Nuclear Level Structure of Nd^{151}†

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Forty-nine states in Nd^{151} have been observed between the ground state and 2208 keV utilizing 10-MeV deuterons and the reaction $Nd^{150}(d,p)Nd^{151}$. The ground-state Q value for this reaction was measured as 3084 ± 15 keV. Absolute cross sections of the proton groups were measured and angular distributions allowed the determination of l values for eight of these groups. The interpretation of the experimental results was based upon the energy systematics in a deformed nucleus and the relative strengths of the (d,p) transitions in a deformed odd-A nucleus. Levels are assigned as belonging to the $\frac{5}{2}-[523]$, $\frac{3}{2}-[521]$, $\frac{1}{2}-[530]$, and $\frac{1}{2}-[521]$ rotational bands. The $\frac{1}{2}-[521]$ rotational band is shown to be appreciably mixed with the K-2 γ-vibrational bands built on the $\frac{5}{2}-[523]$ and $\frac{3}{2}-[521]$ bands. The comparison between the differing ground-state Nilsson orbitals in Nd^{151}, Sm^{153}, and Gd^{155} suggests increasing deformation in this sequence.

I. INTRODUCTION

A REGION of nuclear deformation from approximately $150\leq A\leq190$ has been clearly experimentally characterized. The onset of this deformation is quite sudden at neutron number 90. However, the properties of 90-neutron nuclei clearly indicate that the usual approximation (in which the intrinsic neutron and/or proton motion and the collective vibrational motion of the nucleus is assumed to follow the rotational motion adiabatically) is considerably less appropriate in the 90-neutron nuclei such as Nd^{150} and Sm^{152} than it is in the nearby 92- and 94-neutron nuclei. Accordingly it is of great interest to see how well the energy-level systematics of 91-neutron odd-A nuclei such as Nd^{151} fit the Nilsson model and to compare the observed systematics with that of other neighboring odd-A nuclei. It is to be hoped that knowledge of the Nilsson systematics on the very edge of the region of nuclear deformation will ultimately provide insight into the complicated "spherical" region of nuclei which occurs just before the region of deformation. Since nuclei in this region cannot be easily described from the point of view of the spherical-shell model because of the complexity of the shell-model states involved, it is possible that a description using Nilsson-model configurations and smaller deformations might be a better zeroth approximation. This paper presents an interpretation of the level structure of the 91-neutron nucleus Nd^{151} obtained from the reaction $Nd^{150}(d,p)Nd^{151}$. The interpretation is based upon the rotational energy systematics in a deformed nucleus and the relative strength of the (d,p) transitions in deformed odd-A nuclei.

II. EXPERIMENTAL PROCEDURE

Targets of Nd^{150} were prepared by vacuum evaporation of approximately 200 $\mu g/cm^2$ of the separated isotope as Nd_2O_3 onto a thin ($\sim$30–50 $\mu g/cm^2$) carbon backing. They were bombarded with approximately 10-MeV deuterons produced with the Florida State University Tandem Van de Graaff accelerator.[1] The protons resulting from the (d,p) reaction on Nd^{150} were analyzed at a number of angles in a magnetic spectrograph and detected by means of nuclear track emulsions. Details of the experimental procedure have been described previously.[2]

Angular distributions of the proton groups were determined by utilizing the ratio of Rutherford to reaction cross section. Rutherford-scattering cross sections were measured at 4 MeV and then without changing the position of the target or spectrograph the (d,p) exposure was taken at 10 MeV.

III. EXPERIMENTAL RESULTS AND THEIR INTERPRETATION

A typical proton spectrum is shown in Fig. 1. Identification of peaks belonging to Nd^{151} was complicated by the existence of a large number of impurities present in the targets. Light impurities were identified by their kinematic shift. Heavy impurities were identified by using exposures taken at 45° on two different targets. One of these targets contained at least twice as much of other isotopes of neodymium as the other.[3] This allowed the identification of peaks resulting from the Nd isotopes other than Nd^{151}, as well as other impurities from their deviations in relative intensities. Table I contains a list of the energy levels in Nd^{151} deduced by this procedure. The energy levels are based on a ground-state Q value of 3084 ± 15 keV. Within the error limits, this value is in agreement with that calculated from the mass table,[4] $Q=3185\pm100$ keV.

