Decay of ^{187}W and the $1/2^+[411]$ band in odd-mass Re isotopes*

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(Received 22 September 1975)

The γ-ray spectrum of 23.9-h ^{187}W has been measured using Ge(Li) detectors. Singles data obtained with a Compton-suppression γ-ray spectrometer and (GeLi) detectors have been particularly useful in enabling us to detect very low intensity transitions not seen by previous experimenters. Some of these transitions have been used to establish new levels in ^{187}Re at 816.56, 826.6, 844.7, 960.17, 1190.38, and 1220.8 keV, and evidence is presented for assignment of the first four of these levels as the $\frac{5}{2}\frac{1}{2}^+[411]$, $\frac{7}{2}\frac{1}{2}^+[411]$, $\frac{7}{2}\frac{7}{2}^+[404]$, and $\frac{5}{2}\frac{3}{2}^+[411]$ Nilsson states, respectively.

[RADIOACTIVITY ^{187}W [from ^{186}W(n,γ)]; measured E_γ, I_γ, $T_{1/2}$; deduced logft. ^{187}Re deduced levels, J, π. Ge(Li) detectors, natural targets.]

I. INTRODUCTION

The experimental investigation of transitional nuclei, where the nuclear shape changes considerably with nucleon number, remains a fertile testing ground as theoretical nuclear models become more refined. One such series of nuclei is the odd-proton $^{183-187}$Re isotopes, where the nuclear deformation decreases substantially with the addition of each neutron pair. It is of interest to map the systematic changes in energy-level structure with deformation in these nuclei, and the purpose of the present investigation was to extend our knowledge of the levels in ^{187}Re.

Over the past decade, the level scheme of ^{187}Re has been investigated using a variety of experimental techniques, with the result that most of the energy levels below 1 MeV in excitation are reasonably well characterized. Decay measurements by Herman, Heighway, and MacArthur[1] and Brabec, Maly, and Vobecky,[2] which included both γ-ray and conversion electron measurements for the more intense transitions, were used to determine the spin and parity of most of these levels. Additional understanding has been gained from other types of experiments. Lu and Alford[3] investigated the odd-A Re isotopes ^{183}Re, ^{185}Re, and ^{187}Re, using the transfer reactions (α, t) and $(^3\mathrm{He}, d)$ on the appropriate even-A targets. Resonance fluorescence measurements,[4] lifetime measurements,[5] inelastic scattering data,[6] and nuclear orientation studies[7] have all contributed to the elucidation of the low-energy level structure of ^{187}Re.

The results of these experiments have been interpreted successfully for the most part in terms of the Nilsson model,[8] although there remain some aspects of the level structure that need to be explained. Perhaps the most striking anomaly in this region is the inverted ordering of the $\frac{1}{2}^+[411]$ rotational band in ^{185}Re and ^{187}Re. In ^{187}Re the $\frac{1}{2}^+$ member is found at 625.5 keV and the $\frac{3}{2}^+$ member at 618.4 keV. A similar inversion is found in ^{185}Re while ^{183}Re exhibits a "normal" sequence, which typically has the $\frac{3}{2}^+$ band member at an energy 5 to 15 keV above the $\frac{1}{2}^+$ member. The Re data are illustrated in Fig. 1 together with some other examples of the $\frac{1}{2}^+[411]$ band in well-deformed nuclides. Within this context we undertook investigations of the level structures of ^{183}Re and ^{187}Re as observed in radioactive decay of ^{183}Os^{g,m} and ^{187}W. In the ^{187}W decay experiments, we emphasized the search for very weak γ-ray transitions. We shall report the results of ^{183}Os^{g,m} decay studies in detail in a later publication, but preliminary results on the $\frac{1}{2}^+[411]$ band are noted below.

II. EXPERIMENTAL METHODS AND RESULTS

A. Source preparation

Radioactive sources of 23.9-h ^{187}W were produced by the (n,γ) reaction on very high-purity natural-abundance tungsten metal foil and powder at the Livermore Pool Type Reactor (LPTR). In some early experiments tungsten was purified chemically by dissolving the target and precipitating the tungsten as tungstate. In general it was found that the radiochemical purity of untreated sources was comparable to those chemically purified; as a consequence most sources were counted directly. Radiochemical impurities due to the (n,γ) reaction on ^{180}W and ^{184}W were quite low and easily distinguishable by half-life (122 and 75 days) so

