Two-quasiparticle excited neutron levels in ^{180}Ta

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Excited neutron rotational levels have been observed in ^{180}Ta up to an excitation energy of 1 MeV using the ^{181}Ta(d,t)^{180}Ta reaction. New assignments have been proposed for levels in the $\frac{7}{2}^+[404]_\pi \pm \frac{1}{2}^-[521]_\nu$ and $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configurations. Levels in the latter are discussed with regard to configuration mixing between low energy $K^\pi=8^+$ bands expected in ^{180}Ta.

[NUCLEAR REACTIONS ^{181}Ta(d,t)^{180}Ta with natural tantalum oxide target; $E_d=17.4$ MeV; measured E_t and $\sigma(\theta)$ with QDDD spectrometer; DWBA analysis; deduced levels I^π, K.
NUCLEAR STRUCTURE ^{180}Ta assigned Nilsson configurations; failure to observe configuration mixing between expected low energy $K^\pi=8^+$ bands.]

I. INTRODUCTION

In the mass 180 region there are well-known $K^\pi=8^-$ isomeric states in ^{176,178,180,182}Hf (Ref. 1) and a 10^{13} yr isomer (probably 9^-) (Ref. 2) of ^{180}Ta. Additionally there are very high spin isomers in ^{177,179}Hf and ^{177}Lu which probably result from coupling the ground state odd particle to a two-quasiparticle 8^- core state. The long-lived isomer of ^{180}Ta and the 8^- levels in ^{178}Hf have been the focus of interest in several previous investigations.[2–7] We begin here a series of experiments to study these 8^- isomers and the 9^- isomer and other low energy states in ^{180}Ta.

From an examination of Nilsson diagrams in the neighborhood of $Z=72$ and $N=106$ we observe that $K^\pi=8^-$ levels can be formed in the even-even Hf isotopes by breaking either a neutron pair or a proton pair to make the respective two-quasiparticle wave functions $\frac{9}{2}^+[624]_\nu\pm\frac{7}{2}^-[514]_\nu$ or $\frac{7}{2}^+[404]_\pi\pm\frac{9}{2}^-[514]_\pi$. In the mass range $^{176-182}$Hf it is anticipated that these levels would lie at most only a few hundred keV apart and could therefore mix measurably. Notably the lowest 8^- levels in ^{178}Hf are at 1.147 and 1.479 MeV. Ward and Chu[6] measured the two-neutron admixture in the predominantly two-proton 1.479 MeV state to be approximately 30%.

In the odd-odd nucleus ^{180}Ta these Nilsson orbitals can recouple to form $K^\pi=8^+$ bands. In the ^{181}Ta(p,d)^{180}Ta spectrum Warde *et al.*[7] observed the $\frac{7}{2}^+[404]+\frac{7}{2}^-[514]$ $K^\pi=7^-$ band beginning at 173 keV, and in the ^{179}Hf(^{3}He,d)^{180}Ta and ^{179}Hf(α,t)^{180}Ta spectra they observe the $\frac{9}{2}^-[514]\pm\frac{9}{2}^+[624]$ $K^\pi=9^-$ band beginning at 82 keV. Therefore the $\frac{9}{2}^-[514]\pm\frac{7}{2}^-[514]$ $K^\pi=8^+$ band can be predicted to begin at approximately 255 keV, and the $\frac{7}{2}^+[404]\pm\frac{9}{2}^+[624]$ $K^\pi=8^+$ band is known to be from the ground state configuration.[7] This puts the two $K^\pi=8^+$ bands closer together than the two lowest 8^- bands in ^{178}Hf, and we would expect to observe measurable configuration mixing between them.

Many or most of the peaks in the ^{181}Ta(p,d)^{180}Ta spectra taken by Warde *et al.*[7–9] appear to be doublets or multiplets. It was therefore hoped that the high resolution QDDD spectrometer at Princeton University could obtain better resolution of these multiplets and perhaps allow us to observe population of both $K^\pi=8^+$ bands in ^{180}Ta using the ^{181}Ta(d,t)^{180}Ta reaction. Since the $\frac{9}{2}^-[514]\pm\frac{7}{2}^-[514]$ configuration represents excitation of both a neutron and a proton above the $\frac{7}{2}^+[404]\pm\frac{9}{2}^+[624]$ ground state configuration, such an observation would firmly establish a measurable configuration mixing matrix element.

