EVIDENCE FOR TRIAXIAL SHAPES IN Pt NUCLEI[☆]

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Received 4 December 1975

Positive parity levels in ^{191}Pt obtained from (α, x$n\gamma$) reactions and β-decay are presented as a first example of a rather complete $i_{13/2}$ level family. The spectrum confirms triaxial shapes found before from $h_{11/2}$ and $h_{9/2}$ proton structures in this mass region. In addition to the usual decoupled yrast band, a second $\Delta I = 2$ band within the $i_{13/2}$ family, built on a low-lying $j-1 = 11/2$ state, is observed in agreement with theory.

From a theoretical standpoint, there are significant advantages in studying the motion of a high-j particle (e.g. $i_{13/2}$ or $h_{11/2}$) around a deformed core. First, these high j-orbitals have unique parity and hence the high-j system may be treated to a good approximation by considering only a single j-shell. Furthermore, positive (negative) parity states in odd nuclei in the mass region $A = 150-200$ may be immediately associated with a predomiantn $\nu i_{13/2}$ ($\pi h_{11/2}$ or $\pi h_{9/2}$) component. Second, the large Coriolis force acting on the high-j particle tends to align its spin along the rotation vector giving rise to characteristic decoupled level structures [1]. The degree to which the particle couples to or decouples from the intrinsic axes of the core strongly depends on the shape of the core, not only on its deformation β but also in a rather sensitive way on the γ-parameter which distinguishes between prolate ($\gamma = 0°$), oblate ($\gamma = 60°$), and various asymmetric, triaxial ($0° < \gamma < 60°$) shapes [2,3]. This leads to striking variations of the odd-A spectrum as a function of γ. As one of the characteristic features, second and third states of the same spin are considerably lowered in energy for triaxial shapes, parallel to the 2_2^+, 3_1^+, 4_2^+ ... states of the even core. This is important for odd-A Pt nuclei.

A number of these features have previously been noted [2,3] in the $h_{11/2}$ and $h_{9/2}$ proton structures of some odd-A Ir, Au, and Tl nuclei. It thus appears that the shape change from the axially symmetric deformed rare-earths to the spherical Pb nuclei proceeds through a triaxial region. The levels of the doubly even Pt nuclei which lie in this transitional region do indeed suggest triaxial shapes, with the 2_2^+ levels lying below the 4_1^+ levels.

In light of the above discussion, we have examined the positive parity structures of a series of odd-A Pt nuclei to obtain information on their shapes. The pertinent experimental information comes from an extensive (α, x$n\gamma$) investigation of a series of odd- and even-Pt isotopes ($A = 184-194$) which we have recently completed. Prompt and delayed γ-ray singles, prompt and delayed γ-γ coincidence, excitation function and angular distribution measurements were performed, using 26–50 MeV α-particle beams from the Michigan State University cyclotron. The main systematic fea-

