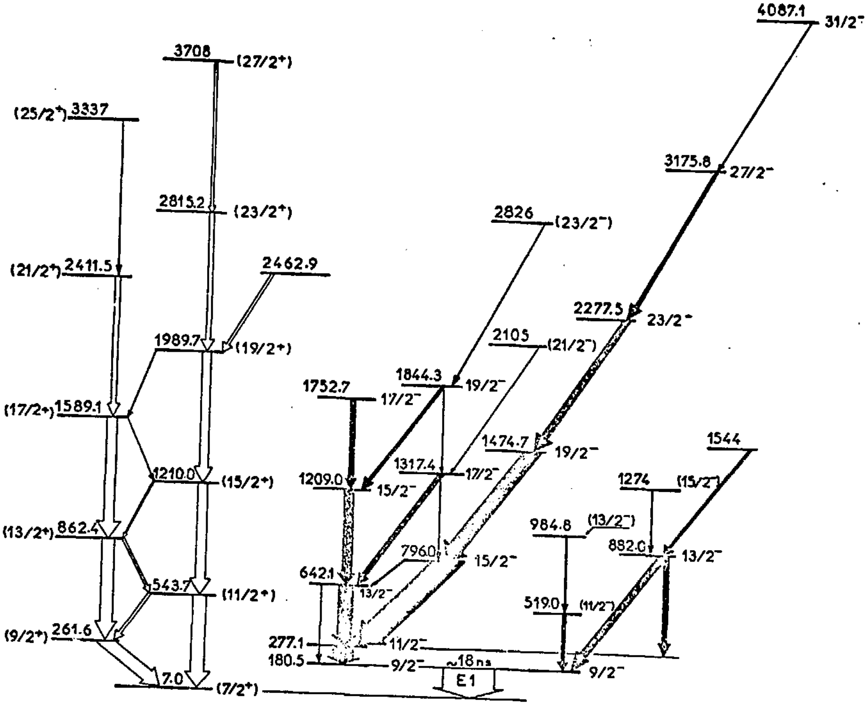
FIGURE CAPTION

Fig. 1 High spin levels in ^{129}Ba populated through the ^{120}Sn(^{12}C,3n) reaction. The black arrows indicate the odd-parity system. The $1/2^{+}$ ground state has not been drawn on this level scheme.


3708
(27/2+)
(25/2+) 3337
2815.2
(23/2+)
(21/2+) 2411.5
2462.9
1989.7
(19/2+)
(17/2+) 1589.1
1210.0
(15/2+)
(13/2+) 862.4
543.7
(11/2+)
(9/2+) 261.6
7.0
(7/2+)
4087.1
31/2−
3175.8
27/2−
2826
(23/2−)
2277.5
23/2−
2105
(21/2−)
1844.3
19/2−
1752.7
17/2−
1474.7
19/2−
1317.4
17/2−
1209.0
15/2−
796.0
15/2−
642.1
13/2−
277.1
11/2−
180.5
9/2−
~18ns
E1
1544
1274
(15/2−)
984.8
(13/2−)
882.0
13/2−
519.0
(11/2−)
9/2−