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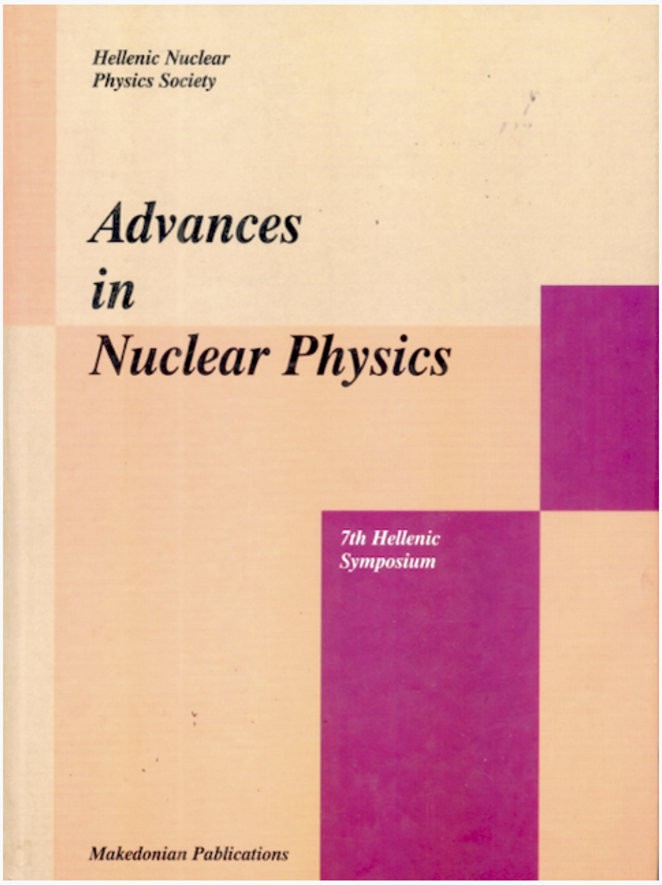

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Nuclear shape coexistence in ^{194}Hg

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Abstract

High spin states in the isotope ^{194}Hg were populated using the ^{150}Nd (^{48}Ca,4n) reaction at a beam energy of 213 MeV. A sequence of dipole transitions has been observed above 8 MeV excitation energy. Cross-over transitions have also been identified. An interpretation connecting this sequence to a nuclear shape change is attempted. A comparison with similar structures in the neighbouring Hg isotopes is also attempted.

1 Introduction

At low excitation energies the deformation of mercury isotopes is oblate. It is a result of a number of neutron excitations out of a collectively rotating core [1]. The level scheme of this region is well established with the presence of several rotational bands [1]. At higher excitation energies proton excitations become possible and departures from the original oblate shape are theoretically expected [2]. Theoretical calculations for ^{194}Hg [3] predict prolate non-collective, triaxial weakly collective and superdeformed shapes. The first evidence of such nuclear changes is this isotope has been reported recently [4].

Here we give experimental evidence in ^{194}Hg for a sequence of dipole transitions located above a previously known region of complicated level pattern [4]. Experimentally deduced B(M1)/B(E2) ratios for the levels of this sequence are compared to theoretical calculations for various possible configurations.

2 Experimental Procedure

We used the reaction ^{150}Nd (^{48}Ca,4n) ^{194}Hg to populate high spin states of ^{194}Hg at beam energy E(^{48}Ca) = 213 MeV. The beam was provided by the 20 MV tandem Van de Graaff accelerator at the Nuclear Structure Facility at Daresbury, U.K.. The ^{150}Nd target was 2 mg/cm^2 thick and evaporated on a 7 mg/cm^2 thick gold foil. Gamma-rays were detected using the EUROGAM detector array which, in our measurement, consisted of 35 Compton suppresed Ge detectors. Approximately 4×10^9 coincident events, of unsuppressed fold five or higher, were collected. Several two-dimensional 4096×4096 channel matrices were built. One of them was symmetrized and used to investigate the coincidence relationships between the γ-rays. A second matrix was built to establish the directional correlations of the γ-rays $I(158° - 90°)/I(90° - 158°)$ (DCO ratio). The rest of matrices were especially built from triples or quadruples to "filter" the regions of the level scheme at high excitations.

