PAIR OF BANDS IN THE OBLATE DOUBLY-ODD ^{198}Tl NUCLEUS*

E.A. Lawrie[a], P. Vymers[a,b], Ch. Vieu[c], J.J. Lawrie[a], C. Schück[c]
R.A. Bark[a], R. Lindsay[b], S.M. Maliage[a,b], S.M. Mullins[a]
S.H.T. Murray[a], T.M. Ramashidzha[a,b], J.F. Sharpey-Schafer[a]

[a]iThemba LABS
PO Box 722, 7129 Somerset West, South Africa
[b]University of the Western Cape
Private Bag X17, 7535 Bellvile, South Africa
[c]Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse
CNRS — IN2P3, F-91405 Orsay, France

(Received November 2, 2006)

The excited states in ^{198}Tl populated in the ^{197}Au(α,3n) reaction at a beam energy of 40 MeV were studied using two complementary experiments aimed at γ-ray spectroscopy at iThemba LABS, and at electron-γ spectroscopy at Orsay, respectively. The level scheme of ^{198}Tl was extended and a weak side band feeding into the yrast $\pi h_{9/2} \otimes i_{13/2}$ band was observed. The properties of these two bands are similar to these of the pairs of bands in the $A = 130$ mass region initially interpreted as chiral doublets.

PACS numbers: 23.20.Lv, 27.80.+w, 29.30.Kv, 29.30.Dn

1. Introduction

The high-spin states in the Tl isotopes correspond to an excitation of the odd proton into the $K = 9/2\, h_{9/2}$ intruder orbital, which induces oblate moderately deformed shape to these otherwise nearly spherical nuclei. Neutron orbitals from low-K $i_{13/2}$, and low-j $p_{3/2}$, $f_{5/2}$ shells lie close to the Fermi surface. Second 2_2^+ states are known in the even–even Hg core nuclei, and calculations with rigid triaxial rotor model indicated considerable non-axiality of $\gamma \sim 35°$ [1]. Furthermore, calculations with triaxial rotor plus particle model assuming $\beta_2 = 0.15$ and $\gamma = 37°$ showed very good agreement with experimental results for the low-spin states in the odd ^{199}Tl nucleus [2]. The yrast band in the odd–odd $^{190-200}$Tl nuclei was associated with a configuration of a high-K proton and a low-K neutron, *i.e.* $\pi h_{9/2} \otimes \nu i_{13/2}$ [3–8].

* Presented at the Zakopane Conference on Nuclear Physics, September 4–10, 2006, Zakopane, Poland.

Considering also that the nuclear shape might be triaxial, these nuclei seem to be good cases for a search for chiral symmetry partner bands.

Transitions with low energies are known to belong to the bottom of the yrast bands in the odd–odd Tl nuclei, but it was noted that some of them could have been missed out due to their large internal conversion coefficients [9]. A transition of 71 keV was referred to as part of the yrast band of ^{198}Tl [9], but the original results have not been published. Furthermore, in these odd–odd Tl nuclei it was never clear how many low-energy transitions belong to the yrast band [9] and thus if a signature splitting or a signature inversion is present. In order to perform a complete spectroscopy study of ^{198}Tl we carried out two complementary experiments, one aimed at electron-γ spectroscopy, and a second one aimed at standard γ-ray spectroscopy.

2. Experiments and data analysis

The same ^{197}Au(α,3n)^{198}Tl reaction at a beam energy of 40 MeV was used in two complementary experiments aimed at studying excited states in ^{198}Tl. The first experiment was performed at Orsay, and its goal was searching for low-energy transitions and measuring internal conversion coefficients through electron-γ spectroscopy. We used the electron spectrometer of Orsay [10], consisting of two magnetic lenses directing the internal conversion electrons towards two Si(Li) detectors. The two lenses were positioned at 90° and at 180° with respect to the beam direction, respectively. Due to problems with the focusing of the beam through the 180° lens, only the spectrometer at 90° was used. The magnetic field swept to focus electrons with different energies to the Si(Li) detectors. Eight large Ge detectors were positioned in the hemisphere opposite to the 90° lens. Seven BaF_2 detectors were also used as a filter. The target was a 0.2 mg/cm^2 thin selfsupporting foil of ^{197}Au. Events were collected when two γ rays or an electron and a γ ray were detected in coincidence with the beam burst and a BaF_2 signal. Data were collected for about 48 hours.

The data analysis involved a search for low-energy transitions in the electron-γ and γ–γ matrices and measurements of the internal conversion coefficients using *(i)* direct electron and γ-spectra, and *(ii)* spectra gated on a γ ray.

The second experiment was performed at iThemba LABS, South Africa. A thick, 13 mg/cm^2, foil of ^{197}Au was used and the γ rays were detected with the AFRODITE array [11,12], consisting of 8 clover and 6 LEPS detectors. The trigger condition required a coincidence of at least two clovers.

The γ coincidences were studied using a γ–γ matrix. The multipolarities of the transitions were assigned based on DCO ratio and linear polarization measurements.

3. Results and discussion

Electron and γ spectra gated on the 391 keV γ ray, de-exciting the 8^- bandhead level of the yrast band are plotted in Fig. 1. The new 72 keV transition was identified through its L, M and N conversion lines and placed at the bottom of the yrast band. Two new bands and several other transitions were also added to the known level scheme of ^{198}Tl. Links between the new bands and the yrast band proved that no other low-energy transitions belong to the yrast band confirming a signature inversion for this band.

