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INVESTIGATION OF THE QUADRUPOLE DEFORMATION OF $^{11}$B BY MEANS OF 30 MeV POLARIZED PROTON INELASTIC SCATTERING

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Résumé. — Les sections efficaces et pouvoirs d’analyse de la diffusion inélastique $^{11}$B(p, p') à $E_p = 30.3$ MeV ont été analysés dans le formalisme des équations couplées. Ces calculs suggèrent la valeur positive de la déformation quadrupolaire $\beta_2$ du $^{11}$B (prolate) et donnent le résultat suivant $\beta_2 = +0.52$.

Abstract. — The cross-sections and resolving powers of the $^{11}$B(p, p') inelastic scattering at $E_p = 30.3$ MeV are analyzed in the coupled-channels formalism. These calculations suggest a positive value for the quadrupole deformation $\beta_2$ of $^{11}$B (prolate) and give the result $\beta_2 = +0.52$.

In the understanding of lp shell nuclei, the investigation of their deformation plays an important role. For the $^{11}$B nucleus, Hartree-Fock calculations [1] do not give a prolate lower minimum compatible with the positive electric quadrupole moment obtained from experiments. For this nucleus a strong-coupling rotational model [2] has given a better result although a quantitative disagreement with the experimentally determined electric quadrupole moment still remains [3].

The above discrepancies have suggested that we need much more investigations about the quadruple deformation of the $^{11}$B nucleus by means of inelastic scattering. In particular a recent investigation of the quadruple deformation of $^{11}$B by inelastic helion ($^3$He) scattering at $E_{^3$He} = 74 MeV [4] has shown, with analysis using the coupled-channels (CC) method, the possible existence of oblate-prolate effects of $^{11}$B in this reaction. It would therefore appear necessary to determine the quadrupole deformation of $^{11}$B by means of polarized proton inelastic scattering.

In view of the determination of the sign and the value for the quadrupole deformation $\beta_2$ of $^{11}$B, we have analyzed, in the coupled-channels (CC) formalism with the rotational model using the code ECIS 75 [5], the experimental data for the cross-sections and resolving powers in the $^{11}$B(p, p) and $^{11}$B(p, p') scattering to the lower two members of the $K^t = {-}\frac{3}{2}$ band of $^{11}$B, i.e. the $\frac{1}{2}^-$ ground state and the $\frac{3}{2}^-$ second-excited state ($E_x = 4.46$ MeV) at $E_p = 30.3$ MeV [6]. The optical parameters used as initial values for the optical model search procedure were taken from the analysis performed by Karban et al. [6] and are listed in table I. In the CC formalism, the nuclear radius is defined by

$$ R = R_0(1 + \beta_2 Y_{20} + \cdots) $$

where the $\beta$'s are the deformation parameters determined by the experiment, the $Y$'s are spherical harmonics and $R_0$ corresponds to the various optical potential radii. The interaction potential arises from the deformation of the Coulomb potential, the complex central potential and the spin-orbit potential. The deformed spin-orbit potential was of the full Thomas form [7]. In the CC calculations, the states explicitly coupled are the lower two members of a

### Table I

<p>| Optical model parameters used in the analysis of the $^{11}$B(p, p)$^{11}$B scattering |
|---|---|---|---|---|---|---|---|---|---|</p>
<table>
<thead>
<tr>
<th>$V_0$ (MeV)</th>
<th>$r_0$ (fm)</th>
<th>$a_0$ (fm)</th>
<th>$W_V$ (MeV)</th>
<th>$W_D$ (MeV)</th>
<th>$r_1$ (fm)</th>
<th>$a_1$ (fm)</th>
<th>$V_{s0}$ (MeV)</th>
<th>$r_{s0}$ (fm)</th>
<th>$a_{s0}$ (fm)</th>
<th>$r_C$ (fm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.18</td>
<td>1.09</td>
<td>0.59</td>
<td>0</td>
<td>3.38</td>
<td>1.30</td>
<td>1.01</td>
<td>7.78</td>
<td>0.98</td>
<td>0.57</td>
<td>1.09</td>
</tr>
</tbody>
</table>
K = 3/2 \text{–} \text{rotational band in } ^{11}\text{B}. The results are presented in figure 1 and the corresponding parameters listed in table II.

The two values $\beta_2 = +0.43$ and $\beta_2 = -0.50$ obtained from reference [4] by analyzing only the cross-sections of the $^{11}\text{B}(^3\text{He}, ^3\text{He'})$ inelastic scattering at $E_{^3\text{He}} = 74 \text{ MeV}$ with the CC method give equally low $\chi^2$ values. But it should be mentioned [4] that $\beta_2 = +0.43$ agrees quite well with the experimental value of $+0.0372 \text{ b}$ [3] for the electric quadrupole moment. The results we have obtained by analyzing simultaneously the cross-sections and resolving powers of the $^{11}\text{B}(p, p')$ inelastic scattering at $E_p = 30.3 \text{ MeV}$ using the CC calculations suggest also a positive value for the quadrupole deformation $\beta_2$ of $^{11}\text{B}$ (prolate) and give the result $\beta_2 = +0.52$.

We are grateful to Dr. R. de Swiniarski for valuable discussions and his interest in this work.

### Table II

**Coupled-channel parameters used in the analysis of the $^{11}\text{B}(p, p')^{11}\text{B}$ inelastic scattering**

<table>
<thead>
<tr>
<th>$\beta_2$</th>
<th>$V_0$ (MeV)</th>
<th>$r_0$ (fm)</th>
<th>$a_0$ (fm)</th>
<th>$W_V$ (MeV)</th>
<th>$W_Q$ (MeV)</th>
<th>$r_1$ (fm)</th>
<th>$a_1$ (fm)</th>
<th>$V_0$ (MeV)</th>
<th>$r_0$ (fm)</th>
<th>$a_0$ (fm)</th>
<th>$r_C$ (fm)</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.52</td>
<td>46.65</td>
<td>1.09</td>
<td>0.59</td>
<td>3.22</td>
<td>1.30</td>
<td>1.01</td>
<td>8.38</td>
<td>0.98</td>
<td>0.57</td>
<td>1.09</td>
<td>$34.83 \times 10^2$</td>
<td></td>
</tr>
<tr>
<td>-0.60</td>
<td>46.98</td>
<td>1.09</td>
<td>0.59</td>
<td>3.34</td>
<td>1.30</td>
<td>1.01</td>
<td>8.34</td>
<td>0.98</td>
<td>0.57</td>
<td>1.09</td>
<td>$38.48 \times 10^2$</td>
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### References