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New rotational bands in ^{174}Ta

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Abstract. Three new bands in ^{174}Ta have been identified by using the ^{160}Gd(^{19}F,5n) reaction at beam energies of 87 MeV and 96 MeV. Nilsson configurations are assigned to these bands. In the $9/2^-[514]_p$+$5/2^-[512]_n$ band, the AB neutron crossing occurs at a rotational frequency of 0.30 MeV. This is indicative of the disappearance of the evidence for a reduction in neutron pair correlations.

PACS. 23.20.Lv Gamma transitions and level energies – 21.10.Hw Spin, parity, and isobaric spin – 27.70.+q $150 \leq A \leq 189$

Prior to the beginning of this work, the information on ^{174}Ta was comprised of four rotational bands [1]. A great deal of new information about these bands was revealed in our earlier work [2] and in the recent work of Bark et al [3]. In the present work we have identified three new coupled bands of ^{174}Ta.

The study of ^{174}Ta was performed in two separate experiments both by using the ^{160}Gd(^{19}F,5n) reaction. In experiment I, the beam energy was 87 MeV; and in the experiment II it was 96 MeV. The experimental details for experiment I are given in [2, 4]. For experiment II, the main details were the same as those of experiment I except the following three points: (1) the detector array consisted of seven Compton-suppressed HpGe detectors and one planar HpGe detector; (2) 75 million coincidence events were collected; and (3) relative intensities of γ-rays and B(M1)/B(E2) ratios of coupled bands were measured. In the reaction at 87 MeV, the high spin states in ^{175}Ta [4] were strongly populated whereas those in ^{173}Ta [5] were weakly populated; in the reaction at 96 MeV, the reverse was true. In contrast, the high spin states in ^{174}Ta were strongly populated at both energies. ^{171}Lu, ^{174}Hf and ^{160}Gd are the nuclei whose excited states were also populated at both energies; however, only the yrast bands of these nuclei can be well observed in off-line analysis. Taking into account the above information we can assign those bands which were strongly populated at both energies to ^{174}Ta with great confidence. These bands (labeled B, C and D), together with a previously known [1, 2] band (labeled A), are shown in Fig. 1.

In order to identify the possible configurations for the bands shown in Fig. 1, we have employed several arguments as exemplified below. For band B, based on the comparison (see Fig. 2) of experimental B(M1)/B(E2) values with theoretical values estimated from the geometric model [6], three configurations, i.e. $9/2^-[514]_p$+$5/2^-[512]_n$ ($K = 7$), $5/2^+[402]_p \otimes 1/2^-[521]_n$ ($K = 2$ or 3) and $5/2^+[402]_p$+$7/2^+[633]_n$ ($K = 6$), are the candidates. Considering that the alignment curve of band B upbends sharply at a rotational frequency of 0.30 MeV (see Fig. 3) whereas that of the $(i_{13/2})_n$ band in ^{173}Hf upbends gently around 0.35 MeV [7], the last one is rejected. And then, based on the arguments presented below, the first one is selected:

(1) Because no further lower state can be established from the analysis of prompt coincidence data, the lowest observed state, which is fed by two strong g-transitions (the 152 keV line and the 159 keV line), is believed to be the band head. On this basis, under the choice of the first configuration, the experimental rotational parameter computed from the 152 keV transition energy is 9.5 keV; and under the choice of the second configuration ($K = 3$) it is 19.0 keV. On the other hand, the rotational parameter predicted using the procedure described in [8] is 10.5±1.0 keV for the first configuration and 12.4±1.7 keV for the second configuration.
(2) Routhians obtained by summing up those of the corresponding configurations of the odd-A neighbors [5, 7] indicate that the first configuration lies noticeably lower in energy than the second one.