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[1] Operation of the Florida State University Tandem van de Graaff Accelerator is supported in part by the U. S. Air Force Office of Scientific Research.
[2] R. A. Kenefick and R. K. Sheline, Phys. Rev. **133**, B25 (1964).
[3] The neodymium isotopic composition of the targets as given by the Separated Isotopes Division of Oak Ridge is:

Target No.	142	143	144	145	146	148	150
1	0.69	0.37	0.89	0.45	1.03	0.94	95.65
2	2.08	1.05	2.28	0.96	2.53	2.01	89.08

[4] J. H. E. Mattauch, W. Thiele, and A. H. Wapstra, Nucl. Phys. **67**, 32 (1965).

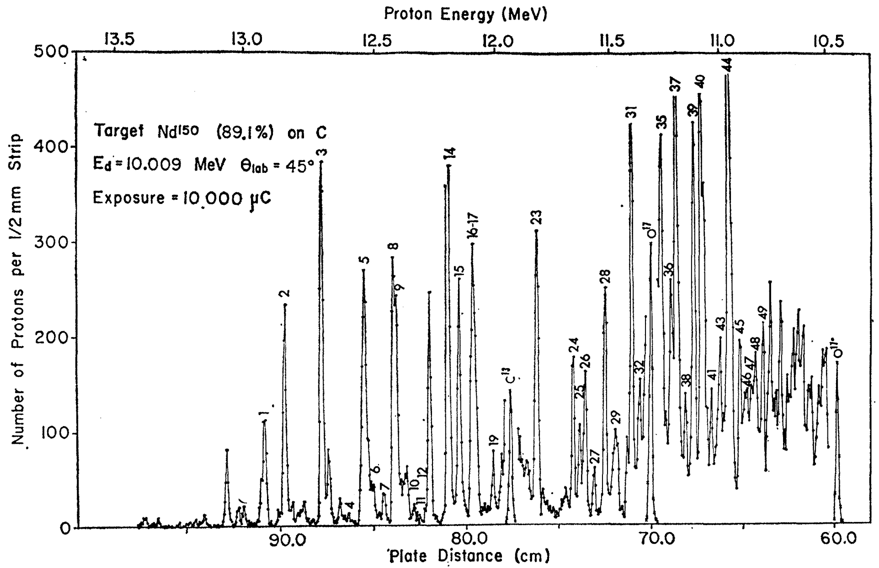

FIG. 1 Spectrum of the levels in Nd^{151} populated in the reaction Nd^{150} (d,p) Nd^{151} at 45°.

Angular distributions were determined in the same manner as for the reaction $Nd^{142}(d,p)Nd^{143}$.[5] The optical-model parameters used were those determined in the (d,p) reaction on Nd^{142}. Since it had been observed that other elements in this mass region had similar parameters, and because the number of protons remained the same with only a small percentage mass change, it was felt that these parameters would be sufficient to determine the angular distributions for the reaction Nd^{150}-$(d,p)Nd^{151}$. These calculated angular distributions are shown as the solid lines in Figs. 2 and 3. A nonlinear

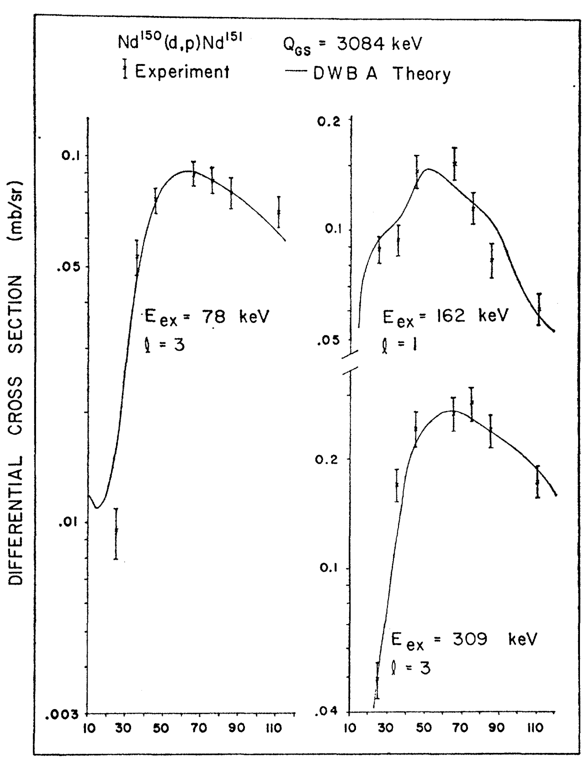

FIG. 2. Angular distributions of the 78, 162, and 309-keV levels in Nd^{151}. (DWBA≡distorted-wave Born approximation.)

