High-Resolution Study of ^{11}B to ^{11}C Gamow-Teller Strengths -as a test case of *ab initio* shell-model calculations-

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The *ab initio* no-core shell-model (NCSM) calculations starting from very light nuclei have become possible up to p-shell nuclei. Recently, Navrátil and Ormand extended the calculations to include a realistic three-nucleon interaction (TNI) [1]. It was suggested that the TNI can affect various structural properties, like excitation energies and quadrupole as well as magnetic moments of the ground states (g.s.). It was also shown that the TNI has a relatively large effect on Gamow-Teller (GT) ($\Delta L = 0$, $\Delta J^{\pi} = 1^{+}$) transition strengths. In particular, a large effect was predicted for the GT transition strengths in the $A = 11$ mirror nuclei ^{11}B and ^{11}C [1]. The ^{11}B$(p,n)^{11}$C reactions were performed at various incident energies between $E_p = 160$ and 795 MeV with resolutions of ≈ 700 keV, and several GT states were studied [2]. An improved resolution of about 300 keV [3]. was reported We found, however, a better resolution was required to make a quantitative comparison with the states predicted by the NCSM calculation.

The ^{11}B$(^3$He$,t)^{11}$C experiment was performed at the high energy-resolution facility of RCNP, consisting of the "WS course" and the Grand Raiden spectrometer using a 140 MeV/nucleon ^{3}He beam from the $K = 400$ Ring Cyclotron. For a better energy and angle resolutions, matching techniques were used. A self-supporting foil of boron oxide (B_2O_3) with a thickness of ≈ 1.5 mg/cm^2 was used. Details of the experiment is found in Ref, [4].

Owing to the high energy-resolution of 45 keV, well separated states were observed up to $E_x = 8.4$ MeV in the "0° spectrum" [Fig. 1(a)] showing events for scattering angles $\Theta \leq 0.5°$. By consulting Ref. [5], all of these prominent states could be identified as ^{11}C states with J^{π} values of either $1/2^-, 3/2^-$, or $5/2^-$. In the earlier (p,n) experiments [2], one broad peak was observed at 4.5 MeV. This peak was resolved into two sharp states at 4.319 and 4.804 MeV with nearly equal strengths. A previously unresolved peak at 8.4 MeV was also resolved into 8.105 and 8.420 MeV states in agreement with Ref. [5]. It was found that there was almost no strength in the transition to the $J^{\pi} = 3/2^-$, 8.105 MeV state, although the transition from the ^{11}B g.s. with $J^{\pi} = 3/2^-$ is allowed by the J^{π} selection-rule. The excitation energies and J^{π} values of ^{11}C states given in Fig. 1(a) are taken from Ref. [5].

In order to extract the cross section for the GT component, we used the fact that the ratio of GT and Fermi unit cross sections denoted as R^2 [6] is only weakly dependent on the mass number A and can be deduced to be 5.1(7) for the $A = 11$ nuclei by an interpolation from separately determined R^2 values for $A = 7$, 18, 26, and 58 nuclei. The unit GT intensity for the 0° spectrum was calculated by using this R^2 value, the B(GT) value of 0.345(8) from the β-decay measurement [5], and B(F) = 1 for the g.s. to g.s. transition. The B(GT) values

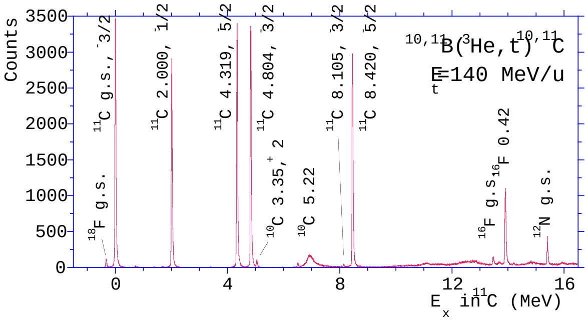

Figure 1: Spectra of the ^{11}B(^{3}He, t)^{11}C reaction of the range up to the excitation energy of 16 MeV for scattering angles $\Theta \leq 0.5°$.

for other excited states were calculated from their peak intensities, corrected for excitation energy using the results of DWBA calculations and assuming the proportionality between the peak intensities and the B(GT) values. The B(GT) values from (p, n) experiments [2] agree within errors with the (^{3}He, t) values, but the total B(GT) value of 2.15 summed up to $E_x = 8.4$ MeV was smaller by about 7% than the (^{3}He, t) value of 2.30.

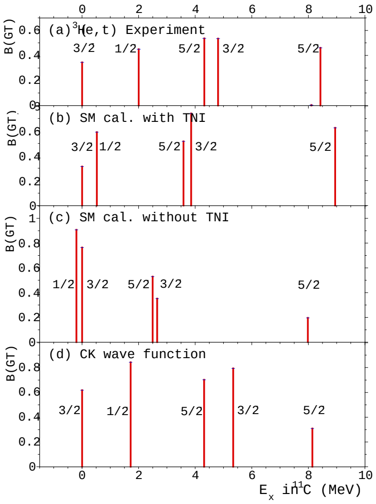

Figure 2: Experimental and shell-model B(GT) distributions. The J^π values of states are indicated. The B(GT) distributions are shown (a) for the present ^{11}B(^{3}He,t)^{11}C experiment, (b) for a NCSM calculation by Navrátil and Ormand including the TNI [1], (c) for a NCSM calculation without a TNI [1], and (d) for a shell-model calculation obtained by using the Cohen-Kurath interaction (from Ref. [2]). Note the change in size of the panels.

The B(GT) values determined here are plotted in Fig. 2(a). The results from the NCSM calculations [1] are shown in Figs. 2(b) and (c) for the results with and without the TNI, respectively. It is seen that the inclusion of the TNI significantly improves the agreement with the experimental results. This suggests that it is essential to include the TNI in NCSM calculations. The total B(GT) value of 2.79 in the NCSM calculation with the TNI was larger than the experimental value of 2.30, but they differ by only 20%.

The B(GT) distribution was studied in Ref. [2] using the Cohen-Kurath interaction [7] and the result is shown in Fig. 2(d). The agreement between the calculated and experimental excitation energies is excellent, however, the total calculated strength is about 40% larger than the experimental one.

Detailed discussions are given in Ref. [4].

References

[1] P. Navrátil and W.E. Ormand, Phys. Rev. C **68**, 034305 (2003).
[2] T.N. Taddeucci *et al.*, Phys. Rev. C **42**, 935 (1990).
[3] T. Kawabata *et al.*, RCNP (Osaka Univ.), Annual Report, 2002, p. 21.
[4] Y. Fujita *et al.*, Phys. Rev. C **70**, section Rapid Communications (2004).
[5] F. Ajzenberg-Selove and J.H. Kelley, Nucl. Phys. **A506**, 1 (1990).
[6] T.N. Taddeucci *et al.*, Nucl. Phys. **A469**, 125 (1987), and references therein.
[7] S. Cohen and D. Kurath, Nucl. Phys. **73**, 1 (1965); T.-S.H. Lee and D. Kurath, Phys. Rev. C **21**, 293 (1980).