Likewise, band A, C and D are proposed to be built on the $7/2^+[404]_p$+$7/2^+[633]_n$ ($K = 7$), $7/2^+[404]_p$+$1/2^-[521]_n$ ($K = 4$) and $9/2^-[514]_p \otimes 1/2^-[521]_n$ ($K = 4$ or 5) configurations respectively. It

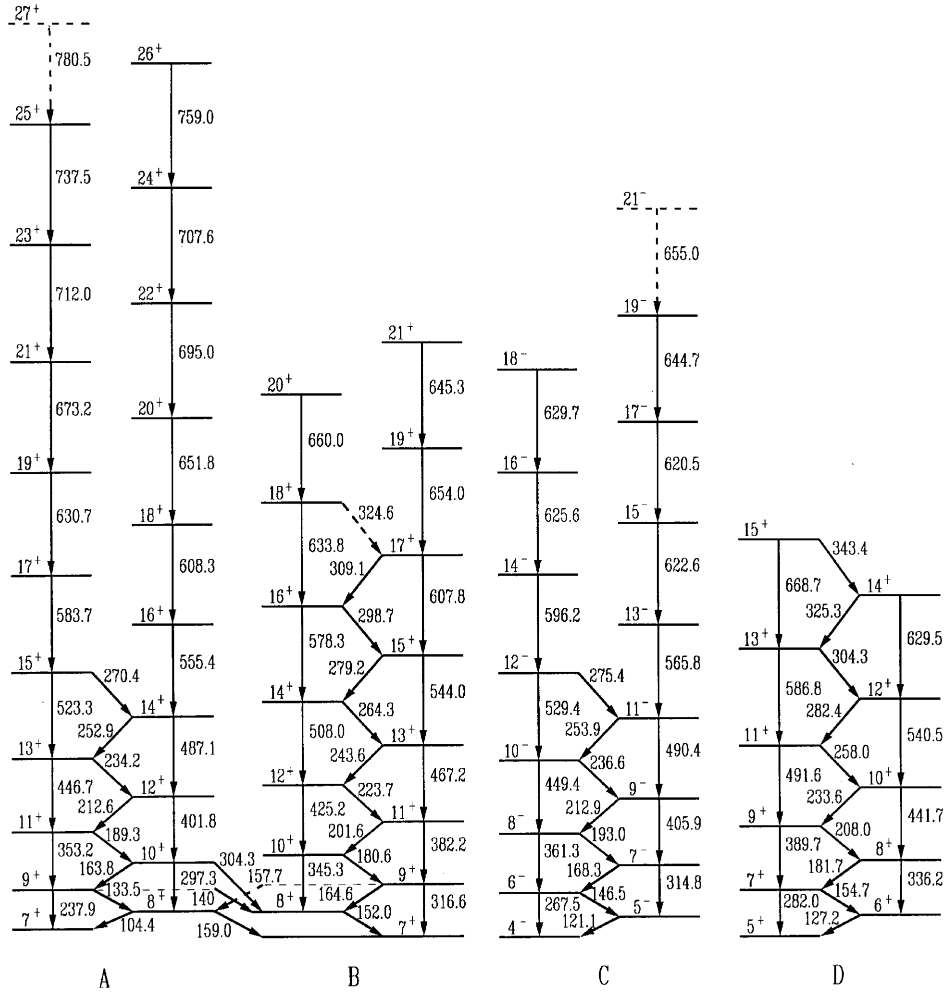

Fig. 1. Partial level scheme of ^{174}Ta, as deduced from the present work. (For simplicity, the spin and parity of each level is not put into brackets although they are not assigned firmly.)

should be noted that band A was assigned [1] previously to the $5/2^+[402]_p$+$7/2^+[633]_n$ configuration.

The spin assignments for band A, B and C are based on the conclusion that the lowest observed state in each band is the band head. The argument which leads to this conclusion has been discussed above for band B. The similar argument holds also for bands A and C. However, it does not hold for band D. The spin assignment for band D is made from a comparison with band C.

The experimental alignments for the presently reported bands of ^{174}Ta are shown in Fig. 3. It is interesting to note that the AB neutron band crossing frequency of 0.30 MeV observed in the $9/2^-[514]_p$+$5/2^-[512]_n$ band is very close to that in the neighboring even-even nucleus ^{172}Hf [9]. In contrast, the AB neutron band crossing frequency of 0.275 MeV observed in the $5/2^-[512]_n$ band of the odd-N neighboring nucleus ^{173}Hf [7] is reduced by 25keV with respect to ^{172}Hf. According to the discussion by Garrett et al [10], the reduction in crossing frequency for ^{173}Hf can be interpreted as a reduction in neutron pair correlations, the result of a "blocking" of pairing contribution from the valence configuration in an odd-N nucleus. However, it is unclear why the band crossing frequency in the $9/2^-[514]_p$+$5/2^-[512]_n$ band of ^{174}Ta is not reduced. Observations similar to the case of ^{174}Ta have also been reported for odd-odd ^{160}Tm and ^{164}Lu, and led to the speculation that proton-neutron interactions may play an important role [11].

