Gamow-Teller Transitions in High-Resolution ^{23}Na(^{3}He, t)^{23}Mg Reaction

Y. Fujita[a], Y. Shimbara[a], T. Adachi[a], G.P.A. Berg[b], H. Fujimura[b], H. Fujita[a], K. Hara[b], K. Hatanaka[b], J. Kamiya[b], T. Kawabata[b], Y. Kitamura[b], Y. Shimizu[b], M. Uchida[c], H.P. Yoshida[b], M. Yoshifuku[a] and M. Yosoi[c]

[a]*Dept. Phys., Osaka University, Toyonaka, Osaka 560-0043*
[b]*RCNP, Osaka University, Ibaraki, Osaka 567-0047*
[c]*Dept. Phys., Kyoto University, Sakyo, Kyoto 606-8224*

In order to study the transitions to the GT states in ^{23}Mg, the ^{23}Na(^{3}He, t) experiment was performed at RCNP, Osaka by using a 140 MeV/nucleon ^{3}He beam from the $K = 400$ RCNP Ring Cyclotron and the Grand Raiden spectrometer [1] placed at 0°.

The target was a thin foil of Na_2CO_3 using polyvinylalcohol as supporting material [2]. The total thickness of the target was approximately 2 mg/cm^2. The target is effectively a mixture of ^{23}Na, carbon isotopes ^{12}C and ^{13}C (natural abundance 98.9% and 1.1%, respectively), and oxygen isotopes ^{16}O and ^{18}O (natural abundance 99.8% and 0.2%, respectively). After the (^{3}He, t) charge-exchange reactions, these nuclei become ^{23}Mg, ^{12}N, ^{13}N, ^{16}F, and ^{18}F, where the Q values of the reactions are -4.08, -17.36, -2.24, -15.44, and -1.67 MeV, respectively. Owing to the large difference of Q values, the low-lying states in ^{23}Mg are observed without being affected by the strongly excited states in ^{12}N and ^{16}F. Since the Q values of ^{13}C and ^{18}O impurities are rather similar to that of ^{23}Na target, states of ^{13}N and ^{18}F may disturb the ^{23}Mg spectrum. The identification of these states and the states of ^{23}Mg was possible in the good resolution experiment described below.

A resolution far better than the momentum spread of the beam was realized by applying the *dispersion-matching technique* [3]. Using the new high-resolution "WS" course [4] for the beam transportation and the "faint beam method" to diagnose the matching conditions [5, 6], an energy resolution of 45 keV (FWHM) was achieved. With the improvement of resolution, states of ^{23}Mg up to $E_x = 9$ MeV were clearly resolved as shown in Fig. 1. Good angular resolutions in x and y directions were achieved, respectively, by applying the *angular dispersion-matching technique* and by realizing the "over-focus mode" in the spectrometer [7]. The "0° spectrum" in Fig. 1 shows events within the scattering angle $\leq 0.8°$.

In order to identify the states originating from ^{13}C and ^{18}O nuclei in the target, a spectrum of a Mylar target was measured under the same condition as the Na_2CO_3 target. From the comparison of both spectra, it was found that the wider state at $E_x \approx 1.7$ MeV in Fig. 1 was the 3.502 MeV state in ^{13}N.

The excitation energies of states were determined with the help of kinematic calculations, where known states of ^{13}N and ^{16}F observed in the spectrum of Mylar target were used as overall calibration standard for a wide Q value. Owing to the small Q value of the (^{3}He, t) reaction on ^{13}C and the large Q value on ^{16}O, the E_x values of ^{23}Mg states were determined by interpolation.

It is known that at 0° the CE cross section for a GT transition is approximately proportional to B(GT) [9]. In order to obtain the absolute B(GT) values, a standard of B(GT) is needed. Assuming isospin symmetry, the B(GT) values of mirror transitions are the same. As the standard, we used the B(GT) value of 0.146 obtained in the β-decay from the ^{23}Mg ground state to the 0.440 MeV state of ^{23}Na [8]. We presumed the same B(GT) value for the mirror transition to the ^{23}Mg, 0.451 MeV state in the ^{23}Na(^{3}He, t) reaction. By using the proportionality, the B(GT) values for other excited states were calculated from their peak