☆ Supported in part by U.S. Energy Research and Development Agency and U.S. National Science Foundation.
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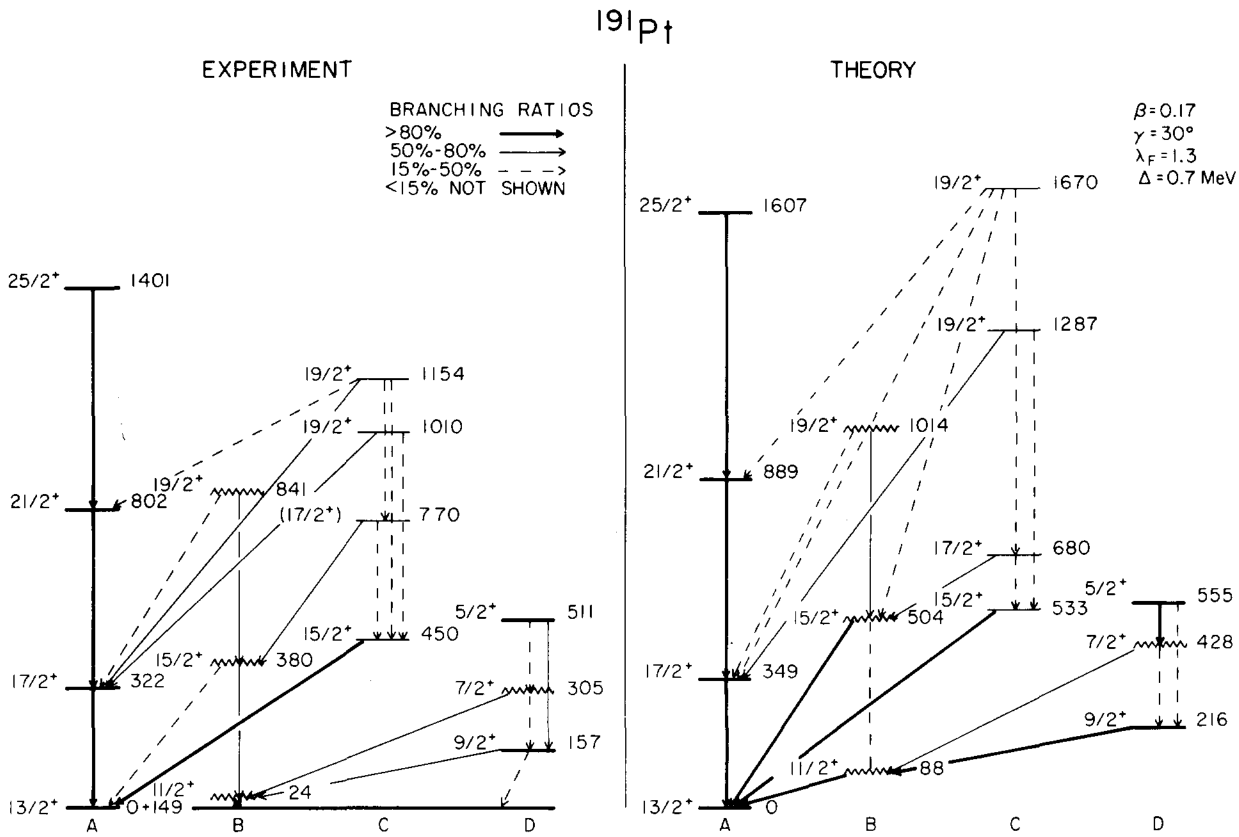

Fig. 1. Comparison of experimental and theoretical energies and branching ratios of positive parity levels in ^{191}Pt. Here zero energy is defined by the 13/2$^+$ level (E_X = 149.0 keV). The 29/2$^+$ and (33/2$^+$) members of the decoupled band located at 2084 and 2791 keV are not shown. Parameters, β, γ, λ_F and Δ, used in the calculation are defined in ref. [3]. Theoretical transition intensities were determined using calculated B(M1) and B(E2) values, but experimental energies. Members of the favoured band are denoted by thick lines and those of the unfavoured band by wavy lines.

tures have already been reported [4], with particular emphasis on backbending aspects of the even-A spectra.

In general, all the odd Pt nuclei we have studied have similar positive parity structures, a distinctive feature being the occurrence of decoupled $i_{13/2}$ bands with spacings very similar to those of the even-even neighbours. Many other positive parity levels are also observed, especially in ^{191}Pt, which we have also studied in the radioactive decay of ^{191}Au. In fact, the combined ^{191}Pt results provide the most complete set of data for an $i_{13/2}$ family and therefore a new, important test of the model of a high-j hole or particle coupled to a triaxial core. It should be noted that the Fermi surface lies well within the $i_{13/2}$ shell in Pt nuclei, a situation not hitherto encountered in tests of this model.