II. EXPERIMENTAL PROCEDURE AND ANALYSIS

We have performed the ^{181}Ta(d,t)^{180}Ta reaction with a 17.4 MeV deuteron beam from the Princeton University cyclotron. The reaction products were magnetically analyzed with the QDDD spectrometer.[10] The targets were natural Ta_2O_5 foils 98 μg/cm^2 thick in Ta. Spectra of ^{180}Ta were obtained up to 1 MeV of excitation at spectrometer angles of 7.5° to 90° in 7.5° increments, and one additional spectrum was obtained at 25°. The spectra were calibrated with the ^{174}Yb(d,t)^{173}Yb reaction.[11] Typical spectra are shown in Fig. 1. Table I contains a list of the peaks observed in ^{180}Ta with their experimental energies and cross sections at 60°. Where assignments were made they are listed in the last column.

Our spectra display slightly better resolution than the ^{181}Ta(p,d)^{180}Ta spectra of Warde *et al.*[7] and our counting statistics are much larger. The large solid angle of the QDDD spectrometer allows more rapid accumulation of data than does the Büechner spectrograph used in the (p,d) studies. Therefore, we have obtained clearly fit doublets of the peaks near 184, 473, 573, and 654 keV. These peaks had been treated as single peaks in the (p,d) spectra.[7] Finally the excitation energies we obtained were not

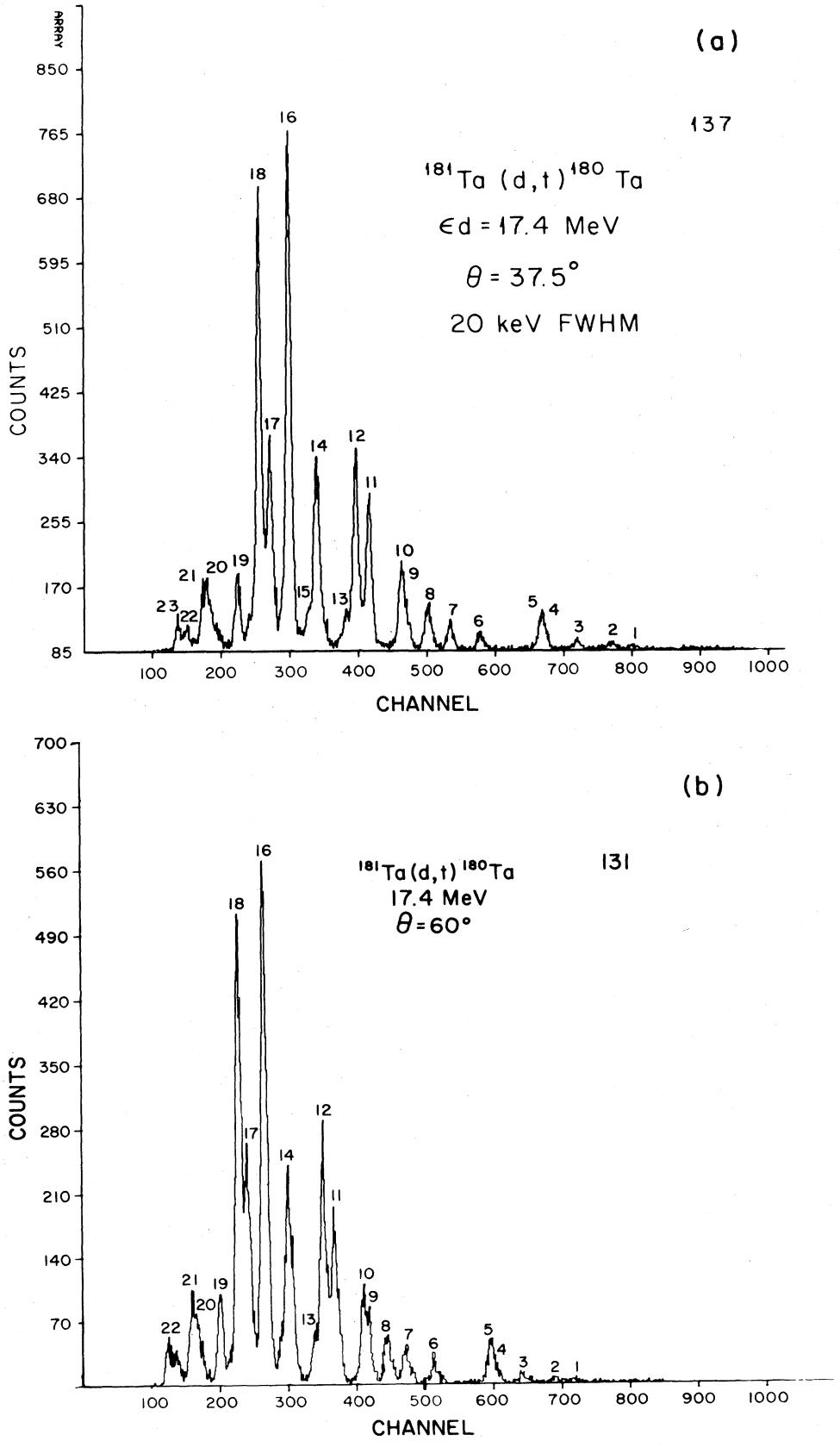

FIG. 1. The ^{181}Ta(d,t)^{180}Ta spectra observed at 37.5° and 60° with an incident energy of $E_d = 17.4$ MeV.

