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Short note

Identification of Rotational Band in Doubly Odd ^{170}Ta

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Abstract. High spin states in ^{170}Ta have been studied via ^{159}Tb(^{16}O,5nγ)^{170}Ta reaction through excitation functions, K X-γ and γ-γ-t coincidence measurements. Three rotational bands have been identified among which one coupled band and an unfavored ΔI=2 E2 transition sequence are newly found in this work. The possible quasiparticle configurations of these bands are discussed.

PACS. 23.20.Lv Gamma transitions and level energies – 27.70.+q $150 \leq A \leq 189$

The high-spin states of deformed doubly odd nuclei are normally difficult for spectroscopic studies because of the high level density at low excitation energies. In spite of this, more and more experimental data have been accumulated concerning the band structures of doubly odd nuclei in the rare-earth region; many yrast and yrare bands have been identified in Eu, Tb, Ho, Tm and Lu isotopes. Detailed investigations for a doubly odd nucleus may provide rich nuclear structure information such as the residual n-p interactions and the configuration-dependent shapes, pairing, and so on. Prior to this work, the high-spin states of ^{170}Ta were less extensively studied [1]; three rotational bands were observed and attributed to ^{170}Ta. These results have been collected in the most recent compilation of [2]. However the assignment to ^{170}Ta was mainly based on a low multiplicity measurement by using the 50 element BGO array but was not confirmed by the excitation functions and the K X-γ coincidence measurements. In order to get more information about the band structures of ^{170}Ta, a further investigation has been carried out in our laboratory.

The excitation functions, K X-γ and γ-γ coincidences have been measured at the HI-13 tandem accelerator of the China Institute of Atomic Energy (CIAE) via ^{159}Tb (^{16}O,5nγ)^{170}Ta reaction at beam energies of 85−102 MeV. One planar detector and 7 HPGe's with BGO(AC) shields were used for the K X and the γ-rays detections. About 4.5 million K X-γ and 33 million γ-γ coincidence events were accumulated. The singles γ spectrum in this experiment was very complex and the photon peaks were contaminated by the residual radioactivities. In order to avoid these contaminations, an 18 element BGO multiplicity filter was used which covered 70% solid angles of the upsemisphere around the target. At least 4 fold requirement of this BGO array has been imposed during the excitation function measurements.

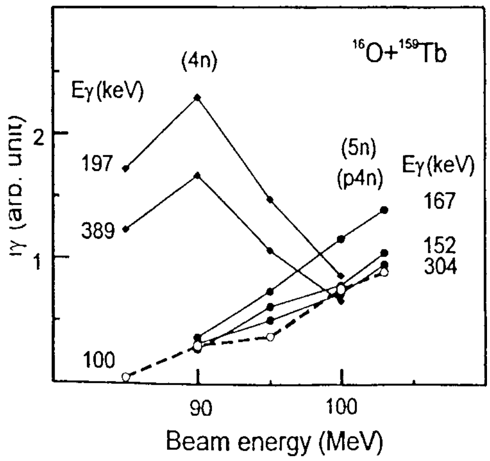

Fig. 1. Excitation functions for some clean γ-rays

The excitation functions for some clean γ-rays have been obtained and shown in Fig. 1, from which the γ-rays of ^{170}Ta (5n channel) and ^{170}Hf (p4n channel) can been clearly separated from that of ^{169}Ta (4n channel). Figure 2 shows the low energy coincidence spectrum gated by the clean γ-rays recorded in the HPGe detectors; the K X-rays from Ta and Hf isotopes are firmly distinguished. These results indicate that the rotational band associated with 211 and 304 keV cascade belongs to ^{170}Ta, while the band coincided with 100 and 221 keV lines belongs to ^{170}Hf [2]. This assignment is different from that suggested

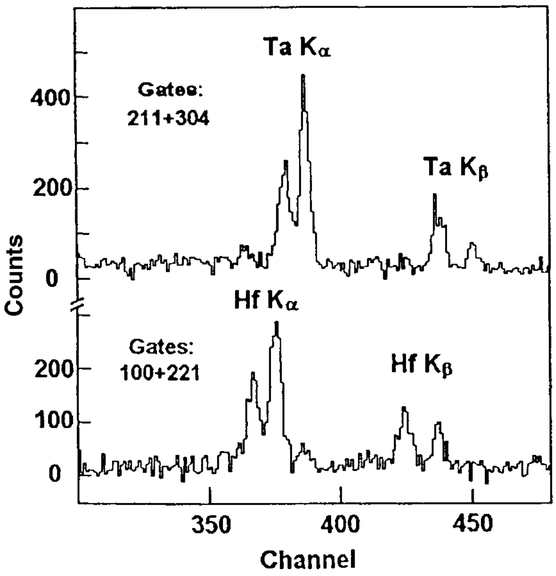

Fig. 2. Spectra measured in X-ray detector in coincidence with γ-rays in HPGe detectors

in [1] where the 221−321−400 ··· γ-transition sequence was assigned to ^{170}Ta as the favored band based on the $\pi 1/2^-[541]\otimes\nu i_{13/2}$ configuration.

The extensive γ-γ-t coincidence measurement was carried out in the Heavy Ion Research Facility Lanzhou (HIRFL), by using the same reaction as in CIAE at 105 MeV ^{16}O beam energy. 4 HPGe's with BGO(AC) shields were used for the γ-ray detections. A total of 80×10^6 γ-γ-t events were accumulated. In both experiments, a 2 mg/cm^2 ^{159}Tb target with 3 mg/cm^2 Pb backing was used. The detectors were calibrated by the standard ^{152}Eu, ^{133}Ba and ^{60}Co sources and also checked by the known in-beam γ-rays of ^{169}Ta and ^{170}Hf. The typical energy resolutions were about 2.0∼2.4 keV at FWHM for the 1332.5 keV line. From detailed analysis of the gated spectra, the level scheme of ^{170}Ta consisting of three rotational bands has been constructed as shown in Fig. 3, where the γ-transition energies are within an uncertainty of 0.3 keV. The spin values of the energy levels are suggested according to the additivity rule for alignments and the transition energy systematics of the similar bands in ^{166}Ta [3], ^{168}Ta [4],^{170}Ta, ^{172}Ta [5] and ^{174}Ta [6].