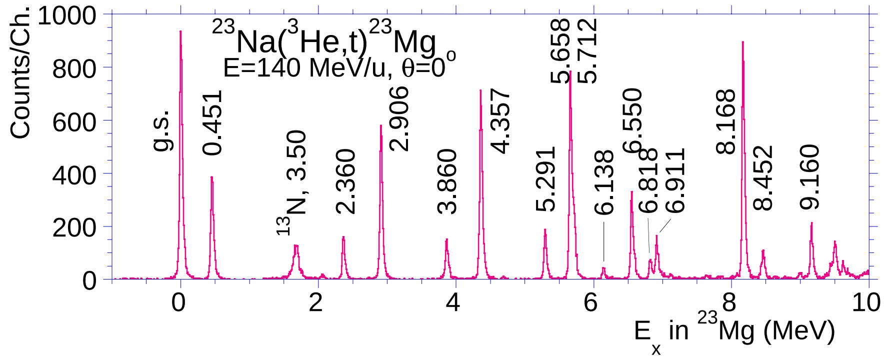

Figure 1: The low-excitation region of the 0°, ^{23}Na(^{3}He, t) spectrum measured by using a Na_2CO_3 target. A good resolution of 45 keV has been achieved.

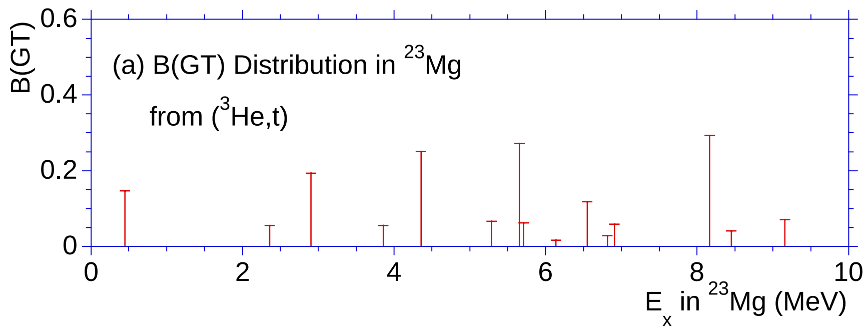

Figure 2: The B(GT) strength distribution from ^{23}Na(^{3}He,t)^{23}Mg reaction.

intensities after making the excitation-energy correction. The B(GT) distribution is shown in Fig. 2.

The B(GT) values were previously evaluated for the transitions to two low-lying states in a (p, n) reaction at $E_p = 160$ MeV [10]. The values were 0.153 and 0.062 for the 0.45 and 2.36 MeV states, respectively. In deriving these values, they assumed a universal unit cross section averaged for various nuclei. If these values are normalized by the above-mentioned β-decay B(GT) value which we used, then the B(GT) values would become 0.146 and 0.059, which are in agreement with our values of 0.146 and 0.055, respectively.

References

[1] M. Fujiwara *et al.*, Nucl. Instrum. Meth. Phys. Res. A **422**, 484 (1999).
[2] Y. Shimbara *et al.*, OULNS (Osaka Univ.), Annual Report, 2001, and Nucl. Instrum. Meth. Phys. Res. A, to be submitted.
[3] Y. Fujita *et al.*, Nucl. Instrum. Meth. Phys. Res. B **126**, 274 (1997); and references therein.
[4] T. Wakasa *et al.*, Nucl. Instrum. Meth. Phys. Res. A **482**, 79 (2002).
[5] H. Fujita *et al.*, Nucl. Instrum. Meth. Phys. Res. A **484**, 17 (2002).
[6] Y. Fujita *et al.*, J. Mass Spectrom. Soc. Jpn. **48(5)**, 306 (2000).
[7] H. Fujita *et al.*, Nucl. Instrum. Meth. Phys. Res. A, **A 469**, 55 (2001).
[8] P. M. Endt, Nucl. Phys. **A521**, 1 (1990); P. M. Endt, *ibid*, **A633**, 1 (1998), and references therein.
[9] T.N. Taddeucci *et al.*, Nucl. Phys. **A469**, 125 (1987), and refs. therein.
[10] C.D. Goodman, in: Proc. Int. Symp. on Nuclear Reaction Dynamics of Nucleon-Hadron Many Body System, Editors, H. Ejiri, T. Noro, K. Takahisa, and H. Toki (World Scientific Singapore), p. 125.