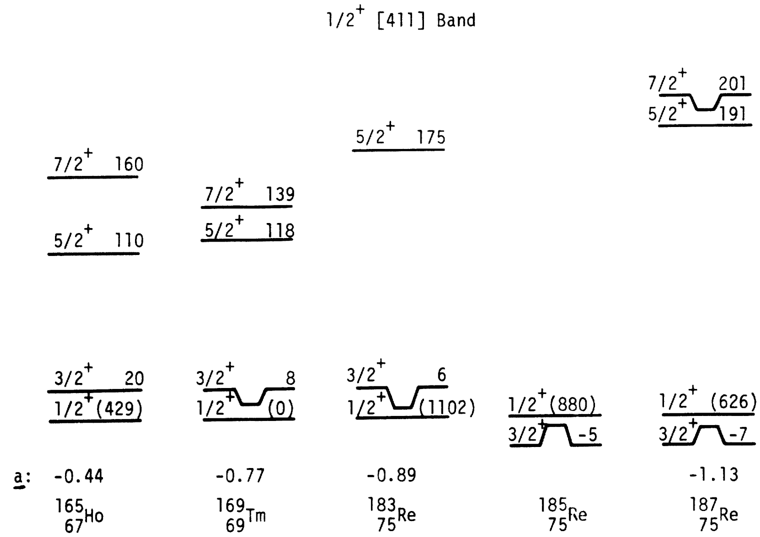

FIG. 1. The $\frac{1}{2}^+$[411] rotational band in various deformed nuclei. Rotational energies are given relative to the bandhead energy in keV. The bandhead excitation energy is enclosed in parentheses.

that the use of enriched target material was not necessary and in fact, undesirable, since the separated isotope contained a larger amount of chemical impurity than the natural abundance materials used in these experiments.

B. γ-ray singles measurements

In the present study, we concentrated our effort on a search for low-intensity lines, which our counting and computer analysis systems are particularly adept at identifying. One of our intentions was to identify the β population of levels known from reaction spectroscopy studies. Some coincidence experiments were done but yielded no new information. Since most of our concern is with very weak lines, the coincidence results are not reported here.

We used a variety of detector systems to measure the singles γ-ray spectra from ^{187}W decay. Several large volume Ge(Li) detectors (~50 cm^3) of moderate resolution (~1.9-keV full width at half-maximum at 1332 (keV) were used to periodically record spectra over the energy range 0 to 2 MeV during the week following the bombardment. Various combinations of Cd and Pb absorbers up to 2.54 cm thickness of Pb were used to suppress low-energy γ rays and x rays in some experiments. These spectra provided half-life data for assignment of lines to ^{187}W decay and were used for photopeak intensity determinations. These data were supplemented at low energies with spectra taken on a planar Ge(Li) detector equipped with a Be window. The identification of some of the weaker lines below 1 MeV was enhanced by using a Ge(Li) Compton-suppression spectrometer. The spectrometer consists of a 7-cm^3 Ge(Li) detector with a NaI(Tl) anticoincidence shield as reported by Camp.[9] γ-ray decay rates were also followed with this instrument. Very weak high-energy lines were recorded through a 2.54-cm Pb absorber with a large volume Ge(Li) detector. Data accumulated over a 9-day period was searched for weak transitions. Repetitive experiments using different target materials and handling procedures were used to assign weak high-energy lines to ^{187}W decay, since in some instances the half-life data were inconclusive.

Detector efficiencies were determined with primary standard sources. Several secondary standards whose relative γ-ray intensities are well known were used to further define the response curve. Energy calibrations were made using combinations of the above sources as internal standards during data acquisition.

A computer code GAMANAL developed by Gunnink, Levy, and Niday[10] was used to analyze the γ-ray spectra. Decay data were used to establish the contribution of impurity lines in most instances. The detailed results of γ-ray energies and intensities are found in Table I. Very weak lines of questionable assignment to ^{187}W decay are enclosed in parentheses. In some instances these lines have been placed between levels in the ^{187}Re scheme, and the reader is cautioned about the tentativeness of these assignments.

In general our results augment those of previous investigators, with some 40 additional γ rays reported here for the first time; however, there is one notable discrepancy. The value we report for the intensity of the 638.7-keV γ ray is about an

TABLE I. γ rays assigned to ^{187}W decay.