3 Results and discussion

The partial level scheme of Fig. 1 shows the sequence of dipole transitions observed above level 7941 keV and extending up to 9933 keV excitation energy. It deexcites through a region of complicated level pattern [4] to the bands AB, ABCD and ABCE [1]. Excitation energies, intensities and DCO values for the transitions of this sequence are given in Table 1. Due to low statistics the DCO value has been found only for the first two transitions of the sequence (345.4 and 377.6 keV transitions). These values are consistent with the dipole character we suggested for the transitions of this sequence. Note that no DCO value was found for the weak cross-over transitions. Due to the low statistics in the region of complicated level pattern no spin assignment has been possible for the levels above level 22^+.

Overviewing the level pattern in Fig. 1 we can clearly identify three different regions: a) a lower region governed by bands of E2 transitions and extending up to roughly 6.0 MeV b) an intermediate region of complicated level pattern extending up to roughly 8.0 MeV and c) an upper region more regular than the intermediate one governed by the sequence of dipole transitions and extending up to roughly 9.5 MeV. The limits of these regions can not be strictly defined since there is a certain overlapping between them.

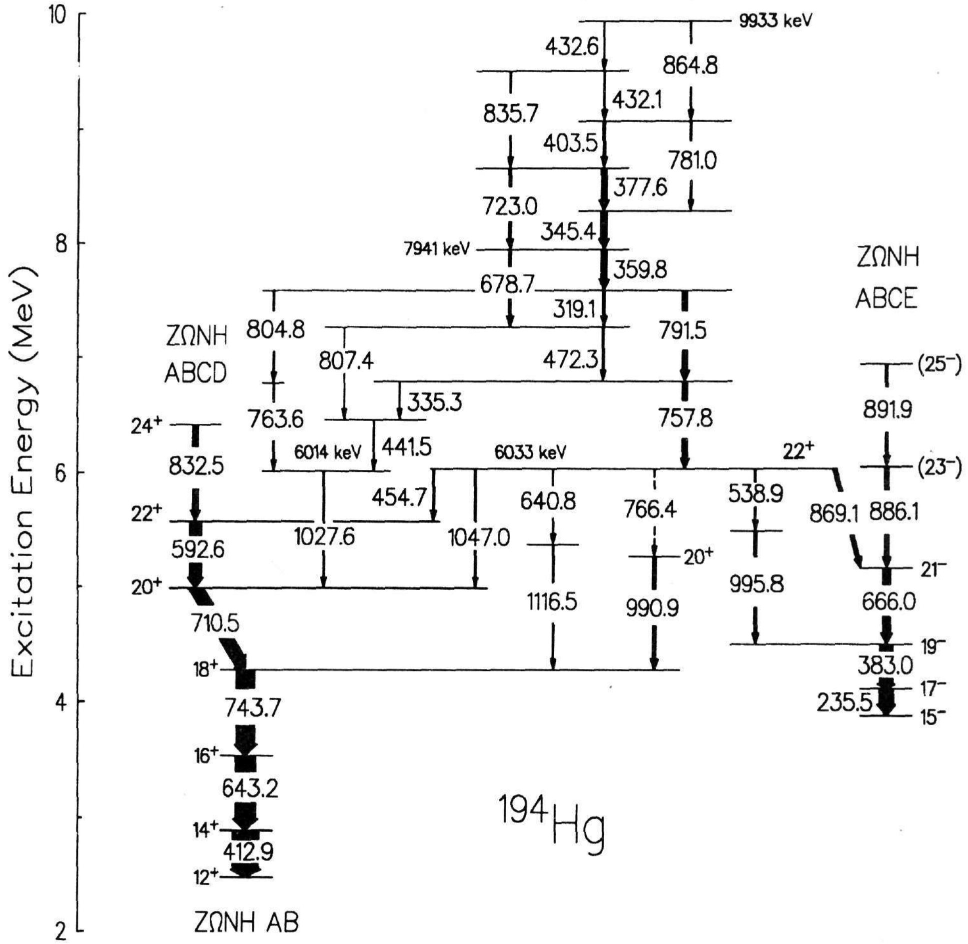

Fig. 1 : Partial level scheme obtained in the present work. The γ-ray transitions are labeled by their energy in units of keV. The width of the arrows represent the intensity of the transitions relative to the 427.9 keV ($2^+ \mapsto 0^+$) transition [1]. The uncertainty on the γ-ray energies varies from 0.2 keV for the strong transitions to 1.0 keV for the weakest ones. Spins and parities in brackets are not firmly established.