The band A is the most strongly populated and considered to be based on the $\pi h_{11/2}\otimes\nu i_{13/2}$ configuration because it shows a well-known behavior of signature inversion [7] as the yrast bands of its lower N isotopes and the lower Z odd-odd rare-earth nuclei. Furthermore the extracted B(M1)/B(E2) values are consistent with the theoretical calculations by using the formula quoted in [8]. The level structure of this band is in agreement with the results of [1].

For band B, a less extended cascade (shown in the left) is newly found and it connects with the known E2 transition sequence [1] through 5 γ transitions. Under the assumption of M1/E2 character of these transitions, the band B could be considered to be based on the $\pi 1/2^-[541]$ $(\alpha=1/2)\otimes\nu i_{13/2}(\alpha=\pm1/2)$ configuration. This assignment is supported by the apparent level staggering (indicating the participation of a $i_{13/2}$ neutron) and the large band crossing frequency of $\hbar\omega_c\geq0.34$ MeV (probably caused by both the blocking effect of the lowest $\nu i_{13/2}$ neutron orbital and the shape driving effect of the intruder $1/2^-[541]$ proton orbital).

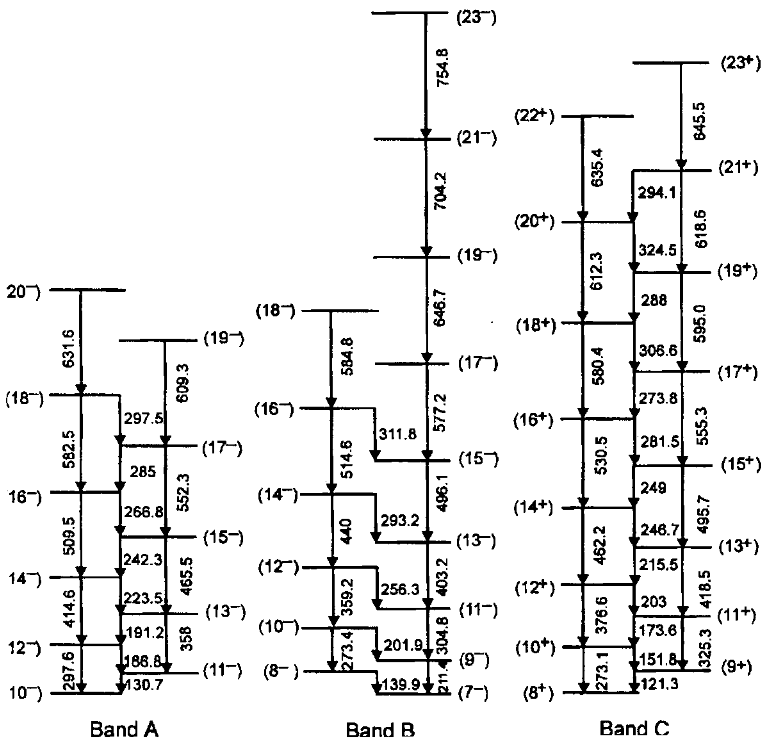

Fig. 3. Proposed level scheme for ^{170}Ta

The band C is newly found by this work; the assignment of this band to ^{170}Ta is strongly supported by the excitation functions and K X-γ coincidence measurements. This band shows an upbend at $\hbar\omega_c \approx$0.290 MeV and the signature splitting is quite small. To distinguish the possible lower-lying configurations: $\pi 5/2^+$ [402]$\otimes\nu$i$_{13/2}$, $\pi 7/2^+$ [404]$\otimes\nu$i$_{13/2}$ and $\pi 1/2^-$ [541]$\otimes\nu 5/2^-$ [523], we have extracted the B(M1)/B(E2) values which scatter around 0.6 $(\mu_N/eb)^2$; this value can be reproduced theoretically if the first configuration is assumed. The other two suggestions will result in much lower predicted B(M1)/B(E2) values. It should be noted that the crossing frequency is smaller than the value of its odd-N even-Z neighbors corresponding to the neutron BC crossing ($\hbar\omega_c$=0.315 MeV for example in ^{169}Hf [9]), this may be due to the n-p residual interaction and/or the shape driving force of $\pi 5/2^+$[402] proton orbital. Detailed discussion of the results will be presented in a forthcoming article.

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References

1. J. C. Bacelar et al., Nucl. Phys. **A442** (1985) 547
2. Coral M. Baglin, Nucl. Data Sheets, **77** (1996) 125
3. H. Zheng et at., Book of Abstracts in the International Nuclear Physics Conference, Aug. 21-26, 1995, Beijing, China, 6.2-26
4. Theine et al., Nucl. Phys. **A536** (1992) 418 and Y. Z. Liu et al., Phys. Rev. **C52** (1995) 2514
5. A. J. Kreiner et al., Phys. Lett. **B215** (1988) 629
6. D. Hojman et al., Phys. Rev. **C46** (1992) 1203
7. S. Drissi et al., Nucl. Phys. **A451** (1986) 313
8. S. Drissi et al., Nucl. Phys. **A600** (1996) 63
9. W. B. Gao et al., Phys. Rev. **C44** (1991) 1380