TABLE I. Nuclear levels in ^{180}Ta populated in the ^{181}Ta(d,t) reaction. (The experimental and theoretical cross sections are for 60° except where noted.)

	Previous energy (keV)	Energy (d,t) (keV)	Error (keV)	$\left[\frac{d\sigma}{d\Omega}\right]_{\text{exp}}\left[\frac{\mu b}{sr}\right]^a$	$\left[\frac{d\sigma}{d\Omega}\right]^{th}\left[\frac{\mu b}{sr}\right]^a$ $N=1.33$	Assignment I^π	K	Neutron transferred
1	0	4	4	0.949	0.867	1^+	1	$\frac{9}{2}^+[624]$
2	38	45	2	2.62	0.937	2^+	1	$\frac{9}{2}^+[624]$
3	109	114	2	3.33	2.56	3^+	1	$\frac{9}{2}^+[624]$
4	181	172	5	3.67	5.32	8^+	8	$\frac{9}{2}^+[624]$
5	181	187	2	17.7	5.09	4^+	1	$\frac{9}{2}^+[624]$
6	309	312	3	6.89	5.94	5^+	1	$\frac{9}{2}^+[624]$
7	366	376	4	13.1	9.21	9^+	8	$\frac{8}{2}^+[624]$
8	414	420	4	19.6	35.3	1^-	1	$\frac{5}{2}^-[512]$
9		462	4	16.2	25.4	7^-	7	$\frac{7}{2}^-[514]$
10	476	476	4	49.5	103	2^-	1	$\frac{5}{2}^-[512]$
11	540	545	4	84.2	131	3^-	1	$\frac{5}{2}^-[512]$
12	573	571	4	117	207	6^-	6	$\frac{5}{2}^-[512]$
13	573	592	3	15.6	8.02	10^+	8	$\frac{9}{2}^+[624]$
14	659	652	4	135	94.4	4^-	1	$\frac{5}{2}^-[512]$
15		671	6	12.6	17.5	8^-	7	$\frac{7}{2}^-[514]$
16	723	712	5	193	203	4^-	4	$\frac{1}{2}^-[521]$
17	759	753	5	112	206	7^-	6	$\frac{5}{2}^-[512]$
18	785	775	5	172	175	3^-	3	$\frac{1}{2}^-[521]$
19	837	822	5	32.1	54.7	5^-	4	$\frac{1}{2}^-[521]$
20	914	875	8	15.4	67.8	4^-	3	$\frac{1}{2}^-[521]$
21		893	6	32.1				
22		930	2	10.8				
23		948	2	16.0	34.2	6^-	4	$\frac{1}{2}^-[521]$

[a]Pickup of $\frac{5}{2}^-[512]$ neutron measured and calculated at 30°.

in complete agreement with those of the ^{181}Ta(p,d)^{180}Ta spectra, though they are in agreement within 20 keV for all peaks below 800 keV. We believe that our energies are more reliable since the kinematic corrections using the ^{174}Yb(d,t)^{173}Yb calibration are much smaller than those using the ^{13}C(p,d)^{12}C calibration of the (p,d) study.

In the analysis of the data, we have assumed a single particle Hamiltonian with the odd particles strongly coupled to the deformed core. Details of the theoretical treatment are given in a previous paper and references therein.[12] Theoretical differential cross sections were determined by

$$\frac{d\sigma}{d\Omega}=N\sum_j (S_{jl})^2\frac{\phi_{jl}(\theta)}{2j+1}\,, \tag{1}$$

TABLE II. Nilsson orbital expansion coefficients and pairing factors used in theoretical calculations.

Neutron pickup	V^2	$C_{(1/2)1}$	$C_{(3/2)1}$	$C_{(5/2)3}$	$C_{(7/2)3}$	$C_{(9/2)5}$	$C_{(11/2)5}$
$\frac{1}{2}^-[521]$	0.86	−0.4985	−0.1528	−0.4251	+0.4813	0.5193	−0.2147
$\frac{7}{2}^-[514]$	0.83				0.2046	0.9629	−0.1757
$\frac{5}{2}^-[512]$	0.87			0.1017	0.8863	−0.3749	−0.2523
					$C_{(9/2)4}$	$C_{(11/2)6}$	$C_{(13/2)6}$
$\frac{9}{2}^+[624]$	0.50				0.1519	0.1147	0.9817

TABLE III. DWBA optical model parameters used in the ^{181}Ta(d,t)^{180}Ta reaction.

