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Observation of a Decoupled Band in ^{123}Cs

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The methods of in-beam γ-ray spectroscopy have been used to study ^{123}Cs produced by the ^{115}In(^{12}C, 4n) reaction. Five coincident stretched $E2$ transitions, previously assigned in the literature to ^{123}Ba, have been identified as members of a decoupled band in ^{123}Cs.

1. Introduction

In 1972, it was first observed [1] experimentally that certain odd-A isotopes of lanthanum exhibited a band structure quite similar to the structure of the ground-state bands (g.s.b.) in the adjacent even-even barium nuclei. These "decoupled" bands have been explained [1] within the framework of the "rotation-aligned" coupling scheme. In this particle+core model, the Coriolis force can decouple the valence particle and align its angular momentum j in the direction of the rotation axis of the core. When the particle and core angular momenta are nearly aligned, the Coriolis force is small and there is no longer any appreciable coupling between the particle and the rotation of the core. The resulting band has a spin sequence $j, j+2, j+4, \ldots$ with energy spacings which approximate those in the g.s.b. of the even-even core. Observation of a decoupled band is most likely in a nucleus with moderate deformation ($0.10<|\beta|<0.25$) [2] and when the valence particle is in a relatively pure angular momentum state of high j and unique parity. These conditions maximize the decoupling effect of the Coriolis force. In addition, if the particle is to attain maximum alignment along the rotation axis of the core, the Fermi surface must lie near the Nilsson levels of low Ω. In the region between tin and lead, this condition is fulfilled for protons in $h_{11/2}$ orbitals at the beginning of the shell for prolate deformations and at the end of the shell for oblate deformations.

Since the discovery of decoupled bands in lanthanum, decoupled bands have also been observed in rare-earth nuclei (Dy [3], Er [3, 4], Yb [5]) and in the transitional region (Hg [6], Au [7, 8], Ir [9]). From the accumulated evidence, it is now apparent that core rotational motion in odd-A nuclei is much more common than previously thought.

2. Experimental Procedure and Results

In the present work, the odd-A nuclide $^{123}_{55}$Cs$_{68}$ has been produced by the ^{115}In(^{12}C, 4n) reaction and studied using the methods of in-beam γ-ray spectroscopy. Self-supporting targets (≈ 15 mg/cm^2) of natural indium (95.7% ^{115}In) were bombarded with 72 MeV ^{12}C ions from the University of Michigan cyclotron. Singles and coincidence spectra were recorded event by event on magnetic tape using two coaxial Ge(Li) detectors (≈ 6% efficiency) positioned at 90° with respect to the beam. Angular distributions of the decay γ-rays were measured in the horizontal plane with one detector fixed at 90°, while the other detector was positioned between 90° and 163.5° with respect to the beam direction.

In the spectra, a band of five coincident γ-rays was observed. In Figure 1 is shown a summed coincidence spectrum in which the coincident γ-spectra resulting from gates placed on all five transitions have been added together.

We assign these transitions to an 11/2$^-$ decoupled band ($\Delta I=2$) in ^{123}Cs on the basis of the following arguments:

i) At 72 MeV bombarding energy, the five-member band was produced with strong yield. In addition, γ-

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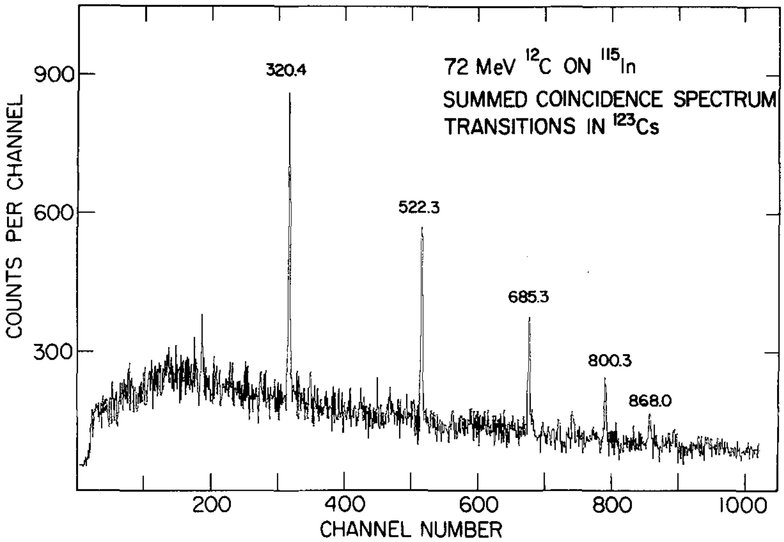

Fig. 1. A summed coincidence spectrum in which the coincident γ-spectra resulting from gates placed on all five transitions have been added together

Table 1. Energies and angular distribution coefficients of γ-rays from the ^{115}In(^{12}C, $4n$)^{123}Cs reaction at 72 MeV

Transition	E_γ (keV)[a]	A_2/A_0	A_4/A_0
$15/2^- \rightarrow 11/2^-$	320.4	0.504 ± 0.099	-0.223 ± 0.124
$19/2^- \rightarrow 15/2^-$	522.3	0.380 ± 0.032	-0.102 ± 0.039
$23/2^- \rightarrow 19/2^-$	685.3	0.459 ± 0.051	-0.098 ± 0.063
$27/2^- \rightarrow 23/2^-$	800.3	0.402 ± 0.070	0.217 ± 0.085
$31/2^- \rightarrow 27/2^-$	868.0	0.297 ± 0.154	0.209 ± 0.184