$E\gamma\,(\Delta E\gamma)$ (keV)	$I\gamma\,(\Delta I\gamma)$ [a]	Assignment	$E\gamma\,(\Delta E\gamma)$ (keV)	$I\gamma\,(\Delta I\gamma)$ [a]	Assignment
16.61(2) [a]	0.07(1)		551.55(1)	58.9(2)	686→134
29.23(3)	0.044(10)	618→589	564.62(19)	0.14(5)	1190→626
(36.38)	≤0.25	(626→589)	573.71(14) [b]	0.006(2)	
40.92(5) [b]	0.02(1)		576.31(8)	0.077(11)	879→303
43.66(6)	0.02(1)	816→773	578.72(11) [b]	0.011(4)	
72.46(1)	129.0(4)	206→134	589.09(3)	1.41(3)	589→0
77.37(5)	0.08(2)	589→512	612.92(42)	0.024(12)	1230→618
93.22(5) [b]	0.07(1)		618.37(1)	72.7(1)	618→0
100.14(2) [b]	0.104(15)		625.52(1)	12.6(1)	626→0
106.59(1)	0.295(7)	618→512 (879→773)	638.65(13)	0.037(11)	773→134 (845→206)
113.75(2)	0.89(2)	626→512	647.30(25)	0.009(4)	647→0
123.79(11) [b]	0.03(1)		682.34(20)	0.08(8)	816→134
134.22(1)	102.5(5)	134→0	685.81(1)	316(3)	686→0
138.50(6) [b]	0.05(2)		693.06(22)	0.015(9)	827→134
165.67(40) [b]	0.010(4)		(730.32)	≤0.2	(864→134)
168.50(40)	0.030(11)	303→134	745.21(2)	3.45(4)	879→134
(174.04)	≤0.005	(685→511)	767.37(75) [b]	0.018(7)	
198.34(12)	0.020(5)	816→618	772.87(2)	47.7(1)	773→0
206.29(3)	1.65(4)	206→0	816.56(2)	0.114(8)	816→0
208.29(16)	0.008(3)	827→618	825.95(25)	0.0027(4)	960→134
239.03(3)	1.00(4)	864→626	826.65(25)	0.0027(4)	827→0
246.18(1)	1.38(4)	864→618	844.70(50)	0.0028(16)	845→0
275.61(12)	0.024(7)	864→589	864.55(1)	3.89(3)	864→0
352.86(17)	0.018(7)	865→512	879.43(5)	1.64(2)	879→0
374.31(14) [b]	0.03(1)		960.17(5)	0.0153(8)	960→0
375.93(13) [b]	0.04(1)		1056.24(5)	0.0026(7)	1190→134
454.92(2)	0.34(2)	589→134	(1086.60)	≤0.001	(1221→134)
479.53(1)	253(1)	686→206	(1095.90)	≤0.0008	(1230→134)
484.15(3)	0.20(1)	618→134	1190.38(12)	0.0025(3)	1190→0
492.80(20) [b]	0.3(1)		1220.80(25)	0.000 20(6)	1221→0
511.76(1)	7.47(8)	512→0	1230.10(4)	0.0153(17)	1230→0

[a] Photon intensity per 1000 decays of ^{187}W (a 2% error in the knowledge of the Ge(Li) efficiency curve must be added in quadrature to obtain the absolute decay rate).

[b] These γ rays were observed to decay with approximately the ^{187}W half-life. They are not placed in the ^{187}Re level scheme and assignment to ^{187}W decay is considered tentative.

order of magnitude lower than that found by Herman *et al.*[1] when the differences in normalization of intensity scales are taken into account. The relevant portion of the γ-ray spectrum is shown in Fig. 2.

III. DISCUSSION

The decay scheme that best fits the experimental data is shown in Fig. 3. Coincidence evidence, intensity balance, energy sums, and multipolarities are taken into account. Logft values are shown to the left. Evidence that supports new levels proposed here is presented below, and discussion is limited to the new levels except in those instances where we have gained some additional understanding of the nature of previously established levels. Some pertinent facts about the levels and their Nilsson model assignments are summarized in Table II. A comprehensive compilation of the level-scheme evidence to 1974 was recently published by Ellis[11] and is an excellent source of background material for our discussion.

In our discussion we shall treat new levels first, comment on known levels, and conclude with some remarks on the $\frac{1}{2}^+[411]$ band in $^{183-187}$Re isotopes.

A. New energy levels

Based on our experimental decay data six new energy levels are proposed at 816.56, 826.6, 844.7, 960.17, 1190.38, and 1220.8 keV.