A partial level scheme for ^{191}Pt containing only the positive parity levels is shown on the left of fig. 1. Levels in columns A, B, and C were observed in the (α, x$n\gamma$) experiments; the levels in column D plust the 13/2$^+$ and 11/2$^+$ levels of columns A and B were populated in the decay of ^{191}Au. The right side of fig. 1 shows levels expected from coupling an $i_{13/2}$ hole to a triaxial core calculated as described in rev. [3]. The parameters β and γ were determined from the neighbouring even cores. The Fermi level was located between the fifth and sixth members of the $i_{13/2}$ multiplet (ν = 5 and ν = 6 levels, in the notation of ref. [3]) by examining the single-particle levels at γ = 30° of Larsson [5]; The Coriolis matrix elements were attenuated by using the modified pairing factor, $(u_1u_2 +$

$\nu_1\nu_2)^5$, following the ad hoc prescription of Stephens and Simon [6]. This had the effect of reducing the matrix elements connecting states across the Fermi surface, a procedure previously found necessary for fitting $i_{13/2}$ bands in the rare-earth region.

The arrangement of levels in fig. 1 has been guided by the main decay lines of the experimental spectrum and the calculated results. Although the wave functions of the particle-triaxial-core model consist of a highly complicated mixture of different Nilsson bands and corresponding odd-A γ-bands, there are some approximate features which may give an intuitive picture. (1) Column A represents the decoupled yrast band corresponding to a maximum alignment of the j = 13/2 spin with the core angular momentum R; the 9/2 and 5/2 states in column D can be interpreted as anti-aligned states of the same band. (2) Similarly, column B and the anti-aligned 7/2 state of column D constitute a second (unfavoured) decoupled band. It corresponds to incomplete alignment with a j-projection of approximately 11/2 on R. In the $h_{11/2}$ and $h_{9/2}$ level families observed in neighbouring Ir and Au nuclei, these unfavoured levels appear much higher in energy. They are lowered in ^{191}Pt due to incomplete filling of the j = 13/2 shell by core particles and the resultant effect of the Pauli principle. This second decoupled band within the same j-shell famili is found here for the first time. Similar bands have been observed in neighbouring odd-A Pt isotopes and should also occur in Hg isotopes and in other mass regions. (3) The levels in column C reflect the additional rotational degrees of freedom due to triaxiality; levels with the same spin lie at much higher excitation (1.7–4.7 MeV) in calculations with axially symmetric shapes. There are additional levels in the theoretical spectrum below the 21/2 state which are not shown in fig. 1: two 9/2 states at 367 and 624 keV, two 11/2 states at 574 and 747 keV, and three 13/2 states at 334, 730, and 875 keV. However, these are not expected to be populated with observable strengths in the experiments performed.

Fig. 1 shows clearly that the calculated excitation energies and branching ratios reproduce very well the general trend of the data. The signs of the calcuated E2/M1 mixing ratios also agree with experiment, where measurable. Considering that the parameters entering the calculation were obtained from ‘external’ data and not otherwise adjusted to produce detailed fits here, the agreement between theory and experiment is excellent.

However, there is a general compression of the experimental levels with respect to the calculated ones, a feature common to other cases previously studied in ref. [3]. The larger theoretical $\Delta I = 2$ energies may be decreased by taking into account the known softness of the core, for instance by a VMI prescription [7]. Probably a more serious deficiency is connected with the problem of Coriolis attenuation. The chosen ad hoc prescription succeeds in lowering the unfavoured and anti-aligned states to give better agreement‡ with experiment, but it is clearly unsatisfying from a theoretical standpoint. It also is probably responsible for the incorrect branching ratio of the first 15/2 state; this ratio depends on the mixing and separation of the two close-lying $15/2^+$ levels, which in turn depend sensitively on the size of the Coriolis matrix elements. It should be stressed, however, that Coriolis attenuation serves mainly to give better agreement in the energies but is not necessary to reproduce the general pattern of the data.

The good general agreement between experiment and theory provides persuasive argument for the proposed model of an $i_{13/2}$ hole coupled to a triaxial core. Assumption of either an oblate or prolate symmetric core yields results which are completely unsatisfactory. The other odd-A Pt nuclei we have studied have structures similar to that of ^{191}Pt (although not so many levels have been observed). A strong case can, therefore, be made for triaxial shapes in the Pt isotopes with A around 190. It remains to be seen whether an alternative model [8] based on coupling the $i_{13/2}$ hole with vibrational modes can provide comparably good agreement with the extensive experimental data.

‡ This lowering can be readily understood since reducing the Coriolis interaction favours strong coupling rather than decoupling.

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