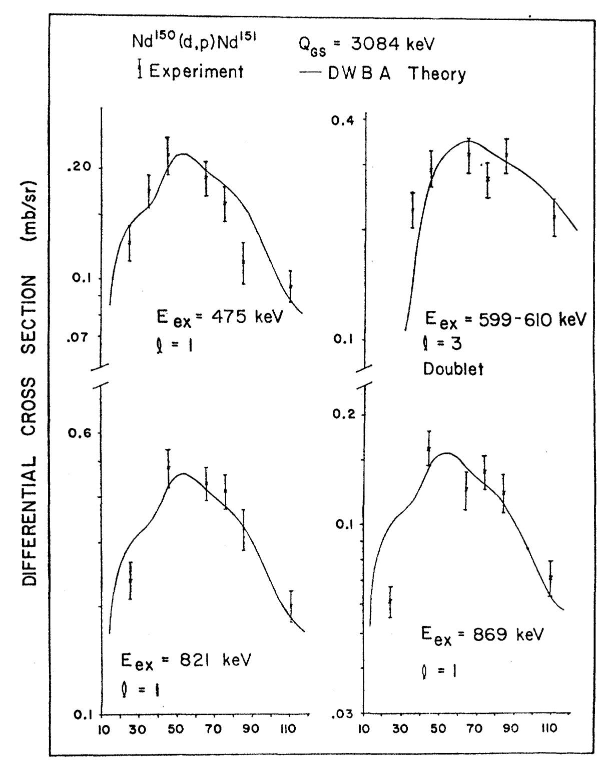

FIG. 3. Angular distributions of the 475, 599–610, 821, and 869-keV levels in Nd^{151}.

[5] C. L. Nealy and R. K. Sheline, Phys. Rev. **155**, 1314 (1967).

least-squares analysis[6,7] of the larger peaks was used to determine their area and the experimental points in Figs. 2 and 3. The results of the angular distributions are also listed in Table I. It should be noted that the 599–610 keV doublet shows a composite angular distribution with $l=3$. Since the relative intensity of the two peaks of this doublet are of the same order of magnitude, it is assumed that both peaks have $l=3$ angular distributions.

The interpretation of these results assumes the applicability of the Nilsson model with superimposed rotational band energy systematics. This assumption allows the relative strengths of the (d,p) population of states in deformed odd-A nuclei to be predicted theoretically.[8] Comparison with the experimentally observed population of states is thus a powerful spectroscopic tool with which to test assignments. The application of this theoretical approach has been discussed previously[9,10].

The deformation δ calculated from the $B(E2)$ values[11] for Nd^{150} is 0.12 ± 0.02; thus it is expected that Nd^{151} will have a somewhat larger deformation. Utilizing a deformation δ of approximately 0.20 the Nilsson orbitals[12] $\frac{3}{2}-[521]$, $\frac{5}{2}-[523]$, $\frac{3}{2}+[651]$ and $\frac{1}{2}+[660]$ are expected to be the ground state or lie low in the excitation spectrum. The first strong state in the spectrum shows an angular distribution of $l=3$. For this reason this state can only be a member of the $\frac{3}{2}-[521]$ or the $\frac{5}{2}-[523]$ bands and must have a spin and parity of $\frac{5}{2}-$ or $\frac{7}{2}-$. From comparisons with the theoretical relative intensities, which are given in Table II, the best agreement is obtained if this state is the $\frac{7}{2}-$ member of the $\frac{5}{2}-[523]$ state. The ground state is assigned as the $\frac{5}{2}-$ member. Using the energy spacing of the $\frac{5}{2}$ and $\frac{7}{2}$ states, the energy of the $\frac{9}{2}$ state, which is expected to be weak, is calculated to be 178 ± 9 keV. Unfortunately much of this energy region is obscured by the large peak at 162 keV. The next rotational band that is expected is the $\frac{3}{2}-[521]$. From the theoretical relative intensities (Table II) two strong members, the $\frac{3}{2}-$ and $\frac{7}{2}-$ states, are expected. The states at 162 and 309 keV show $l=1$ and $l=3$ angular distributions, respectively. These two states also have the right relative intensity (1:1.7) to correspond to the $\frac{3}{2}$ and $\frac{7}{2}$ members of this rotational band. Utilizing the $\frac{3}{2}-\frac{7}{2}$ energy spacing the energy of the $\frac{9}{2}$ state is calculated to be 258 ± 11 keV above the $\frac{3}{2}-$ state or 419 ± 11 keV above the ground state. There is a state at 415 keV of approximately the right intensity. This state was not excited strongly enough to allow its angular distribution to be determined, but, since it has the right energy and intensity, it is assigned as the $\frac{9}{2}-$ member of the $\frac{3}{2}-[521]$ band.