$\frac{5}{2}\frac{1}{2}^+$[411] state at 816.56 keV. Brabec *et al.*[2] and Langhoff[4] tentatively suggested the existence of a level at 816 keV based on the observation of a single γ ray of that energy and considered it as a possible $\frac{5}{2}^+$ member of the $\frac{1}{2}^+[411]$ rotational band in ^{187}Re. Our observation of four transitions that fit energetically as depopulating a level at 816.56 keV establishes the existence of this level with a mod-

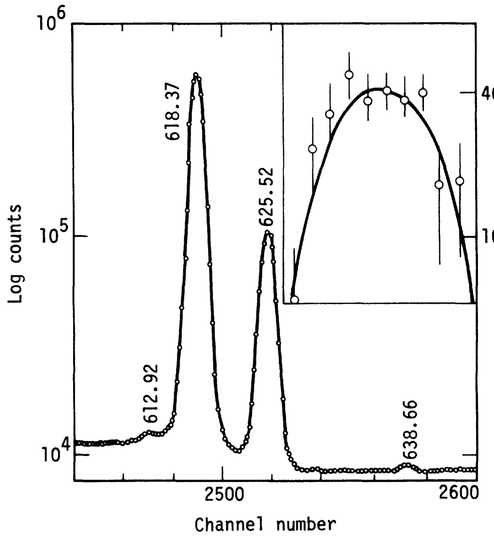

FIG. 2. A portion of the γ-ray spectrum showing the 638.7-keV transition. *(Nota bene:* insert is GAMANAL peak shape fit to the data less background counts for channels 2565-2574.)

erate degree of certainty. The assigned transitions to the $\frac{3}{2}\frac{1}{2}^+[411]$ band member at 618.35 keV and the $\frac{3}{2}\frac{3}{2}^+[411]$ bandhead at 772.87 keV, in addition to the transitions to the $\frac{5}{2}^+$ and $\frac{7}{2}^+$ members of the $\frac{5}{2}^+[402]$ ground-state band supports the assignment $\frac{5}{2}\frac{1}{2}^+[411]$ for this level. The $\frac{1}{2}^+[411]$ band will be discussed later in this section.

$\frac{7}{2}\frac{1}{2}^+$ [411] state at 826.6 keV. The transitions of energy 826.6, 693.1, and 208.29 keV suggest the existence of a new level at 826.6 keV, which depopulates to the $\frac{5}{2}^+$ and $\frac{7}{2}^+$ ground-state band members and to the $\frac{3}{2}\frac{1}{2}^+[411]$ state at 772.87 keV. We propose that this level is the $\frac{7}{2}^+$ member of the $\frac{1}{2}^+$ [411] rotational band. The theoretical, reduced-transition-probability ratio $B(E2, \frac{7}{2}\frac{1}{2} \to \frac{7}{2}\frac{5}{2})/B(E2, \frac{7}{2}\frac{1}{2} \to \frac{5}{2}\frac{5}{2}) = 5.96$ agrees reasonably with the experimental value of 5.6 ±2.5, and the apparent $\log f_1 t$ value of 10.4 is consistent with the $\frac{7}{2}^+$ assignment.

$\frac{7}{2}\frac{7}{2}^+$ [404] state at 844.7 keV. We suggest that the 844.7 keV γ ray, the highest energy transition in ^{187}Re that does not fit between established levels, deexcites a level of the same energy to the ground state. Of course, any energy level based on a single depopulating transition is very speculative.

Assuming the existence of the 844.7 keV level we calculate an apparent $\log f_1 t$ of 11.4, which is consistent with a $\frac{7}{2}^{\pm}$ assignment. There are two spin $\frac{7}{2}$ Nilsson states expected at about 850 keV; $\frac{7}{2}\frac{7}{2}^+$ [404] and the $\frac{7}{2}^-$ member of the $K^\pi = \frac{5}{2}^-$ vibrational band $\{\frac{9}{2}^-[514], 2^+\}$ based at 685.81 keV. The $\frac{7}{2}\frac{7}{2}^+$ [404] assignment is suggested by Fig. 4, which is a Nilsson level scheme[8] calculated with $A = 187$ parameters, and by the calculation of Malov, Soloviev, and Fainer,[12] who, using a Woods-Saxon potential, predicted the $\frac{7}{2}\frac{7}{2}^+[404]$ state in ^{187}Re to be 95% pure and to lie at 910 keV. The corresponding state in ^{183}Re is firmly established at 851.1 keV, which compares favorably with the calculated value[12] of 900 keV.

