Title
OCTUPOLE STATES IN N15 AND O16

Permalink
https://escholarship.org/uc/item/6598g508

Authors
Bussiere, Andre
Glendenning, Norman K.
Harvey, Bernard G.
et al.

Publication Date
1964-08-01
University of California

Ernest O. Lawrence
Radiation Laboratory

OCTUPOLE STATES IN N^{15} AND O^{16}

TWO-WEEK LOAN COPY
This is a Library Circulating Copy which may be borrowed for two weeks.
For a personal retention copy, call Tech. Info. Division, Ext. 5545

Berkeley, California
DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.
OCTUPOLE STATES IN $^{15}N$ AND $^{16}O$

Andre Bussiere, Norman K. Glendenning, Bernard G. Harvey, Jeannette Mahoney, John R. Meriwether, and Daniel J. Horen

August 1964
OCTUPOLE STATES IN $^{15}N$ AND $^{16}O$

Andre Bussiere, * Norman K. Glendenning, Bernard G. Harvey, Jeannette Mahoney, and John R. Metiwether

Lawrence Radiation Laboratory
University of California
Berkeley, California

and

Daniel J. Horen

Naval Radiological Defense Laboratory
San Francisco, California

Many examples are known of nuclear energy levels whose properties can be described by a moderately weak coupling of an odd particle to a strongly collective vibrational 2+ level of an even-even nuclear core (1). For example, the first three excited states of Cu$^{63}$ are connected to the ground state by E2 transitions whose strengths are nearly equal to each other and to the strength of the transition in Ni$^{62}$ from its first 2+ excited state to the ground state (2).

The 6.134-MeV 3- level of O$^{16}$ has an enhanced E3 transition strength to the ground state (3). In inelastic helium ion scattering from O$^{16}$, the 6.134-MeV level is strongly excited (4), and the angular distribution of the scattered particles is characteristic of an $\ell = 3$ transition.

According to the weak coupling model, there should be two strong octupole levels in $^{15}N$ with spins 5/2+ and 7/2+, formed by coupling a p$_{1/2}$ proton hole to an octupole vibration of the nucleus which is related to the octupole level of O$^{16}$. These two levels should be found at excitations not far from 6.1 MeV. They should have octupole strengths equal to each other and equal to that of the 6.1-MeV level of O$^{16}$. The angular distributions for all three levels.

---

* This work was done under the auspices of the U. S. Atomic Energy Commission and by BUSHIPS.
* NATO Fellow. On leave from Laboratoire de Physique Nucléaire, Orsay (S et O), France.
should have the same shape. \( ^{15}N \) has 5/2+ levels at 5.276 and 7.16 MeV and a 7/2+ level at 7.57 MeV.\(^{5}\)

The elastic and inelastic scattering by \( ^{15}N \) and \( ^{16}O \) of 40.6-MeV helium ions from the Berkeley 224 cm spiral ridge cyclotron was studied with equipment that has been previously described.\(^{4}\) The target gases were confined in a cell with 0.00025 cm windows of Havar foil.\(^{†}\) Pulses from a lithium-drifted silicon detector were recorded in a 1024-channel Nuclear Data analyzer. The energy resolution varied from 100 keV at small angles to about 250 keV at large angles. Spectra taken at an angle of 24° in the laboratory system are shown in fig. 1.

The levels of \( ^{15}N \) at 5.276 and 7.57 MeV were found to be strongly excited; excitation of the 7.16-MeV level was very weak at all angles. We assume that the 5.304-MeV level of \( ^{15}N \) (which would be unresolved) does not contribute significantly to the observed peak at 5.8 MeV, because its spin is 1/2 instead of 5/2 and because the \( J = 1 \) transitions in \( ^{16}O \) and \( ^{14}N \) are weaker than the \( J = 3 \) transitions. The 6.06-MeV 0+ level of \( ^{16}O \) is assumed not to contribute significantly to the observed peak at 6.1 MeV. The angular distributions for the 5.276-MeV and 7.57-MeV levels of \( ^{15}N \) and for the 6.134-MeV level of \( ^{16}O \) are shown in fig. 2. They are quite similar in shape.

Optical model fits to the elastic angular distributions were made for \( ^{15}N \) and \( ^{16}O \) with the computer program GULLEY.\(^{6}\) The best parameter sets are shown in table 1. The notation in the table is conventional; \( r_0 \) is the parameter relating the nuclear radius to the mass number \( A \). The helium ion is given a radius \( r_\alpha \) so that the optical potential radius is \( R = r_0 A^{1/3} + r_\alpha \); the

\[ \text{† Hamilton Watch Co., Lancaster, Pennsylvania.} \]
Table 1.