The next state at 475 keV has an angular distribution of $l=1$, which suggests either a $K=\frac{1}{2}-$ or $\frac{3}{2}-$ rotational band. There are no rotational bands within the expected energy range that give only one strong state of the right spin, therefore higher members of its rotational band are expected to be observed. One member of the doublet at 599–610 keV could be a member of this band. Based on these facts, the only band which gives the

Table I. Energy levels of Nd^{151}.

Group No.	E(ex) (keV)	σ (keV)	l	Comments[a]
0	0			w
1	78	3	3	
2	162	3	1	
3	309	3	3	
4	415	4		w
5	475	3	1	
6	515	3		w
7	554	5		w
8	599	5	3	
9	610	5	3	
10	676	5		c
11	698	5		c
12	706	4		c
13	739	5		c
14	821	3	1	
15	869	4	1	
16	922	5		d
17	939	5		d
18	974	4		w
19	1010	4		
20	1052	7		c
21	1083	10		c
22	1128	6		
23	1193	4		
24	1353	4		
25	1383	6		
26	1405	5		
27	1447	6		c
28	1492	7		
29	1532	7		
30	1589	8		
31	1612	5		
32	1645	5		
33	1670	8		
34	1724	7		
35	1750	7		
36	1786	5		
37	1807	8		
38	1854	9		
39	1891	4		
40	1925	3		
41	1974	7		
42	1997	5		
43	2013	7		
44	2053	4		
45	2102	5		
46	2133	5		
47	2155	8		
48	2178	6		
49	2208	6		

[a] w-weak levels; d-doubtful; c-the existence of these levels in Nd^{151} is doubtful but there is slight evidence for them.

[6] R. H. Moore and R. K. Zeigler, Atomic Energy Commission Report No. La-2367 (unpublished).

[7] G. L. Struble, Ph.D. dissertation, Florida State University, 1964 (unpublished).

[8] G. R. Satchler, Ann. Phys. (N. Y.) **3**, 275 (1958).

[9] M. N. Vergnes and R. K. Sheline, Phys. Rev. **132**, 1736 (1963).

[10] R. A. Kenefick and R. K. Sheline, Phys. Rev. **139**, B1479 (1965).

[11] Y. Yoshizawa, B. Elbek, B. Herskind, and M. C. Olesen, in *Proceedings of the Third Conference on Reactions Between Complex Nuclei*, edited by A. Ghiorso, R. M. Diamond, and H. E. Conzett (University of California Press, Berkeley, California, 1963), p. 289.

[12] S. G. Nilsson, Kgl. Danske Videnskab. Selskab, Mat. Fys. Medd. **29**, No. 16 (1955).

TABLE II. Theoretical relative intensity.