If the spin $\frac{7}{2}$ state is instead assigned as $\frac{7}{2}\{\frac{9}{2}^-$ [514], $2^+\}$, the implied $\hbar^2/2J$ of 22.7 keV for this band is about 7% higher than that of the band built on the 772.87-keV level. We prefer the assignment $\frac{7}{2}\frac{7}{2}^+[404]$ over $\frac{7}{2}\{\frac{9}{2}^-[514], 2^+\}$ because no other deexciting transitions to the ground band were seen in our experiments. If the latter assignment were correct we would expect these γ rays to occur within the detection limits of our experiments.

$\frac{5}{2}\frac{3}{2}^+$ [411] state at 960.17 keV. Assuming the same $\hbar^2/2J$ value (19.2 keV) as for the ground-state band, one expects to find the $\frac{5}{2}^+$ member of the $\frac{3}{2}^+[411]$ band at about 960.5 keV. This level should be populated in ^{187}W decay and depopulate primarily to the $\frac{5}{2}^+$ and $\frac{7}{2}^+$ members of the ground state band. We thus propose that our observed 960.17- and 825.9-keV γ rays depopulate the $\frac{5}{2}\frac{3}{2}^+[411]$ state at 960.17 keV even though the deduced $\log ft$ value of 10.1 is higher than we would have expected.

Levels at 1190.38 and 1220.8 keV. New levels at 1190.38 and 1220.8 keV are proposed without assignments. The existence of a level at 1190.38 keV is supported by three deexciting γ rays. The level at 1220.8 keV is proposed on the basis of a single transition to the ground state, since this is the only way to accomodate a 1220.8-keV transition in the decay scheme without exceeding Q(experimental) = 1311 keV.[1]

B. Other levels

Additional evidence in support of previously proposed levels in ^{187}Re was garnered from our results.

$\frac{9}{2}\frac{5}{2}^+$ [402] state at 302.9 keV. The $\frac{9}{2}^+$ member of the $\frac{5}{2}^+[402]$ ground-state rotational band has been seen in radioactive decay for the first time. The $\frac{9}{2}^+$ rotational level, which was previously assigned on the basis of Coulomb excitation and (d,d') and (α,t) reaction spectroscopy,[3,6] is supported by our observation of 576.31- and 168.5-keV γ rays feeding and deexciting this level, respectively. The energy of this level is now known to ±0.2 keV.

$\frac{5}{2}^+$ $(\{\frac{5}{2}^+$ [402], $2^+\} + \frac{1}{2}^+$ [400]) state at 647.3 keV. The $\frac{5}{2}^+$ rotational-band member of the mixed state $(\{\frac{5}{2}^+[402], 2^+\} + \frac{1}{2}^+[400])$ at 647.3 keV has been seen for the first time in radioactive decay with the identification of a transition of this energy. The character of this level is based on observations in Coulomb excitation, and (d, d'), (α,t), and $(^3\text{He}, d)$

reaction experiments.[3,6] Our measurement of the depopulating γ ray fixes the level energy with ±0.3-keV uncertainty.

$\frac{3}{2}\frac{3}{2}^+$ [411] state at 864.6 keV. The observation of a level at 864.6 keV assigned as the bandhead of the $\frac{3}{2}^+$[411] Nilsson orbital is strengthened by our measurement of five depopulating transitions, two more than previously reported.[1]

$\frac{5}{2}\frac{1}{2}^-$ [541] state at 1230.10 keV. Lu and Alford[3] have tentatively assigned a level at 1233 keV as the $\frac{5}{2}^-$ member of the $\frac{1}{2}^-$[541] band based on (α, t) and (^{3}He, d) reaction data and the observation of an apparent $\frac{9}{2}^-$ band member at 1201 keV. We observed two γ rays that can be assigned to depopulate a level at 1230.10 keV, consistent with a $\frac{5}{2}^-$ assignment, which we believe to be the same level observed in the reaction spectroscopy experiments. The logft value is consistent with a $\frac{5}{2}\frac{1}{2}^-$[541] assignment.