Experimental B(M1)/B(E2) ratios for the levels of the new sequence and of the intermediate region (see Fig. 2) are large ($1-5\mu^2/(eb)^2$). Hence, high-K proton configurations, which produce large B(M1)/B(E2) ratios, are invoked for the interpretation in the respective regions. The proton configurations consist of two quasiprotons from the $h_{9/2}$ and $i_{13/2}$ high-Ω orbitals. The high spin of the levels is then reproduced by coupling these configurations to high-J neutron configurations. Theoretical calculations of the B(M1)/B(E2) ratios, based on the model introduced by Dönau and Frauendorf [5], are plotted in Fig. 2. The configurations used in the calculations have been chosen following the suggestions of ref. [6] and [7] for the ^{192}Hg and ^{193}Hg isotopes, respectively. Thus, we used the $\pi(h_{9/2}i_{13/2})_{K=11}$ and $\pi(h_{9/2}^2)_{K=8}$ high-K proton combinations coupled to high-J $(h_{11/2}^{-2})_{J=10}$ proton holes and $i_{13/2}$ neutrons. Combinations of up to four and five $i_{13/2}$ neutrons were used in ^{192}Hg and ^{193}Hg, respectively. We used six neutrons $(i_{13/2}^6)_{J=24}$ in the case of ^{194}Hg. The values for the quadrupole moment and the g-factors used in the calculations were the ones described in ref. [7]. It can be seen from Fig. 2 that the $\pi\ h_{9/2}^2 \otimes \pi\ h_{11/2}^{-2} \otimes \nu\ i_{13/2}^4$ (spin $\sim 31\hbar$ in full alignment) and $\pi\ h_{9/2}^2 \otimes \pi\ h_{11/2}^{-2} \otimes \nu\ i_{13/2}^6$ (spin $\sim 35\hbar$ in full alignment) configurations best reproduce the experimental B(M1)/B(E2) values. Because we expect the spin of the bandhead of the new sequence (7941 keV level) not to exceed the value of $28\hbar$ we consider the first configuration, which gives smaller spin value, to be more probable for the interpretation of the new sequence.

Energy (keV)	Intensity	DCO ratio	Excitation (keV) E_i	E_f
345.4	122(4)	0.53(9)	8287.3	7941.3
377.6	115(3)	0.51(4)	8664.8	8287.2
403.5	45(3)		9068.3	8664.8
432.1	30(5)		9500.4	9068.3
432.6	14(3)		9933.0	9500.4
723.0	49(2)		8664.8	7941.3
781.0	28(1)		9068.3	8287.2
835.7	22(2)		9500.4	8664.8
864.8	26(4)		9933.0	9068.3

Table 1: Energies, intensities, DCO-ratios and excitation energies for the new transitions in ^{194}Hg. The uncertainty on the γ-ray energies and excitations varies from 0.2 keV to 1.0 keV.