Spin \ Orbital	$\frac{1}{2}-[501]$	$\frac{1}{2}-[510]$	$\frac{1}{2}-[521]$	$\frac{1}{2}-[530]$	$\frac{1}{2}-[541]$	$\frac{1}{2}+[660]$	$\frac{3}{2}-[501]$	$\frac{3}{2}-[512]$	$\frac{3}{2}-[521]$	$\frac{3}{2}-[532]$	$\frac{3}{2}+[651]$
$\frac{1}{2}$	1	0.01	3.14	0	0.41	0					
$\frac{3}{2}$	0.21	1	1	1	1	0.14	1	1	1	1	0
$\frac{5}{2}$	0.06	0.18	0.73	0.16	0.20	1	0.05	0.51	0.01	0.95	1
$\frac{7}{2}$	0.01	0.08	0.61	0.61	0.20	0	0.02	0.20	2.10	1.16	0
$\frac{9}{2}$	0	0	0.04	0.06	0.03	1.05	0	0.02	0.08	0.22	1.91
$\frac{11}{2}$	0	0	0	0.01	0	0	0	0.01	0.01	0.04	0
$\frac{13}{2}$											1
Cross section	0.48	0.33	0.06	0.09	0.13	0.01	0.56	0.08	0.05	0.03	0.003
$\frac{1}{2}$											
$\frac{3}{2}$											
$\frac{5}{2}$	1	0.01	0.43	0.19							
$\frac{7}{2}$	0.03	1	1	0.13	1	1	0.01				
$\frac{9}{2}$	0	0.02	0.39	1	0	0.95	1	1	0.02		
$\frac{11}{2}$	0	0	0	0	0	0.19	0.01	0.01	0.01	1	0
$\frac{13}{2}$				0.87			1.90		1		1
Cross section	0.17	0.14	0.02	0.005	0.17	0.01	0.003	0.01	0.006	0.01	0.006

right energies and intensities is the $\frac{1}{2}-[530]$ band. From the theoretical relative intensities it can be seen that the $\frac{1}{2}-$ member should not be observed, but the $\frac{3}{2}$, $\frac{5}{2}$, and $\frac{7}{2}-$ members should have the intensity ratio of 1.0:0.16:0.61. The equation relating the energy separations in a $K=\frac{1}{2}$ band has two first-order constants, the moment-of-inertia parameter $\hbar^2/2\mathfrak{J}$ and the decoupling parameter a. Since only three levels in this band can be expected to be experimentally observed, the two constants can be determined by the choice of levels, but there can be no energy test of the band. Since the intensity of the $\frac{5}{2}-$ state is not large enough to allow its angular distribution determination, its assignment has to be based on energy and intensity

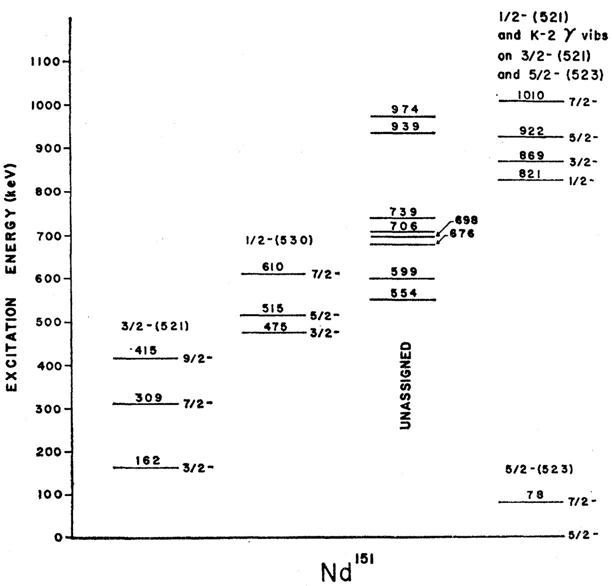

FIG. 4. Rotational bands assigned in Nd^{151}.

considerations. There are two states, one at 515 keV and one as 554 keV, which have approximately the right intensity to be the $\frac{5}{2}-$ state. If the 554-keV level is assigned as the $\frac{5}{2}-$ state a negative value of the decoupling parameter is obtained, while if the 515-keV state is assigned as the $\frac{5}{2}-$ state a positive value is obtained. Since the theoretical value is positive ($a=0.63$), the 515-keV state is assigned as the $\frac{5}{2}-$ member. The assignment of the $\frac{7}{2}-$ member to the 610-keV state is made because it gives a value of the decoupling parameter ($a=0.27\pm0.07$) which is closest to the theoretical relative intensities. However, intensity errors involved in the least-squares fitting of one or the other members of an unresolved doublet (of which the 610-keV state is an example) could be as high as 30 to 50%. In view of the relatively poor agreement between the theoretical value of the decoupling parameter and that experimentally observed, this assignment of the $\frac{1}{2}-[530]$ band must be considered tentative. However, decoupling parameters are often much lower than theoretically expected, particularly when the $K=\frac{1}{2}$ band can be expected to have $K-2$ γ-vibrational admixtures. Furthermore, the fairly good agreement between the calculated and experimental intensities gives us enough confidence in the tentative assignment that it is shown in both Figs. 4 and 5.