C. $\frac{1}{2}^+$[411] rotational band

The $\frac{1}{2}^+$[411] rotational band is found throughout the rare earth region and exhibits an apparent decoupling parameter a, which varies from −0.44 in ^{165}Ho to −1.13 in ^{187}Re (Fig. 1). In some cases there is good agreement between theory and experiment, such as in ^{169}Tm; but in other nuclei,

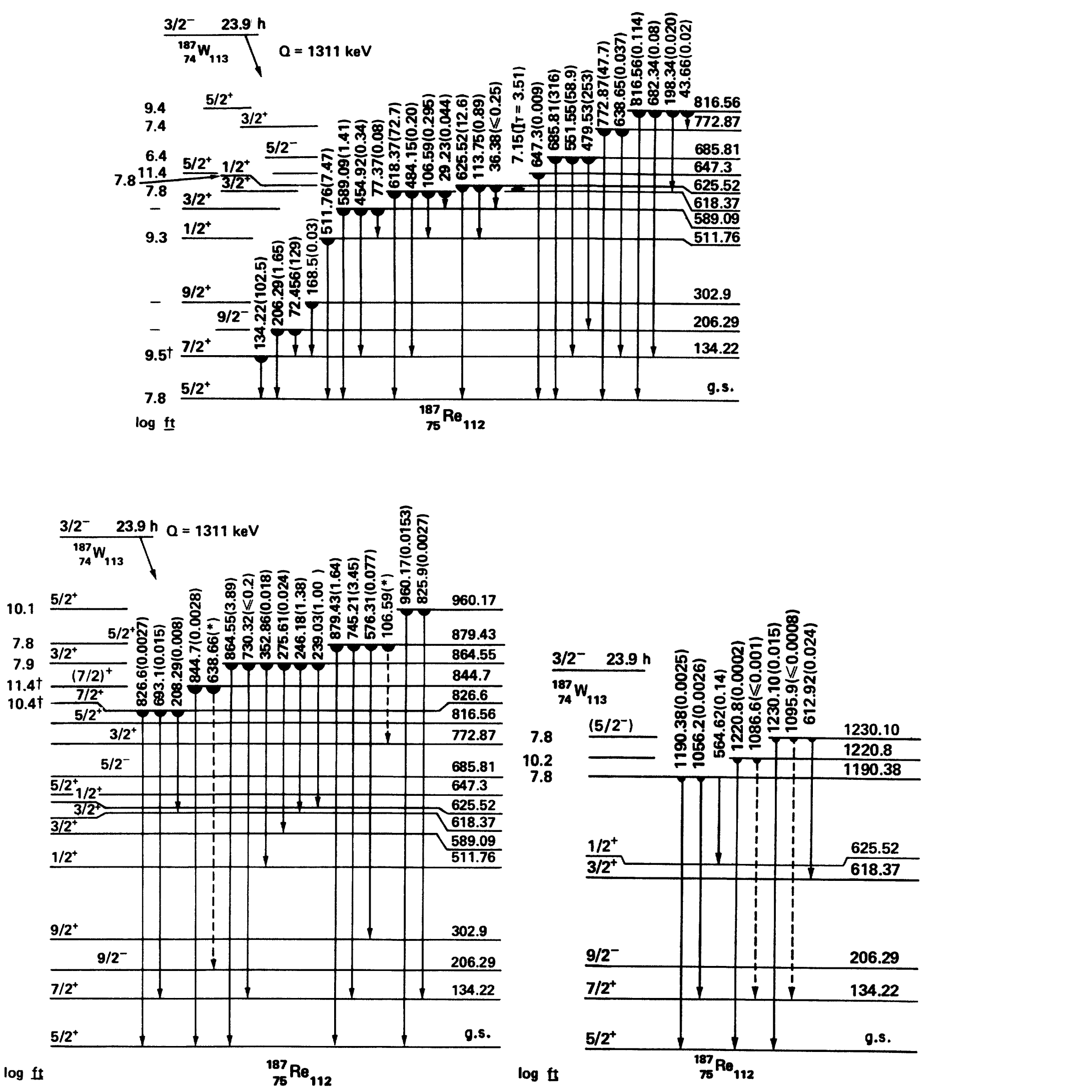

FIG. 3. Level scheme of ^{187}Re as seen in decay of ^{187}W. Energies are in keV and photon intensities per 1000 decays of ^{187}W shown in parentheses. Transitions placed twice in the scheme are marked with an asterisk. To the left of each level is shown the J^{π} assignment and the logft value. The symbol (†) is used to designate a logf_1t value.

TABLE II. Log*ft* values and level assignments in ^{187}Re.