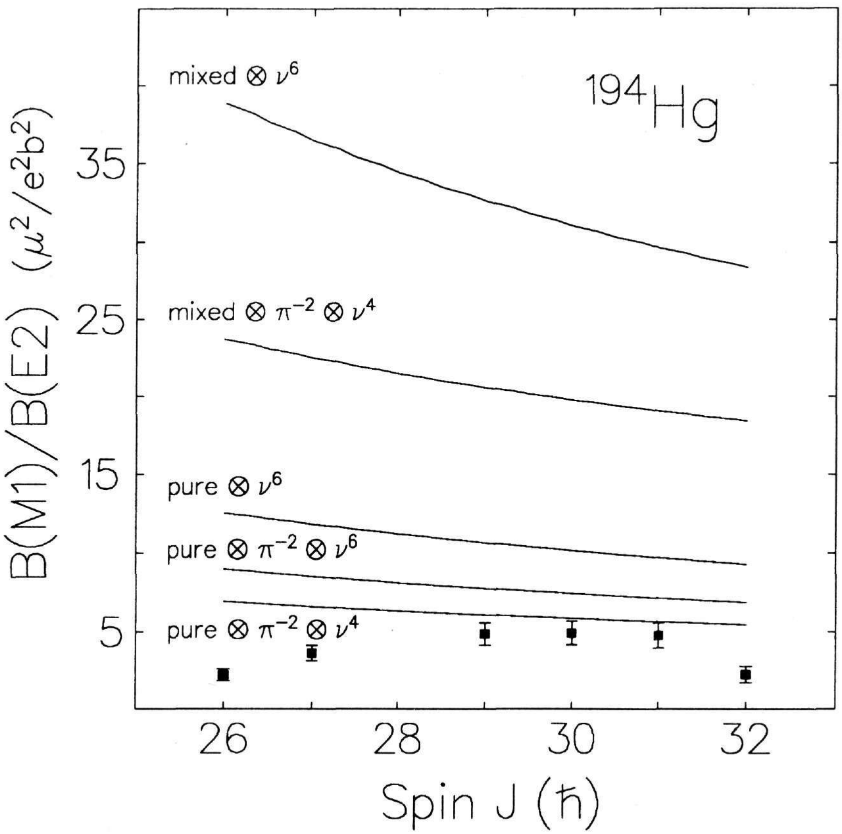

Fig. 2 : Experimental B(M1)/B(E2) values for some of the levels in the intermediate and upper part of the level scheme (filled squares). For the representation of the values versus spin we assumed that the spin of the 7941 keV level is $27\hbar$. Solid lines represent theoretical calculations for various configurations. "Mixed" and "pure" stand for the $\pi(h_{9/2}\ i_{13/2})$ and $\pi(h_{9/2})^2$ proton combinations respectively. π^{-2} stands for $h^{-2}_{11/2}$ proton hole combination and ν^x for $i^x_{13/2}$ neutron combinations.

Complicated level patterns, as the one we observed in the intermediate region, have been already observed in neighbouring Hg isotopes [7,8]. Beside the complexity of the level pattern, other common features are the presence of a level which gathers the decay out of the sequences and then fragments towards several rotational bands of the lower level scheme as well as the unbroadened line shapes in experiments with backed targets suggesting lifetimes expected in non-collective behaviour. The complexity of the intermediate region in ^{194}Hg can be deduced from Fig. 1. The role of the level gathering the bulk of intensity is played by the 22^+ level at 6033 keV excitation energy. The $(\nu i^2_{13/2} \otimes \pi h^{-2}_{11/2})_{J=22}$ and $(\nu i^4_{13/2} p^2_{3/2})_{J=22}$ configurations are possible for the interpretation of this level. Finally, in our spectra no Doppler broadening for the transitions in the intermediate region has been observed. All these facts lead us to suggest that the intermediate region is one of single-particle character.

Theoretical calculations reported in ref. [3] for ^{194}Hg predict a successive shape change of the nucleus from oblate collective (γ=$-65°$) towards prolate non-collective (γ=$-120°$) and triaxial weakly collective (γ=$-80°$) before the prolate (γ=$0°$) superdeformed minimum becomes yrast. The presence of the single-particle region (the intermediate one) in the level scheme of ^{194}Hg is in accordance with these calculations since this region could be associated with a similar shape change. Indeed, TRS calculations performed for the irregular structure in ^{191}Hg [8] support such a shape change. Furthermore, the observation of the dipole sequence is a trace of a subsequent shape change towards triaxality. Note that all the dipole bands observed recently in the neighbouring Hg isotopes (^{192}Hg [6], ^{193}Hg [7] and ^{196}Hg [9]) have been connected to such a shape change. Once more, this is in accordance with the theoretical calculations of ref. [3].

4 Conclusions

In conclusion, a new sequence of dipole transitions, precisely located in excitation energy, has been observed in ^{194}Hg. The overall level pattern allows us to identify three regions. The lower region with the rotational bands, the intermediate region with irregular sequences of γ-rays and finally, the upper region with the sequence of dipole transitions. This splitting of the level scheme in regions is in accordance with the theoretical expectations on the shape changes for this isotope. Comparison of theoretical calculations of the B(M1)/B(E2) ratio to the experimentally deduced values favour the $\pi(h^2_{9/2})_{K=8}$ high-K proton combination coupled to high-J $(h^{-2}_{11/2})_{J=10}$ proton holes and $i_{13/2}$ neutrons for the interpretation of the sequence in the upper region of the level scheme. This configuration is similar to the configurations used in the dipole bands of the neighbouring Hg isotopes.

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