The first strong state about which there is considerable ambiguity in the configurational assignment is that at 599 keV. This state probably has an $l=3$ angular distribution although $l=5$ cannot be completely ruled out. Among the different possible assignments for this relatively strongly populated state are: (1) the $\frac{7}{2}-$ member of the $\frac{5}{2}-[512]$ band, (2) the $\frac{11}{2}-[505]$ band head, (3) the $\frac{1}{2}-[521]+K-2$ γ band built on the $\frac{5}{2}-[523]$ and $\frac{3}{2}-[521]$ bands, and (4) the β and/or pairing vibration band with unknown admixtures of Nilsson states with $K=\frac{5}{2}-$.

The first three of these suggestions seem less probable than the fourth. Suggestion (1) seems improbable because the state has only approximately $\frac{1}{3}$ of the expected intensity and because the Nilsson systematics suggest this state should appear somewhere in the region from ~1000 to 1600 keV. Indeed this state is suggested very tentatively at 1083 keV. Suggestion (2) seems unsatisfactory because the $\frac{11}{2}-[505]$ state if it occurs at 599 keV would be a hole state extremely weakly populated in the (d,p) reaction. Suggestion (3) may be dismissed because the measured angular distribution is inconsistent with $l=1$. Thus we are left with suggestion (4). It is expected that a β and/or pairing vibrational band should fragment the ground-state vibrational band, while retaining its essential energy spacing and cross-section characteristics. Thus if this interpretation is correct, one can expect a weak $\frac{5}{2}-$ state followed approximately 78 keV higher in excitation by a considerably stronger $\frac{7}{2}-$ state. In this interpretation the 599-keV state could be the $\frac{7}{2}-$ state, the $\frac{5}{2}-$ would be obscured by the 515-keV state already assigned, and the $\frac{9}{2}-$ state could be the 698- or 706-keV states. This interpretation is made more plausible by the presence of extremely low β-vibrational bands in all 90-neutron nuclei including Nd^{150} and by the fact that a β-vibrational band has been observed in the isotonic nucleus Gd^{155} at 594 keV.[13,14] However, in view of the uncertainties involved in the interpretation, this assignment is not shown in either Figs. 4 or 5.

The last rotational band which is assigned is the $\frac{1}{2}-[521]$ band. The two strong states at 821 and 869 keV show an $l=1$ angular distribution, and are in an intensity ratio of approximately 3:1, respectively. This is exactly what is expected for the $\frac{1}{2}-$ and $\frac{3}{2}-$ members of the $\frac{1}{2}-[521]$ band. Unfortunately the next large peak is a doublet and does not show an angular distribution associated with any particular l value. Either one of its members is of approximately the right intensity and energy to be the $\frac{5}{2}-$ member. The 922 keV member is chosen as the $\frac{5}{2}-$ state because it gives the largest decoupling parameter, $a=0.17\pm0.06$. The theoretical value is $a=0.95$. The energy of the $\frac{7}{2}-$ state is calculated to be 1013 ± 18 keV. The state at 1010 keV is assigned based on energy and intensity considerations. A comparison between the theoretical and experimental relative intensities within each band is shown in Table III, and a summary of the level assignments to the various rotational bands is shown in Fig. 4.

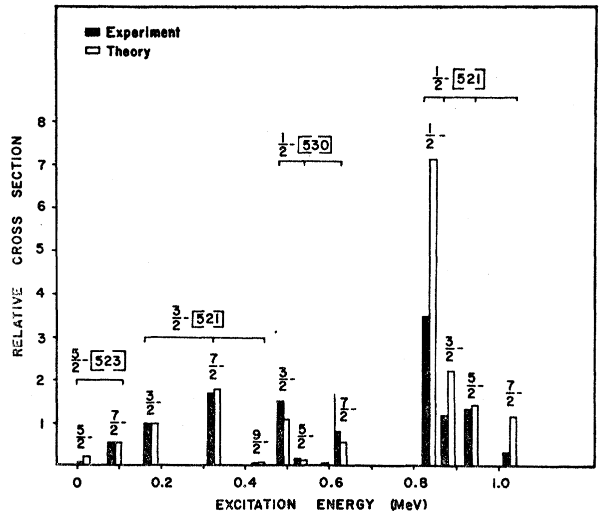

FIG. 5. Comparison of the theoretical relative cross sections with the experimental relative cross sections. Both the theoretical and experimental cross sections have been normalized to the $\frac{3}{2}-$ member of the $\frac{3}{2}-[521]$ rotational band.