Energy (keV)	I_β (%)	log*ft*	J^π	$K^\pi[Nn_z\Lambda]$
0	33.1	7.8	$\frac{5}{2}^+$	$\frac{5}{2}^+[402]$
134.22	1.8	9.5 [a]	$\frac{7}{2}^+$	
302.9	...	...	$\frac{9}{2}^+$	
206.29	...	...	$\frac{9}{2}^-$	$\frac{9}{2}^-[514]$
511.76	0.18	9.3	$\frac{1}{2}^+$	$\{\frac{5}{2}^+[402], 2^+\} + \frac{1}{2}^+[400]$
589.09	...	...	$\frac{3}{2}^+$	
647.3	0.0008	11.4	$\frac{5}{2}^+$	
618.37	3.4	7.8	$\frac{3}{2}^+$	$\frac{1}{2}^+[411]$
625.52	3.1	7.8	$\frac{1}{2}^+$	
816.56	0.03	9.4	$\frac{5}{2}^+$	
826.6 [b]	0.002	10.4 [a]	$\frac{7}{2}^+$	
685.81	53.1 [c]	6.4	$\frac{5}{2}^-$	$\{\frac{9}{2}^-[514], 2^+\}$
772.87	4.1	7.4	$\frac{3}{2}^+$	$\frac{3}{2}^+[402] + (\{\frac{7}{2}^+[404], 2^+\})$
879.43	0.74	7.8	$\frac{5}{2}^+$	
844.7	0.0002	11.4 [a]	$(\frac{7}{2}^+)$	$(\frac{7}{2}^+[404])$
864.55	0.60	7.9	$\frac{3}{2}^+$	$\frac{3}{2}^+[411] + \{\frac{1}{2}^+[411], 2^+\}$
960.17 [b]	0.002	10.1	$\frac{5}{2}^+$	
1190.38 [b]	0.0004	7.8		
1220.8 [b]	0.000 02	10.2		
1230.10	0.0033	7.8	$(\frac{5}{2}^-)$	$(\frac{1}{2}^-[541])$

[a] Logf_1t.
[b] New energy level in ^{187}Re; assignments are discussed in the text.
[c] The experimental value 53.1 of Herman *et al.*[1] was adopted for this analysis.

such as $^{183-187}$Re, the agreement is poor. As one goes from ^{183}Re to ^{187}Re there is a decrease in deformation (ϵ_2), which causes the relative energies of the Nilsson orbitals to change and also affects the size of the decoupling parameter with a becoming more negative with decreasing deformation for the $\frac{1}{2}^+$[411] band. It is this combination of deformation-dependent factors that we believe gives rise to the variation of the relative positions of the $\frac{1}{2}^+$[411] band members in the odd-A Re isotopes and the inversion of the band sequence in ^{185}Re and ^{187}Re (Fig. 1).

In Fig. 5 we depict the variation in the experimental bandhead ordering for $^{183-187}$Re with decreasing deformation (increasing A). Recalling Fig. 1, we note that the two lowest band members in ^{185}Re and ^{187}Re are known to be inverted from radioactive decay studies.[13] It has also been postulated from the decay data[13] that the rotational sequence in ^{183}Re is "normal"; this is now confirmed by our observation of a previously undetected 993.4-keV $E2$ transition, which deexcites the $\frac{3}{2}\frac{1}{2}^+$[411] rotational band member at 1107.9 keV to the $\frac{7}{2}\frac{5}{2}^+$[402] ground-state band member at 114.4 keV in ^{183}Re.[14] Returning to Fig. 5 we note that the $\frac{3}{2}^+$[402] bandhead lies above the lowest members of the $\frac{1}{2}^+$[411] band in ^{185}Re and ^{187}Re and below them in ^{183}Re, while other nearby orbitals retain their relative ordering. This observation suggests to us that the $\frac{3}{2}^+$[402] orbital may in some way be influencing the ordering in the $\frac{1}{2}^+$[411] band. If there is significant Coriolis mixing between the $\frac{1}{2}^+$[411] and $\frac{3}{2}^+$[402] bands in the $^{183-187}$Re isotopes, one would expect to see the $\frac{3}{2}^+$ member of the $\frac{1}{2}^+$[411] band pushed down in energy relative to the $\frac{1}{2}^+$ member when the $\frac{3}{2}^+$[402] band lies above the $\frac{3}{2}\frac{1}{2}^+$[411] state and to see the converse when the situation is reversed, in qualitative agreement with experiment. In order to make a definitive statement one must approach the problem of Coriolis mixing in a quantitative way and also take into account the presence of the nearby $\frac{3}{2}^+$[411] and $(\{\frac{5}{2}^+[402], 2^+\} + \frac{1}{2}^+[400])$ states. We are pursuing a quantitative understanding of the Coriolis coupling and will report our re-

