STUDY OF SHAPE COEXISTENCE IN THE VERY NEUTRON DEFICIENT NUCLEUS ^{176}Hg* **

K. Helariutta, M. Muikku, J.F.C. Cocks, P. Jones, R. Julin, S. Juutinen, H. Kankaanpää, H. Kettunen, P. Kuusiniemi, M. Leino, P. Rahkila, A. Savelius, W.H. Trzaska, J. Uusitalo

University of Jyväskylä, Department of Physics
P.O. Box 35, 40351 Jyväskylä, Finland

P.T. Greenlees and R.D. Page

Oliver Lodge Laboratory, Department of Physics, University of Liverpool
Liverpool, L69 7ZE, UK

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In-beam γ-ray and γ–γ coincidence measurements have been made for the very neutron deficient nucleus ^{176}Hg using the recoil-decay tagging (RDT) technique. The irregular yrast sequence observed to $I = 10\hbar$ indicates that the prolate intruder band, seen in heavier Hg isotopes near the neutron midshell, is crossing the nearly spherical ground-state band of ^{176}Hg above $I = 6\hbar$.

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1. Introduction

Recently, lots of experimental activity has been concentrated on the area of neutron-deficient nuclei with proton number around the closed proton shell of $Z = 82$. In that area a diversity of different coexisting nuclear shapes has been observed — on the contrary what has been expected from the nuclei near a closed shell.

Neutron deficient mercury nuclei ($Z = 80$, N <126) have been studied extensively. With neutron number $110 < N < 124$, the ground state bands

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of mercury isotopes are weakly oblate and their properties stay rather constant. At $N = 108$ the oblate band is crossed by an intruding deformed band associated with a prolate-deformed energy minimum [1–3]. The prolate states minimise their energies at $N = 102$ [4] but they still lie above the ground state [5] which is predicted to evolve from the oblate shape towards a spherical shape [3, 4, 6].

In this work [7] a mercury isotope lying on the neutron-deficient side of the neutron midshell ($N = 104$), ^{176}Hg has been studied. Earlier, yrast levels up to $I^\pi = 12^+$ in ^{178}Hg have been identified by Carpenter *et al.* [6]. In accordance with the theoretical predictions [3] an increase in the energy of the prolate band was seen. In the same experiment three γ transitions were unambiguously assigned to ^{176}Hg and they were tentatively associated with an E2 cascade between the lowest 6^+–4^+–2^+–0^+ states of that nucleus. In our experiment we intended to improve the in-beam γ-spectroscopic data to confirm the tentative assignments of Ref. [6] and to extend the level scheme to higher spin and energy.

2. Experimental technique

Excited states of ^{176}Hg were populated using the reaction ^{36}Ar (190MeV) $+^{144}$Sm (500μg/cm^2, 92.4% enrichment) $\rightarrow$ ^{176}Hg$+4n$. The beam was delivered by the Jyväskylä K130 cyclotron. As this nucleus lies close to the proton drip line the production cross section was very low (few μb). At the same time the cross section of other reaction channels, especially nuclear fission is very high. To resolve the wanted γ rays from the vast background a combination of a germanium array Jurosphere and a recoil separator RITU with the method of recoil-decay tagging [8, 9] was utilised.

Jurosphere array consisted of 12 TESSA-type [10] and 13 Eurogam Phase I [11] Compton suppressed germanium detectors, placed around the target position at angles of 78°, 101°, 134° and 158° with respect to the beam direction. The total photopeak efficiency for 1.3 MeV γ rays was about 1.5%. The fusion-evaporation residues were separated using the gas-filled recoil separator RITU [12] which has a high transmission (about 30% in this case). The separated recoils and their alpha decays were detected using a position sensitive silicon strip detector placed on the focal plane of the separator. ^{176}Hg nuclei were identified by using the known information on their alpha energy and half life [13] and by correlating the α decay with the respective implantation of a recoil and γ rays.

3. Results

In an approximately 240 hours of effective beam time a total alpha spectrum of figure 1 was obtained. The alpha spectrum is strongly dominated by ^{176}Pt which was produced via $2p2n$-evaporation. A total of about 90000 ^{176}Hg alphas were detected and a half-life of 21 $\pm$ 3 ms for the ^{176}Hg α decay was extracted, being consistent with the earlier measured value of 18 ± 10ms [13].