Thus far the theoretical relative intensities have been compared only within the same rotational band. From the equation

$$\frac{d\sigma}{d\omega}=2C_j^2|\langle\psi_i|\psi_f\rangle|^2U^2\left(\frac{d\sigma}{d\omega}\right)_{sp},$$

where C_j is the vector-coupled amplitudes, $\langle\psi_i|\psi_f\rangle$ is the vibrational overlap, U^2 is the probability that the single particle state is empty, and $(d\sigma/d\omega)_{sp}$ is the single-particle (d,p) stripping cross section, it can be seen that a ratio between two states of the same rotational band is simply a ratio between the respective products, $C_j^2(d\sigma/d\omega)_{sp}$, for each state. In order to make comparisons of the cross sections between states of different rotational bands the value of the various U^2's must be known and it must be assumed that the vibrational overlap $\langle\psi_i|\psi_f\rangle$ is the same for all states. Figure 5

TABLE III. Comparison of relative intensities within each band.

Spin \ Orbital	$\frac{1}{2}-[521]$ Theo	$\frac{1}{2}-[521]$ Expt	$\frac{1}{2}-[530]$ Theo	$\frac{1}{2}-[530]$ Expt	$\frac{3}{2}-[521]$ Theo	$\frac{3}{2}-[521]$ Expt	$\frac{5}{2}-[512]$ Theo	$\frac{5}{2}-[512]$ Expt	$\frac{5}{2}-[523]$ Theo	$\frac{5}{2}-[523]$ Expt
$\frac{1}{2}$	3.14	2.92	0	0						
$\frac{3}{2}$	1	1	1	1	1	1				
$\frac{5}{2}$	0.73	1.11	0.16	0.19	0.01	0	0.01		0.43	0.16
$\frac{7}{2}$	0.16	0.27	0.61	0.52	2.10	1.70	1	1	1	1
$\frac{9}{2}$	0.04		0.06		0.08	0.06	0.02		0.39	
$\frac{11}{2}$	0		0.01		0.01		0		0	

[13] P. H. Blickert-Toft, E. G. Funk and J. W. Mikelich, Nucl. Phys. **190**, A96 (1967).
[14] M. Finger, P. Galan, M. Kuznetsova, J. Liptak, J. Urbanec, and J. Vrzal, Report No. JINR-E-2908, 1966 (unpublished).

TABLE IV. Theoretical U^2 values.

Neutron orbital	U^2
$\frac{1}{2}-[521]$	0.930
$\frac{1}{2}-[530]$	0.297
$\frac{1}{2}+[660]$	0.728
$\frac{3}{2}-[521]$	0.505
$\frac{3}{2}-[532]$	0.311
$\frac{3}{2}+[651]$	0.775
$\frac{5}{2}-[512]$	0.785
$\frac{5}{2}-[523]$	0.611
$\frac{7}{2}-[514]$	0.855
$\frac{7}{2}+[633]$	0.902

shows a comparison of the theoretical cross section to the experimental cross sections. Both the theoretical and experimental cross sections have been normalized to the $\frac{3}{2}-$ member of the $\frac{3}{2}-[521]$ ground-state rotational band. Values of the U^2's used are listed in Table IV.[15]

The agreement between experiment and theory is quite good for all bands except that built on the $\frac{1}{2}-[521]$ Nilsson orbital. Soloviev[16] has calculated for the Gd^{155} nucleus (which is isotonic with Nd^{151}) the properties of a $K=\frac{1}{2}-$ band. It should have approximately 50% $\frac{1}{2}-[521]$ character with the other 50% divided between the $K-2\gamma$ bands built on the $\frac{5}{2}-[523]$ and $\frac{3}{2}-[521]$ bands. This hybrid character should result in a considerable reduction over the theoretical decoupling parameter of 0.95. It is extremely gratifying to find the properties of the $K=\frac{1}{2}-$ band in Nd^{151} in such good agreement with the calculations of Soloviev. The population of the band is approximately 50% of that expected for a pure $\frac{1}{2}-[521]$ band and the decoupling parameter a is 0.17.