Optical parameters for interaction of 40.6-MeV helium ions with $^\text{15} \text{N}$ and $^\text{16} \text{O}$

<table>
<thead>
<tr>
<th></th>
<th>$V$ (MeV)</th>
<th>$W$ (MeV)</th>
<th>$r_o(F)$</th>
<th>$r_o(F)'$</th>
<th>$a_o(F)$</th>
<th>$b_o(F)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^\text{15} \text{N}$</td>
<td>-45.1</td>
<td>-15.1</td>
<td>1.30</td>
<td>1.20</td>
<td>0.586</td>
<td>0.500</td>
</tr>
<tr>
<td>$^\text{16} \text{O}$</td>
<td>-45.7</td>
<td>-15.2</td>
<td>1.30</td>
<td>1.20</td>
<td>0.606</td>
<td>0.500</td>
</tr>
</tbody>
</table>

diffuseness parameter of the real potential, $V$, is $a_o$ and that of the imaginary potential, $W$, is $b_o$. The Woods-Saxon shape was used for the real and imaginary parts. The experimental and calculated angular distributions are shown in fig. 3.

The parameters of table 1 were used to calculate the inelastic angular distributions for the three $l = 3$ levels. The DWBA curves, shown in fig. 2 as dashed lines, were normalized to the experimental cross sections at the 40-MeV maximum. In this way it was found that the octupole deformation parameter $\beta_3$ was equal to 0.31 for each of the three levels. Thus the macroscopic model mentioned in the first paragraph yields a consistent interpretation of the experimental results.

The question that we have not yet examined in detail is whether the microscopic wave functions obtained from the shell model calculations mentioned below also yield a consistent interpretation. Qualitatively it appears that this would be possible. The 6.134-MeV level of $^\text{16} \text{O}$, according to the shell model calculations of Elliott and Flowers (3) has a large amplitude for the configuration $^3p_{1/2}^1d_{5/2}$. The shell model calculations of Halbert and French (7) assign the configuration $^3p_{1/2}^1d_{5/2}$ to the 5.27- and 7.57-MeV levels of $^\text{15} \text{N}$. Thus all three levels can be formed from their respective ground states by promotion of a $p_{1/2}$ nucleon to the $d_{5/2}$ shell. In the 5.27-MeV level it is a
proton that is promoted; in the 7.57-MeV level it is a neutron\(^7\). We have observed similar angular distributions and octupole strengths for excitation of the 5.10-MeV 2- and 5.83-MeV 3- levels of \(N^{14}\), both of which can be formed from the ground state by a \(1p_{1/2}\) to \(1d_{5/2}\) promotion. The form factor for these single particle transitions is

\[
F(r) \propto r^3 \exp (- \frac{\gamma}{\nu + \gamma} r^2)
\]

where \(\gamma^{-1/2}\) is the range of the nucleon-alpha potential, and \(\nu (\approx A^{-1/3} F^{-2})\) is the nuclear size parameter\(^8\). This function has one maximum at

\[
r = \left(\frac{3}{2} \frac{\gamma + \nu}{\nu}\right)^{1/2}
\]

or about 3 F. It looks roughly like the form factor, \(\partial V/\partial r\) used in the macroscopic description and therefore would yield similar angular distributions. The actual intensity we do not discuss here. In any case the similarity in inelastic helium ion angular distributions and octupole strengths for all these levels shows that their wave functions are very closely related to each other.
References

2) J. Saudinos, et al., Compt. rend. 252 (1961) 96; J. R. Meriwether, B. G. Harvey, D. J. Horen, A. Bussiere, to be published
4) B. G. Harvey, et al., Nucl. Phys. 52 (1964) 465
6) R. H. Pehl, University of California Report UCRL-10993 (1963), unpublished
8) N. K. Glendenning, Phys. Rev. 114 (1959) 1297
Figure Captions

Fig. 1. Energy spectra of 40.6-MeV helium ions scattered from $^{16}O$ (upper) and $^{15}N$ (lower) at 24° (lab).

Fig. 2. Experimental and calculated angular distributions for elastic scattering of 40.6-MeV helium ions from $^{15}N$ and $^{16}O$. The solid line represents the theoretical curve.

Fig. 3. Angular distributions for 5.27- and 7.57-MeV levels of $^{15}N$ and the 6.13±-MeV level of $^{16}O$. The dashed curves are DWBA calculations for $l = 3$, normalized to the experimental curves at the 40° maximum.
Fig. 1
Fig. 3
This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.