At the time when the revised version of this note is being prepared for submission, we are aware of that another paper by Bark et al has just been published with a substantial level scheme of ^{174}Ta [12]. Three of the four bands reported in this note, i.e. band A, B and C, have also been reported by Bark et al. The configuration and spin assignments in our work are the same as those by Bark et al for band A and B, and are different from those by Bark et al for band C. In Bark et al's work band C was assigned to be built on the $5/2^+[402]_p$+$5/2^-[512]_n$ configuration, instead of the $7/2^+[404]_p$+$1/2^-[521]_n$ configuration proposed in our work. If band C is a band built on the $5/2^+[402]_p$+$5/2^-[512]_n$ configuration, it seems very difficult to understand the non-observation of the $5/2^+[402]_p$+$7/2^+[633]_n$ band, which should be observed with a larger population than the $5/2^+[402]_p$+$5/2^-[512]_n$ band. Furthermore, it is worthwhile to note that transitions in band C below backbending have nearly the same

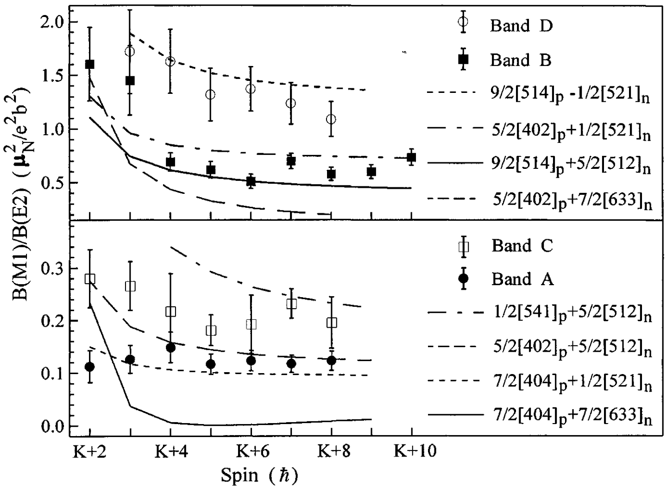

Fig. 2. Experimental B(M1)/B(E2) ratios deduced from the present work. The curves correspond to calculations based on geometric model [6]. In the calculations, $Q_0 = 7.0$ eb; $g_R = 0.35$; intrinsic g factors of quasiprotons and quasineutrons are taken from [5,7]

energies as those in the $7/2^+[404]_p$+$1/2^-[521]_n$ band of ^{170}Lu [13]. Such a phenomenon presents another possible support to our configuration assignment for band C. On the other hand, if there exist further lower in-band states, as observed in Bark et al's work, below the present lowest observed state of band C, we would propose that band C is built on the $1/2^-[541]_p5/2^-[512]_n1$ configuration.

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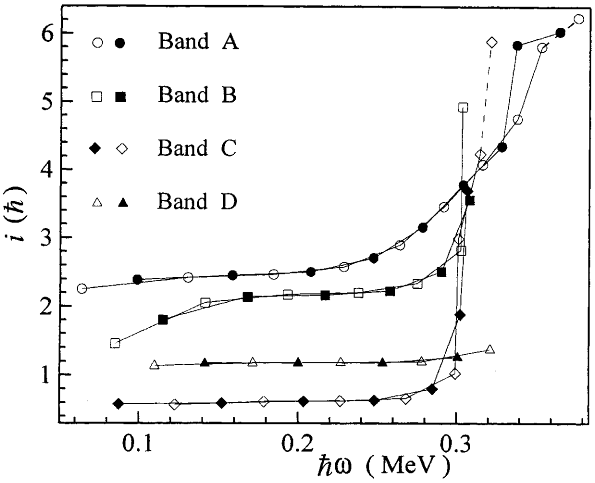

Fig. 3. Experimental alignments as a function of rotational frequency for the bands shown in Fig. 1

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