The interpretation of the data has been carried out up to 1010 keV. Except for the 599-keV state and the second member of the 922–939 keV doublet all of the strong states up to this energy have been interpreted. There are two weak states, 554 and 974 keV, which do not fit into the analysis. Other states are expected in this region which have not been observed. The positive-parity states, $\frac{1}{2}+[660]$, $\frac{3}{2}+[651]$, $\frac{7}{2}+[633]$, and $\frac{5}{2}+[642]$ orbitals, should be in this energy range. From the theoretical cross sections (Table II) it can be seen that these states are predicted to have a low intensity. The $\frac{3}{2}+[651]$, $\frac{5}{2}+[642]$, and $\frac{7}{2}+[633]$ bands are predicted to have an intensity $\sim 1/100$ of those discussed; it is not surprising, therefore, that states resulting from them are not observed. The $\frac{1}{2}+[660]$ band is predicted to have an intensity $\frac{1}{2}$ to $\frac{1}{10}$ of those studied. Thus it is on the borderline of being excited strongly enough to be observed and the fact that states cannot be assigned to it is not disturbing. Besides these positive-parity states there are several negative-parity states expected in this energy region. They are the $\frac{3}{2}-[532]$, $\frac{11}{2}-[505]$, $\frac{7}{2}-[514]$, $\frac{1}{2}-[541]$, and $\frac{5}{2}-[512]$ orbitals. The $\frac{7}{2}-[514]$ and $\frac{1}{2}-[541]$ orbitals are on the borderline of the energy considerations and could be ruled out on this basis. The $\frac{11}{2}-[505]$ orbital has only one observable state and its predicted cross section is quite small. If it is one of the weak peaks, since the angular distribution could not be determined, it would be very difficult to assign. The last orbital, the $\frac{3}{2}-[532]$ orbital, which is not observed, cannot be explained on the basis of energy or cross-section arguments. As a matter of fact, from the Nilsson diagram[12] the $\frac{1}{2}-[530]$ and $\frac{3}{2}-[532]$ orbitals should lie very close in energy, and from the theoretical cross sections they are expected to be of the same order of magnitude in intensity. Since the $\frac{1}{2}-[530]$ band is assigned in the interpretation it is hard to see how it can be excited and not the $\frac{3}{2}-[532]$ orbital. This fact causes some doubt in the assignment of the $\frac{1}{2}-[530]$ band; however, the levels assigned to it cannot be assigned to another orbital with the same consistency. It is entirely possible that the state at 1083 keV could be the $\frac{7}{2}-$ state of the $\frac{5}{2}-[512]$ orbital. This state is the only member of this band expected to be appreciably populated.

In recent observations on Gd^{155}, Gd^{157} and Gd^{159}, and on the neutron-deficient Dy and Er isotopes,[17] considerable evidence has been obtained for the existence of mixed positive-parity orbitals, specifically the $\frac{3}{2}+[402]$ and $\frac{3}{2}+[651]$ mixed orbitals and the $\frac{1}{2}+[400]$ and $\frac{1}{2}+[660]$ mixed orbitals. Since these are hole states most readily seen in the (d,t) reaction, it is not surprising that it has not been possible to observe these states in the (d,p) reaction leading to Nd^{151}. Furthermore, the evidence indicates that the deformation in Nd^{151} may be less than that required for considerable mixing of the orbitals which differ from each other by two units in the principal quantum number.

IV. CONCLUSIONS

Perhaps the most significant conclusion is the fact that Nilsson-level systematics can be used to successfully interpret the levels in Nd^{151} in spite of the fact that it is on the very edge of the region of deformation. The mixed character of the $K=\frac{1}{2}-$ band at 821 keV is quite similar to that observed[14] in the other 91-neutron nuclei Sm^{153}, Gd^{155} and Dy^{157}. However, it is of considerable significance that the ground state of Nd^{151}, Sm^{153} and Gd^{155} are all different. The orbitals are $\frac{5}{2}-[523]$ for Nd^{151}, $\frac{3}{2}+[651]$ probably with some $\frac{3}{2}+[402]$ admixed for Sm^{153}, and $\frac{3}{2}-[521]$ for Gd^{155} and Dy^{157}. This probably results at least in part because of an increasingly large deformation in the sequence Nd^{151}, Sm^{153}, and Gd^{155}.

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