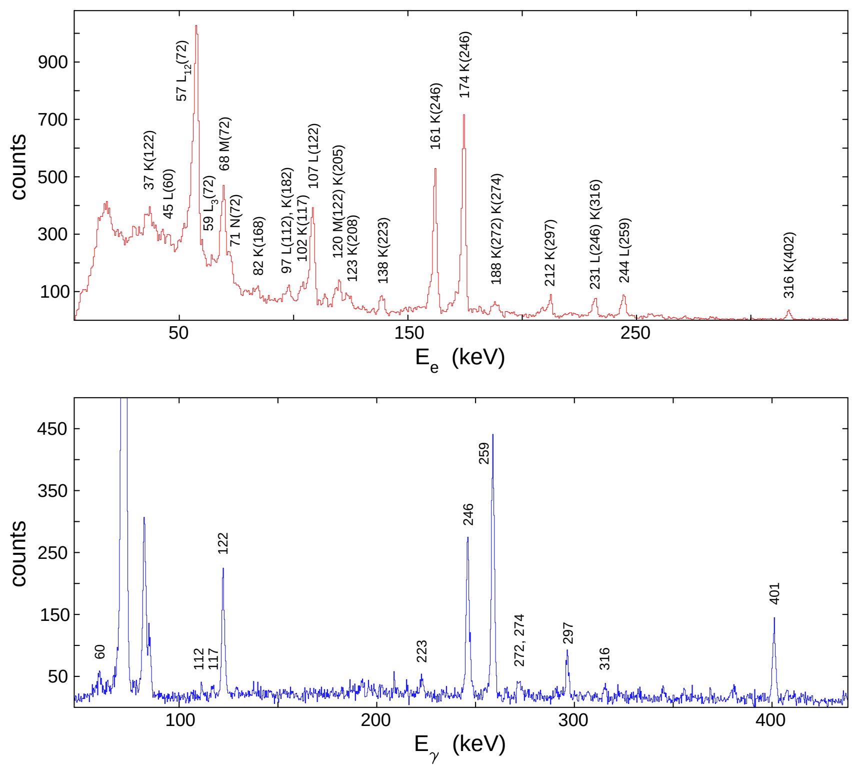

Fig. 1. Electron (top panel) and γ (bottom panel) spectra gated on the 391 keV γ-ray, showing transitions from the yrast band, obtained in the electron-γ experiment.

A partial level scheme showing the extended yrast band and a new band is plotted in Fig. 2. The side band has the same spin and parity as the yrast band, and relative excitation energy of about 500 keV with respect to the yrast band. The configuration of the yrast band involves a high-K proton and a low-K neutron, $\pi h_{9/2} \otimes \nu i_{13/2}$. It seems no other two-single particle configuration can fit the spin and parity of the side band. The intense links between the two bands also suggest similarities in their configurations.

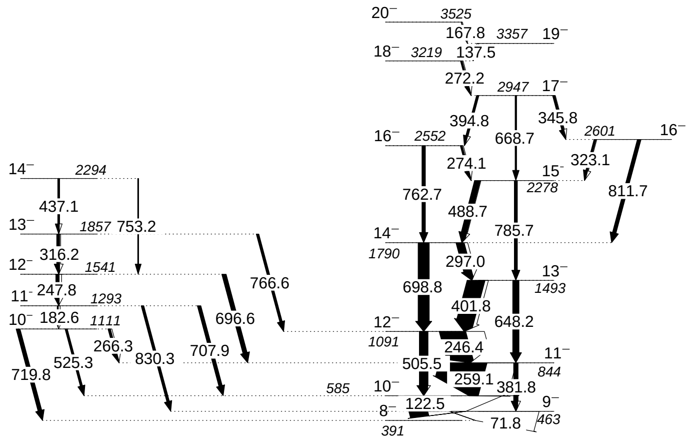

Fig. 2. Partial level scheme showing the pair of bands in ^{198}Tl.

While the triaxial rigid rotor calculations indicated large non-axiality of the neighbouring even–even ^{196}Hg core with $\gamma \sim 35°$ [1], axially symmetric shape is predicted by the total routhian surface calculations. Signature inversion is observed in the yrast band, while no signature splitting is shown in the side band. The properties of this pair of bands seem similar to the properties of the two-quasiparticle bands in odd–odd nuclei in the 130 mass region, which were initially interpreted as chiral doublet bands. More experimental measurements and theoretical calculations are needed in order to reveal the nature of this pair of bands.

REFERENCES

[1] L. Esser *et al.*, *Phys. Rev.* **C55**, 206 (1997).

[2] J. Meyer-ter-Vehn, *Nucl. Phys.* **A249** 111, 141 (1975).

[3] C.Y. Xie *et al.*, *Phys. Rev.* **C72**, 044302 (2005).

[4] A.J. Kreiner *et al.*, *Phys. Rev.* **C21**, 933 (1980).

[5] A.J. Kreiner *et al.*, *Phys. Rev.* **C20**, 2205 (1979).

[6] A.J. Kreiner, M. Fenzl, W. Kutschera, *Nucl. Phys.* **A308**, 147 (1978).

[7] A.J. Kreiner *et al.*, *Nucl. Phys.* **A282**, 243 (1977).

[8] A.J. Kreiner *et al.*, *Phys. Rev.* **C23**, 748 (1981).

[9] A.J. Kreiner, *Phys. Rev.* **C22**, 2570 (1980).

[10] J.S. Dionisio *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A362**, 122 (1995).

[11] J.F. Sharpey-Schafer, *Nucl. Phys. News* **14**, 5 (2004).

[12] R.T.N. Newman *et al.*, *Balkan Phys. Lett.* 182 (1998), special issue.