[a] Energies are accurate to ± 0.4 keV

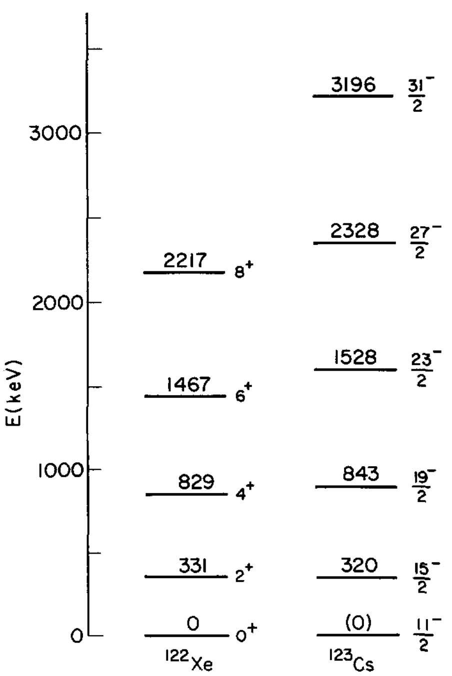

Fig. 2. Comparison of the decoupled band in ^{123}Cs with the ground-state band in the even-even core ^{122}Xe. Note that the lowest member of the decoupled band ($11/2^-$) is not the ground state in ^{123}Cs

rays previously identified [11] in the decay of ^{124}Ba as belonging to ^{124}Cs were observed. When the ^{12}C bombarding energy was decreased to 60 MeV, the band was seen only weakly while the γ-transitions in ^{124}Cs produced by the (^{12}C, $3n$) reaction were more intense.

Using the semiempirical rule by Alexander and Simonoff [12] and the study of systematics in the $100 \leqq A \leqq 150$ mass region by Neubert [13], one estimates that the maximum in the ^{115}In(^{12}C, $4n$)^{123}Cs reaction is attained at a bombarding energy of ≈ 70 MeV. From these facts, we conclude the band occurs in ^{123}Cs.

ii) Angular distributions of the five γ-rays were determined from measurements at angles of 90°, 115°, 131.5° and 163.5° with respect to the beam direction. The angular-distribution function $W(\theta) = A_0 + A_2 P_2(\cos\theta) + A_4 P_4(\cos\theta)$ was fitted to the experimental data points. The coefficients obtained from the analysis are characteristic of a stretched cascade of $E2$ transitions depopulating a strongly aligned high-spin initial state, i.e. the ratios A_2/A_0 are large and positive while the A_4/A_0 ratios are smaller. Table 1 lists the angular distribution coefficients and γ-ray energies.

iii) As can be seen in Figure 2, the energies of the five transitions in the decoupled band are reasonably close to the energy spacings in the g.s.b. of the even-even core ^{122}Xe. The agreement between corresponding energies is not as good, however, as in the lanthanum isotopes [1].

iv) Points ii) and iii) above are suggestive of a decoupled band. In ^{123}Cs, with five protons outside the $Z = 50$ closed shell, for a prolate shape the Fermi surface lies near the unique parity $h_{11/2}$ Nilsson levels of low Ω. Thus the bandhead would be expected to have spin-parity $11/2^-$. While no level with this spin-parity has definitely been identified in ^{123}Cs, the existence of an isomeric state with a half-life of 1.6 s and unknown spin has been established in decay studies using heavy-ion reactions [14]. Also, in-beam γ-ray studies of ^{125}Cs [15] have revealed a cascade of five $\Delta I = 2$ quadrupole transitions with an $11/2^-$ bandhead at 441 keV. In ^{127}Cs, similar measurements [16] have established that a four member $\Delta I = 2$ quadrupole cascade feeds an $11/2^-$ isomeric level at 451 keV. In both ^{125}Cs and ^{127}Cs, the cascade transition energies are similar to the energy spacings in the g.s.b. of the even-even Xe core. Both the systematics of isomeric levels found in this region and the fact that ^{123}Cs, ^{125}Cs and ^{127}Cs are expected to exhibit many similarities in their level structure (as do, for example, the odd isotopes of lanthanum) strongly suggest that the isomer in ^{123}Cs also has spin-parity $11/2^-$. Thus it is a strong candidate for the lowest member of the band which we observe.

3. Discussion

We conclude from the foregoing arguments that the five stretched $E2$ transitions that we have observed belong to a decoupled band in the nuclide ^{123}Cs and that the lowest transition probably feeds an $11/2^-$ isomer.

Conrad and Repnow [17], based on reactions resulting from ^{110}Cd + ^{16}O, have assigned an essentially identical band to ^{123}Ba. Their assignment to ^{123}Ba (rather than ^{123}Cs) was based in part on the absence of these γ-rays in spectra resulting from ^{127}I + 104 MeV α-particles [18]; these conditions were expected to correspond to ^{127}I(α, $8n$)^{123}Cs. However the present In + C reaction cannot produce isotopes of barium and has been shown [19] to produce 5.8-min ^{123}Cs in good yield under these conditions. Therefore we conclude that the previous observations [17] should be interpreted as resulting from the ^{110}Cd(^{16}O, $p2n$)^{123}Cs reaction rather than from ^{110}Cd(^{16}O, $3n$)^{123}Ba.

It should be noted that if this change in interpretation is correct, the relative cross sections reported in Reference 17 require extensive modification.

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