	V_R	r_R	a_R	W_I	r_I	a_I	W_D	r_D	a_D	V_{SO}	r_{SO}	a_{SO}	r_c	λ	β^b
d	−103.0[c]	1.15	0.81	−17.3	1.34	0.68	18.6[c]	1.34	0.68				1.15		0.54
t	−161.2	1.24	0.705	−20.1[d]	1.40	0.84				−2.5	1.2	0.72	1.30		0.29
n	a	1.25	0.65										1.25	25	

[a]Adjusted to produce bound state energy.
[b]Nonlocal range parameter.
[c] $V_R=81.0-0.22E+2.0(Z/A^{1/3}), W_D=14.4+0.24E$.
[d] $V_R=165.0-0.17E-6.4(N-Z)/A, W_I=46.0-0.33E-110(N-Z)/A$.

where σ_{jl} is the intrinsic single particle cross section determined by DWBA (Ref. 13) calculations, S_{jl} is the spectroscopic amplitude given by Jones and Sheline,[14] and N is the DWBA normalization factor. The Nilsson orbital expansion coefficients were calculated with a deformation of $\epsilon_2=0.30$ and with $\mu=0.625$ and $\kappa=0.05$. Table II contains a list of the transferred particle expansion coefficients and pairing factors used in the calculations of Eq. (1). The optical model parameters used in the DWBA calculations were determined from the equations of Perey and Perey[15] and are listed in Table III.

III. RESULTS AND DISCUSSION

The spin and parity assignments in ^{180}Ta which follow are largely based on model-dependent arguments. We have assumed the unpaired $\frac{7}{2}^+[404]$ proton in the ^{181}Ta target is merely a spectator in the neutron pickup reaction, so that only odd neutron states coupled to it can be observed in ^{180}Ta. The peaks observed have been assigned in rotational bands with inverse moments of inertia, $\hbar^2/2\mathcal{I}\approx 11-13$ keV, and with a few exceptions our assignments are in very good agreement with those of Warde *et al.*[7] The intensity pattern for each band has been predicted on the basis of Eq. (1), and the predicted energy systematics of the odd neutrons is based upon neighboring odd-A nuclides in the region.[1] The agreement between theoretical and experimental angular distributions is, however, much less model dependent, and we have obtained very nearly unambiguous assignments of ℓ-transfer values for many of the peaks we observed in ^{180}Ta.

A. The $\frac{7}{2}^+[404]\pm\frac{9}{2}^+[624]$ configuration

The $\frac{7}{2}^+[404]\pm\frac{9}{2}^+[624]$ configuration is known to be the ground state configuration in ^{18}Ta,[2,7–9] and in accordance with the Gallagher-Moszkowski coupling rule[16] the $K^\pi=1^+$ band of this configuration forms the ground state rotational band. Cousins *et al.*[2] assigned rotational states up to the $I=5$ level in the $K^\pi=1^+$ rotational band using (n,γ) and (γ,n) data. Warde *et al.*[7] observed each of these states in the ^{181}Ta(p,d)^{180}Ta reaction and have speculated that the $I=6$ state forms a component of the peak they observe at 414 keV. We have populated the first five members of the 1^+ rotational band with energies and cross sections in very good agreement with the previous assignments. However, we observe no evidence that the peak we observe at 420 keV (labeled 8 in Fig. 1) is a doublet or multiplet. Therefore we cannot confirm the assignment of the $I=6$ state proposed by Warde *et al.*[7]

We have obtained good agreement with the assignments of Warde *et al.*[7] for the $I=8, 9$, and 10 rotational levels of the $K^\pi=8^+$ band of the $\frac{7}{2}^+[404]\pm\frac{9}{2}^+[624]$ configuration. The peak Warde *et al.*[7] observed at 573 keV has been resolved by us into a doublet of 571 and 592 keV. The latter has a good $\ell=6$ angular distribution, as does the peak we observe at 376 keV. These angular distributions appear in Fig. 2. The assignments for the states in this band appear in Table I and Fig. 4, and a comparison between the theoretical and experimental cross sections appears in Fig. 3.

B. The $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration

Warde *et al.*[7–9] give fairly extensive arguments that the peak near 173 keV is an unresolved triplet. We do not believe that it is. We have fit this peak as a resolved doublet and have obtained angular distributions in good agreement with the assignments made in Sec. III A. We do not believe there is any justification for including $\ell=5$ intensity in the peak, and do not agree with the assignment of the I^π, $K=7^-,7$ state of the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration at 173 keV.