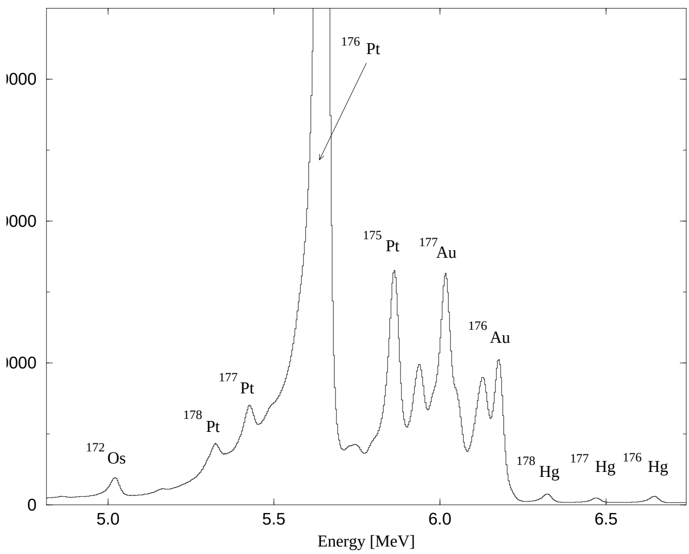

Fig. 1. The total alpha spectrum in the Si detector.

A singles γ-ray spectrum gated with all the recoils detected on the RITU focal plane is shown in figure 2 a). In this spectrum the strongest lines can be identified with the ground-state band of the dominant fusion-evaporation product ^{176}Pt. When the recoil-α correlation technique is utilised for the identification of ^{176}Hg recoils and the respective γ rays, the spectrum shown in figure 2 b) is obtained. Comparison between figures 2 a) and 2 b) shows the power of the method: from a vast background one is able to resolve the γ spectrum of the wanted nucleus with almost no background. An α-tagged recoil-gated γ-γ matrix was constructed for building up the level scheme which is shown in figure 3. The level scheme shows a ground state band of five gamma rays (613.3, 756.4, 551.0, 453.2, 500.5 keV) plus a side band branching from the 6^+ state (529.9, 400.9 keV). The spin assignments are based on the angular distributions of the γ rays.

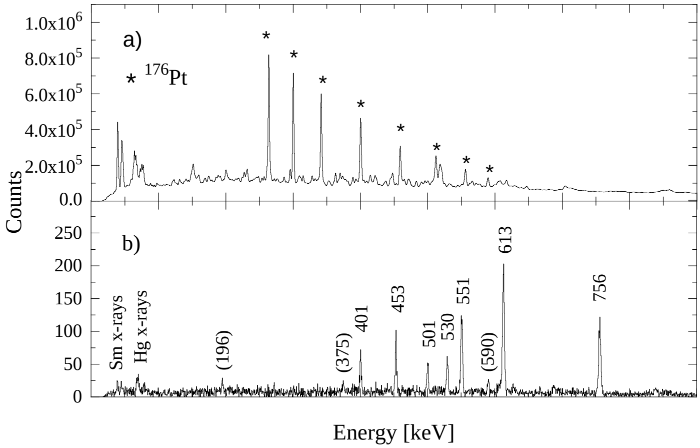

Fig. 2. a) γ rays in coincidence with the fusion-evaporation residues implanted on the strip detector; b) ^{176}Hg α-tagged *gamma* rays.

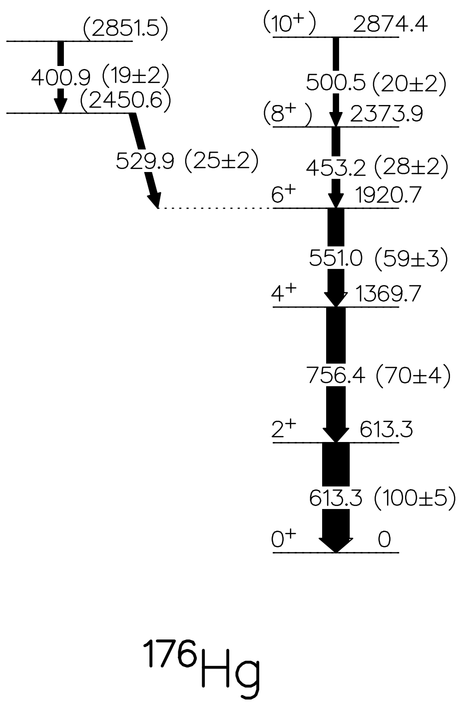

Fig. 3. The level scheme of ^{176}Hg.