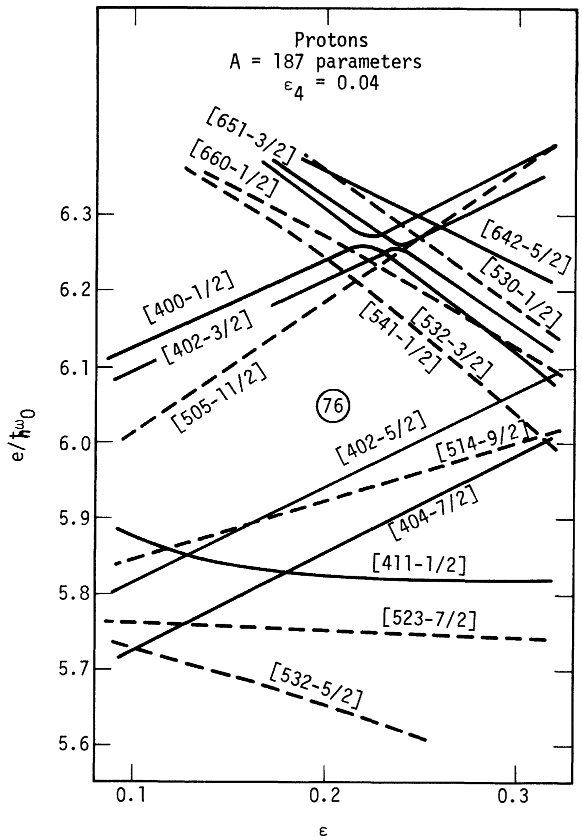

FIG. 4. The Nilsson proton level diagram for $A = 187$ parameters: $\kappa = 0.062$, $\mu = 0.614$, and $\epsilon_4 = 0.04$ (from Ref. 8).

sults together with the $^{183}Os^{g,m}$ decay data in a future article.

IV. SUMMARY AND CONCLUSION

We have proposed a level scheme for ^{187}Re that accommodates more than 99.99% of the γ-ray intensity observed in the decay of 23.9-h ^{187}W. In

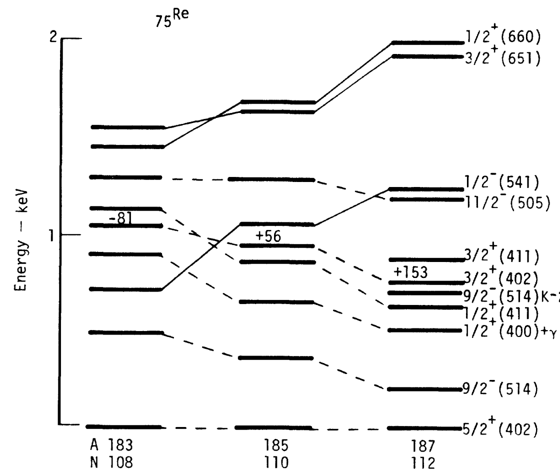

FIG. 5. Systematic trends of experimental levels in $^{183-187}Re$. The numbers above the $\frac{3}{2}^+[402]$ bandheads are energy differences between the $\frac{3}{2}^+[402]$ and $\frac{1}{2}^+[411]$ bandheads in keV.

addition to the previously known levels, the following new levels are proposed: 816.56 keV, $\frac{5}{2}\frac{1}{2}^+[411]$; 826.6 keV, $\frac{7}{2}\frac{1}{2}^+[411]$; 844.7 keV, $\frac{7}{2}\frac{7}{2}^+[404]$; 960.17 keV, $\frac{5}{2}\frac{3}{2}^+[411]$; 1190.38 keV; and 1220.8 keV. It is suggested that Coriolis coupling between the $\frac{1}{2}^+[411]$ and $\frac{3}{2}^+[402]$ bands may be responsible for the inversion of ordering of the two lowest $\frac{1}{2}^+[411]$ band members in ^{185}Re and ^{187}Re.

ACKNOWLEDGMENTS

One of us (D.S.B.) wishes to express his gratitude for the hospitality extended him by members of the Radiochemistry Division at the Lawrence Livermore Laboratory while on leave from Clark University. We wish to thank Dr. M. E. Bunker of Los Alamos Scientific Laboratory and Dr. C. W. Reich of Aerojet Nuclear for their helpful comments.

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*Work supported by the U.S. Energy Research and Development Administration at the Lawrence Livermore Laboratory and in part by the U.S. Energy Research and Development Administration at Clark University.

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