Theoretical calculations predict the I^π, $K=7^-,7$ and $8^-,7$ states of this configuration to have predominantly $\ell=5$ (d,t) angular distributions and relative intensities at 60° of 1.0 and 0.69. We have observed peaks with $\ell=5$ angular distributions, which are shown in Fig. 2, at 462 and 671 keV. These two peaks have relative intensities at 60° of 1.0 and 0.78, and we have assigned them as the I^π, $K=7^-,7$ and $8^-,7$ states of the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration, as shown in Fig. 4. This results in a rotational parameter of

$$(\hbar^2/2\mathcal{I})_{K=7}=13.1 \text{ keV},$$

which is a much more believable value than that of 18.9 keV resulting from the assignments proposed by Warde *et al.*[7] Furthermore, the previous authors[7] indicate that coupling with the $8^-,6$ state pushes the $8^-,7$ state of this configuration up 110 keV. This indicates a lack of understanding of the Coriolis interaction, and casts doubt on all of the Coriolis calculations presented.

In ^{176}Lu the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration is known with an energy splitting of $\Delta A=250$ keV, where ΔA is defined by Eq. (3.2) of Ref. 7, and with a Newby[17]

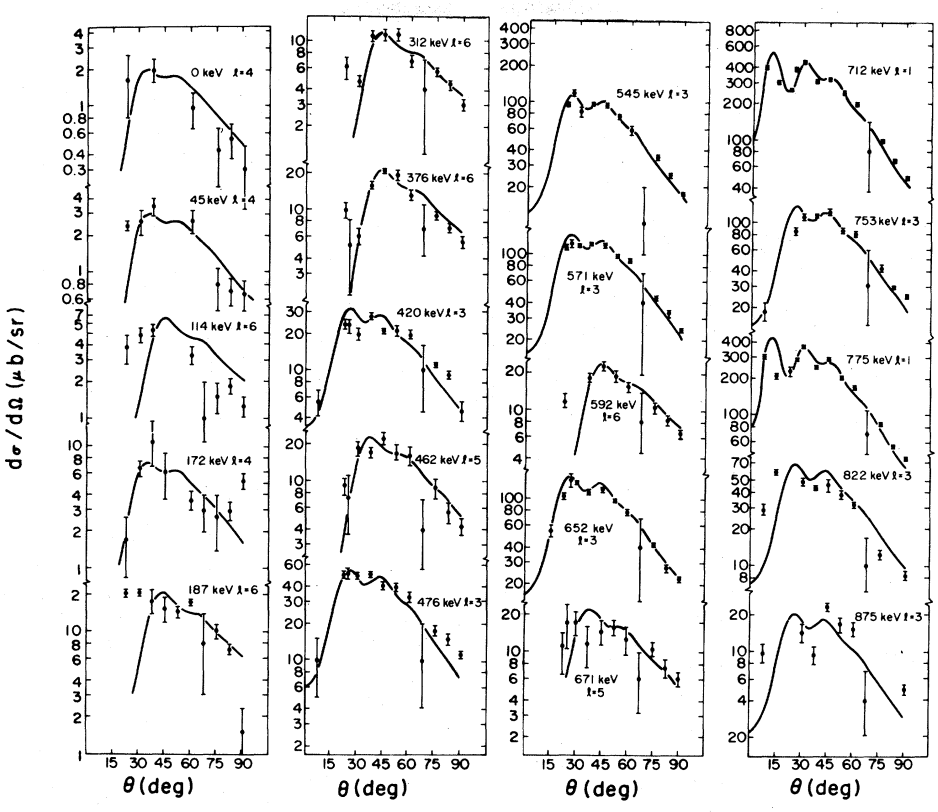

FIG. 2. Angular distributions for the peaks observed in the ^{181}Ta(d,t)^{180}Ta reaction. The solid curves are the results of DWBA calculations.

odd-even shift of 68 keV.[18] Thus in ^{180}Ta we can predict that the $K=0$ band head should appear near 690 keV with the $I=1$, 2, 3, 4, and 5 states lying at about 550, 770, 680, 950, and 920 keV, respectively. We have made no identification of states in the $K=0$ rotational band even though the theoretical calculations predict the first six levels of it should be observable in the ^{181}Ta(d,t) reaction. Apparently no states in the $K=0$ band were observed in the (p,d) reaction, though assignments were made for the first 6 levels of this rotational band in Fig. 7 of Ref. 7. These assignments appear to be based entirely on theoretical calculations and must be considered as unjustifiable.