4. Discussion

Our results confirm the earlier tentative level scheme [6] of ^{176}Hg up to 6^+. Spanning of the level energy systematics of even-mass Hg isotopes down to ^{176}Hg, shows that the first excited 2^+ and 4^+ states lie higher than in any other Hg isotope except the closed-shell nucleus ^{206}Hg. This suggests a transition towards a spherical ground state which is in accordance with the theoretical predictions [3].

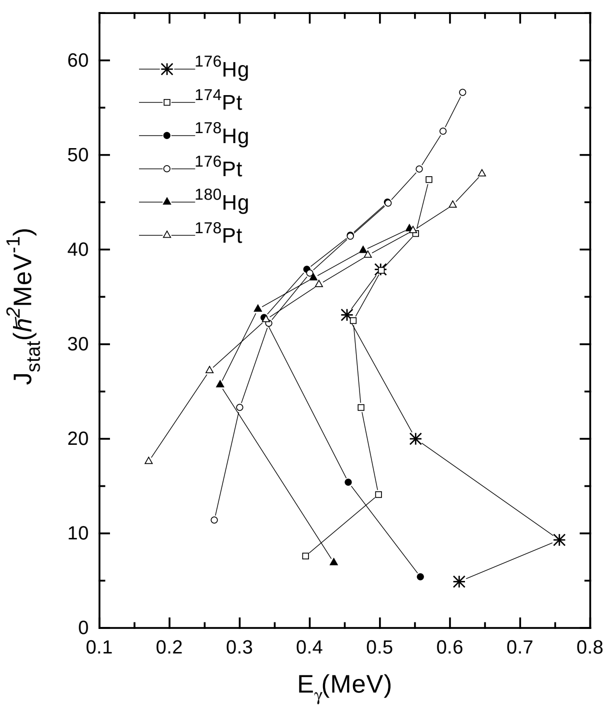

Fig. 4. Static moment of inertia of ^{174,176,178}Pt, ^{176,178,180}Hg plotted as a function of the γ-ray energy.

The similarity between the observed intruder prolate bands in the even-mass Pt, Hg and Pb isotopes close to the neutron midshell is well-known [14]. In figure 4 the static moment of inertia ($J_{\rm stat}$) of Hg and Pt isotones with N=96, 98 and 100 are plotted as a function of the γ-ray energy. In this figure the appearance of the prolate band is seen in slightly increasing and smoothly behaving $J_{\rm stat}$ value. Similarity between the isotones is clear. Thus the behavior of $J_{\rm stat}$ in the high-spin end of the observed yrast band in ^{176}Hg can be regarded as being due to a crossing prolate band, becoming yrast only at the high spins.

The tentatively observed band branching from 6^+ state could be due to the negative-parity states similar to those seen in even-mass Hg isotopes with A $\geq$ 186 [15–17]. Due to the intruding prolate bands these negative-parity states could not be seen close to the neutron midshell as they lie high above the yrast line.

REFERENCES

[1] J.L. Wood *et al.*, *Phys. Rep.* **215**, 101 (1992).
[2] S. Frauendorf *et al.*, *Phys. Lett.* **B55**, 365 (1975).
[3] W. Nazarewicz, *Phys. Lett.* **B305**, 195 (1993).
[4] G.D. Dracoulis *et al.*, *Phys. Lett.* **B208**, 356 (1988).
[5] K.S. Bindra *et al.*, *Phys. Rev.* **C51**, 401 (1995).
[6] M.P. Carpenter *et al.*, *Phys. Rev. Lett.* **78**, 3650 (1997).
[7] M. Muikku *et al.*, to be published.
[8] R.S. Simon *et al.*, *Z. Phys.* **A325**, 197 (1986).
[9] E.S. Paul *et al.*, *Phys. Rev.* **C51**, 78 (1995).
[10] P.J. Nolan *et al.*, *Nucl. Instrum. Methods* **A236**, 95 (1995).
[11] P.J. Nolan, *Nucl. Phys.* **A520**, 657c (1990).
[12] M. Leino *et al.*, *Nucl. Instrum. Methods* **B99**, 653 (1995).
[13] R.D. Page *et al.*, *Phys. Rev.* **C53**, 660 (1996).
[14] G.D. Dracoulis, *Phys. Rev.* **C49**, 3342 (1994).
[15] W.C. Ma *et al.*, *Phys. Rev.* **C47**, R5 (1993).
[16] F. Hannachi *et al.*, *Nucl. Phys.* **A481**, 135 (1988).
[17] H. Hübel *et al.*, *Nucl. Phys.* **A453**, 316 (1986).