C. The $\frac{7}{2}^+[404]\pm\frac{5}{2}^-[512]$ configuration

Warde *et al.*[7] assigned rotational states up to the $I=5$ level in the $K^\pi=1^-$ band of the $\frac{7}{2}^+[404]\pm\frac{5}{2}^-[512]$ configuration at energies of 414, 476, 540, 659, and 757 keV. This results in a highly decoupled rotational spacing between the states, as acknowledged by the authors, and was explained by Coriolis coupling with the $K^\pi=0^-$ band of the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration. We have observed two of these five peaks as resolved doublets, thus giving us a better value of the excitation energies and cross sections for the states in the $K^\pi=1^-$ band. The energies we observe for these states are 420, 476, 545, and 652 keV, resulting in much less decoupling of the rotational spacings. These assignments appear in Fig. 4 and suggest the I^π, $K=5^-,1$ state lies at 778±3 keV, but we believe there is no justification for making an assignment based on the (d,t) or (p,d) data. We observe the I^π, $K=6^-,6$ and $7^-,6$ states of this configuration at 571 and 753 keV, which is in good agreement with the assignments made by Warde of 573 and 759 keV.

The angular distributions for the peaks assigned in the $\frac{7}{2}^+[404]\pm\frac{5}{2}^-[512]$ configuration are shown in Fig. 2. Each has an extremely good $\ell=3$ pattern. The agreement between the theoretical and experimental cross sections is shown in Fig. 3. Clearly the I^π, $K=4^-,1$ state has an anomalously large cross section. This is probably related to the absence of any intensity appearing in the $K^\pi=0^-$ band of the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration.

The $\frac{7}{2}^-[514]$ and $\frac{5}{2}^-[512]$ neutron orbitals satisfy the requirement of $\delta_{\Omega',\Omega\pm1}$ for Coriolis coupling,[19] so it is expected that the $K^\pi=1^-$ band of the $\frac{7}{2}^+[404]$-$\frac{5}{2}^-[512]$ configuration and the $K^\pi=0^-$ band of the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration mix measurably. Performing the theoretical mixing calculations with the equations of Motz *et al.*,[19] we observe that the largest mixing between states in these two bands involves the $I=3$ states and the $I=4$ states. Further the mixed cross sections tend to enhance the $3^-,0$ intensity at the expense of $3^-,1$ intensi-

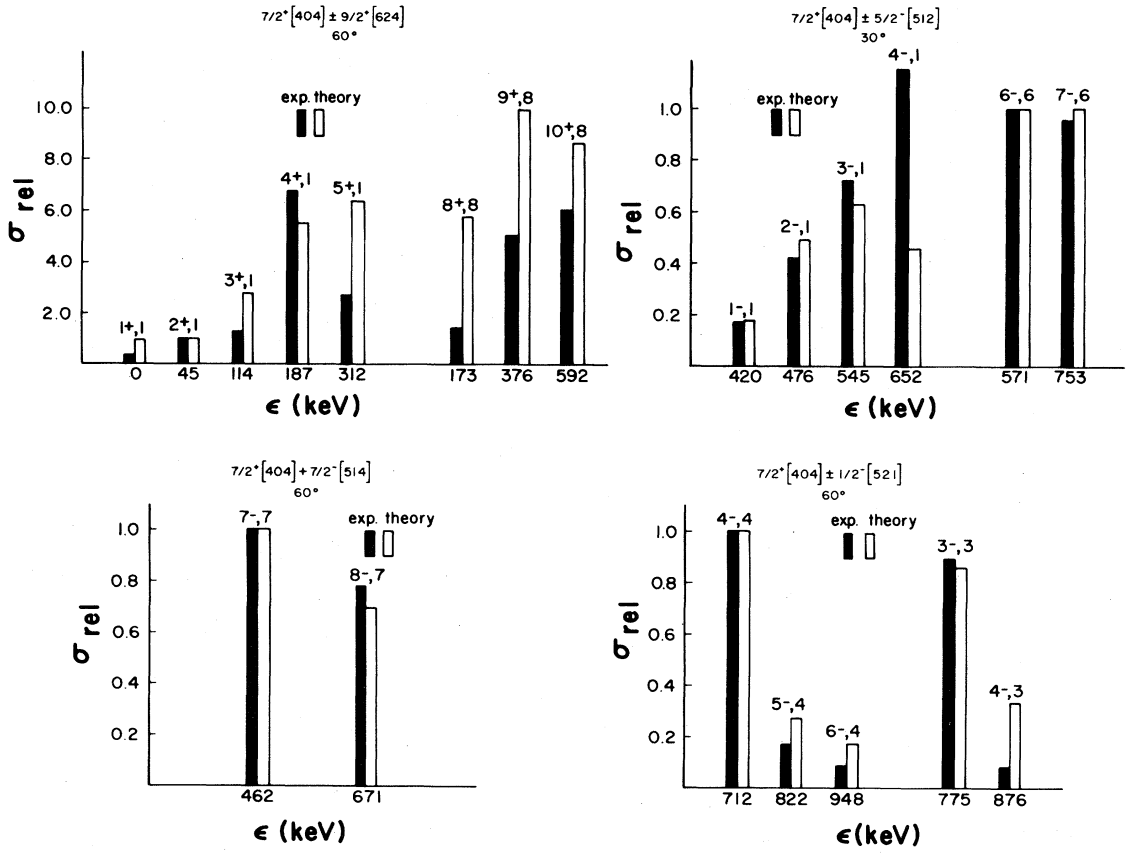

FIG. 3. Comparison between the experimental and theoretical cross section for the states assigned or identified in the ^{181}Ta(d,t)^{180}Ta reaction. The theoretical cross sections were normalized to the experimental cross section for one state in each configuration shown. Thus the DWBA normalization factor is not constant from one configuration to the next in this figure.

ty and to enhance the $4^-,1$ intensity at the expense of the $4^-,0$ intensity. Therefore including Coriolis mixing tends to increase our understanding of the anomalous intensity of the $4^-,1$ state. However, the correction due to the Coriolis perturbation from a purely theoretical treatment is only 3%, while the experimental intensity is approximately 100% larger than the calculations excluding Coriolis coupling predict. Thus Coriolos mixing between the $K^\pi=0^-$ and 1^- bands cannot quantitatively account for the large $4^-,1$ intensity, but it does at least alter the theoretical calculation in the correct direction.

Using the expansion coefficients of Warde *et al.*[7] to calculate the theoretical cross section in the $\frac{7}{2}^+[404]\pm\frac{5}{2}^-[512]$ configuration and excluding Coriolis coupling results in slightly poorer agreement with experiment than the previous calculation yields. However, with these expansion coefficients the Coriolis coupling matrix element between the $K^\pi=0^-$ and 1^- bands is larger, and when Coriolis coupling is included the agreement between experiment and theory are comparable in the two cases.

D. The $\frac{7}{2}^+[404]\pm\frac{1}{2}^-[521]$ configuration

Calculations with Eq. (1) predict that the $I^\pi=3^-,3$ and $4^-,4$ states in the $\frac{7}{2}^+[404]\pm\frac{1}{2}^-[521]$ configuration should be the strongest states observed in the ^{181}Ta(d,t) reaction. These two band heads have been previously assigned at 785 and 723 keV, respectively.[8] We observe the two largest peaks in our spectra at 775 and 712 keV, which have angular distributions in very good agreement with that of an $\ell=1$ transfer, as shown in Fig. 2. This supports their interpretation as resulting from pickup of a $\frac{1}{2}^-[521]$ neutron, and the calculated intensities on the basis of this assignment, shown in Table I, are in very good agreement with the experimental intensities.

We do not agree with the $5^-,4$ and $4^-,3$ assignments made in this configuration by Warde *et al.*[7] In part, this is due to the disagreement we obtained in our energy calibration curves. Assuming rotational parameters of $(\hbar^2/2\mathcal{I})=12\pm1$ keV we predict the I^π, $K=4^-,3$ and $5^-,4$ and $6^-,4$ states at about 870, 830, and 980 keV with characteristic $\ell=3$(d,t) angular distributions. We observe peaks at 822- and 875-keV which display good or fair $\ell=3$ angular distributions, as shown in Fig. 2. Therefore we have assigned the peaks observed at 712, 822, and 948 keV and at 775 and 875 keV as members of the $K=4$ and 3 rotational bands formed by the $\frac{7}{2}^+[404]\pm\frac{1}{2}^-[521]$ configuration, as shown in Fig. 4. A comparison of the experimental and theoretical cross sections for these assignments is shown in Fig. 3. These assignments result in ro-

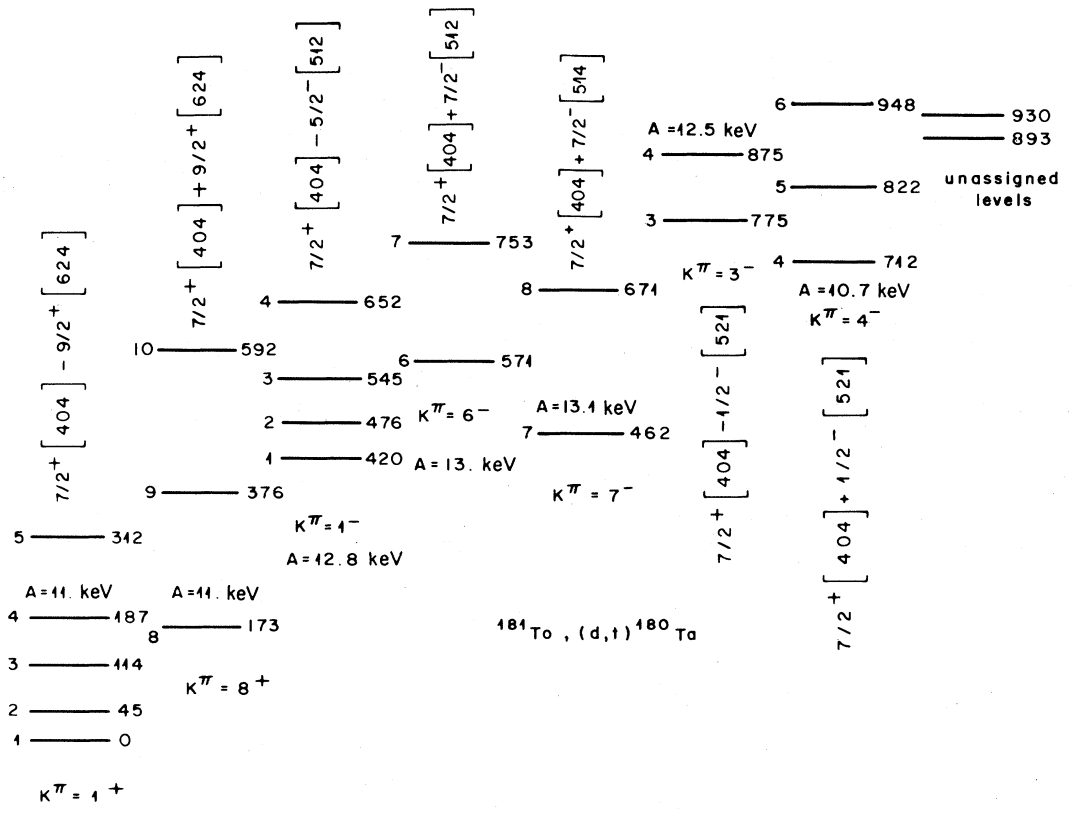

FIG. 4. Level scheme and rotational band structure for the states observed in the ^{181}Ta(d,t)^{180}Ta reaction.

tational parameters of $(\hbar^2/2\mathscr{I})_{K=3}=12.5$ and $(\hbar^2/2\mathscr{I})_{K=4}=10.7$ keV and in a splitting energy of $\Delta A=68$ keV. The $\frac{7}{2}^+[404]\pm\frac{1}{2}^-[521]$ configuration is previously known in ^{174}Lu and ^{170}Tm with splitting energies of 80 keV (Ref. 20) and 140 keV.[21]

IV. CONCLUSION

Twenty-three states have been observed in the ^{181}Ta(d,t)^{180}Ta reaction using a 17.4 deuteron beam. Sixteen of these states were previously observed and assigned in the ^{181}Ta(p,d)^{180}Ta reaction.[7] We obtained good agreement with most of these assignments; however, we have been unable to confirm any assignments made in the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration, nor most of the assignments in the $\frac{7}{2}^+[404]\pm\frac{1}{2}^-[521]$ configuration.

We have observed that the best agreement between the experimental and theoretical cross sections results from the use of $N=1.33$ for the DWBA normalization factor. This is in contrast to theoretical predictions[14] of $N=3.33$, and previous experimenters have used $N=3.33$ successfully for (d,t) reactions in the region.[20,22] We have carefully measured our target thickness with an alpha gauge and we are convinced the cross sections listed are free of any gross experimental error.

We have failed to observe any evidence of configuration mixing in the $K^\pi=8^+$ bands. From the assignments made in this and previous investigations,[2,7-9] we anticipate the $\frac{9}{2}^-[514]\pm\frac{7}{2}^-[514]$ $K^\pi=8^+$ band head near 500 keV in ^{180}Ta. This is about 250 keV higher in excitation than predictions based on previous assignments of the $\frac{7}{2}^+[404]\pm\frac{7}{2}^-[514]$ configuration. There are no unassigned peaks observed in the region of 500 keV of excitation in the spectrum, and the states observed in the $\frac{7}{2}^+[404]\pm\frac{9}{2}^+[624]$ configuration appear to have significantly more experimental intensity relative to the calculated absolute differential cross sections than do the remaining states which were identified in the spectra. Thus we observe no evidence for configuration mixing between the two lowest-lying $K^\pi=8^+$ bands. Since the two bands apparently lie about twice as far apart as previously predicted, this cannot be considered surprising. Thus we consider the observation of configuration mixing among the allowed two-quasiparticle configurations of the $\pi\frac{9}{2}^-[514]$, $\pi\frac{7}{2}^+[404]$, $\nu\frac{9}{2}^+[624]$, and $\nu\frac{7}{2}^-[514]$ Nilsson orbitals to still be an interesting possibility in the ^{178,180}Hf isotopes.

ACKNOWLEDGMENTS

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