Characteristics of (^{6}Li,^{6}He) reactions at E=100 MeV/nucleon.

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For studies of characteristics of (^{6}Li,^{6}He) reactions at E=100 MeV/nucleon, we performed experiments at RCNP using the spectrometer Grand Raiden. Details of the experiments are described in the previous report [1]. We will report further discussion using obtained spectrum shown in Fig. 1.

In order to utilize the (^{6}Li,^{6}He) reaction for the study of spin-flip transition strengths, it is required to know (i) whether the reaction proceeds in a single step and (ii) whether there is a proportionality between the cross section at 0° and the transition strength B(GT). According to Taddeucci *et al.* [2], if the range of excitation energy is not so large, the R^2 value defined by

$$R^2 = \frac{\sigma_{\rm GT}(0^\circ)}{\sigma_{\rm F}(0^\circ)} \frac{B({\rm F})}{B({\rm GT})}, \tag{1}$$

is interpreted as the square of the integrated strength of the $V_{\sigma\tau}$ interaction divided by that for V_τ. It has a dependence on the incident energy [2], and a rather similar value of R^2 is expected for reactions with similar incident energy per nucleon [3]. For convenience we hereafter use $1/R^2$ instead of R^2 to express the suppression of the Fermi transition as smaller values. In the (p, n) reaction at $E_{\rm p}$=100 MeV a value $1/R^2$(p, n)=0.302(4) is estimated from the systematics [2]. From angular momentum selection rules, the (^{6}Li,^{6}He) reaction selects ΔS=1 transitions. The ΔS=0 Fermi transition, therefore, is not allowed if the reaction proceeds in one step. The suppression of the Fermi transition was first estimated by analyzing the ^{26}Mg(^{6}Li,^{6}He)^{26}Al spectrum obtained with a resolution of 370 keV (see Fig. 1(a)). Since the excitation energies of 0^+ and 1^+ states caused by Fermi and GT transitions, respectively, are well known [4], the spectrum was fitted by fixing the centroid values to the positions expected from the known $E_{\rm x}$ values of the states. It is known that the IAS is at $E_{\rm x}$=0.23 MeV, while a well-separated prominent GT state is at $E_{\rm x}$=1.06 MeV. Additionally, a 3^+ state having the ΔL=2 nature is at $E_{\rm x}$=0.42 MeV. The $\sigma_{\rm F}(0^\circ)/\sigma_{\rm GT}(0^\circ)$ ratio was obtained from the peak-fit analysis. Using the log ft value obtained in the study of mirror-conjugate β decay from ^{26}Si to ^{26}Al [4], a value of B(GT) = 1.07(3) is expected for the 1.06 MeV state (for details of the derivation, see Ref. [5]), while B(F) = $N - Z$ = 1 can be assumed for the IAS. Inserting these values into Eq. 1, we find $1/R^2$=0.004(3). Comparing this value

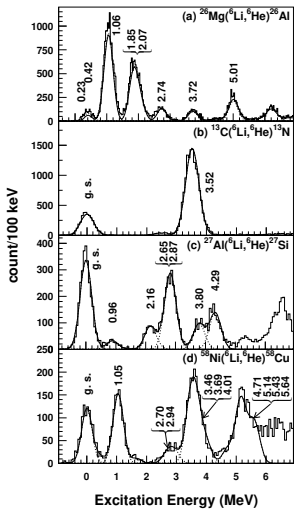

FIG. 1. Excitation energy spectra obtained in the (^{6}Li,^{6}He) reactions at a bombarding energy E = 100 MeV/nucleon within a emission angle $\theta_{\rm c.m.} \leq 6$ mrad on targets of (a) ^{26}Mg, (b) ^{13}C, (c) ^{27}Al, and (d) ^{58}Ni. The solid curves are obtained by the fitting described in the text.

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to the (p, n) result mentioned above, it is calculated that the Fermi transition in the (^{6}Li,^{6} He) reaction is weaker by a factor of 0.012(9). In similar manners, using the ratio of cross sections to the g. s. and to the 3.50 MeV state in ^{13}N, and to the g. s. and to the E_x=2.16 MeV state in ^{27}Si, we deduce $1/R^2$=0.0001(5)and 0.04(3), respectively. Again comparing these values to the (p, n) result mentioned above, it is calculated that the Fermi transition in the (^{6}Li,^{6} He) reaction is weaker by factors of 0.000(2) and 0.1(1), respectively. Taking the weighted average of the above three values, we find that the ΔS=0 Fermi transition is suppressed by 99.7(1)% in the (^{6}Li,^{6} He) reaction at a bombarding energy 100 MeV/nucleon. From this result, we conclude that the reaction proceeds in a single step.

For the study of the proportionality between the cross section at 0° and the transition strength B(GT), the results of ^{26}Mg(^{6}Li,^{6} He)^{26}Al reaction is useful, because B(GT) values are known for several transitions to low-lying states from the study of mirror β decay. As mentioned, an isolated strong 1^+ state is located at E_x=1.06 MeV in ^{26}Al (see Fig. 1(a)), and the B(GT) value is known to be 1.07(3). By comparing the B(GT) and the 0° cross section averaged over 6 mr around 0°, a conversion factor from cross section to B(GT) was obtained. Using the same conversion factor, B(GT) values were then deduced for the other GT transitions. The determined B(GT) values are plotted in Fig. 2, together with those determined in a similar manner for ^{27}Al and ^{58}Ni targets in comparison with those derived from the β-decay values [4] (open circles), and also with those from the (p, n) values [8, 9, 10] (filled circles). They show rather good proportionality within experimental uncertainties except for one point with B(GT)(^{6}Li,^{6} He)=0.79(9) of ^{26}Mg. This B(GT) value was obtained assuming two 1^+ states at E_x=1.85 and 2.07 MeV. The discrepancy may stem from the contribution from a ΔL=2 transition to the 2^+ state at E_x=2.07 MeV.

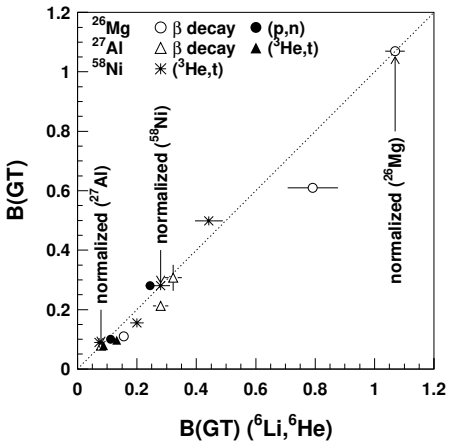

FIG. 2. Comparison of the B(GT) values determied in the (^{6}Li,^{6} He) reaction on ^{26}Mg, ^{27}Al, and ^{58}Ni targets with those of β decay, (p, n), and (^{3}He, t) reactions. For details, see text.

From the above observations of (i) strong suppression of Fermi transitions and (ii) proportionality between 0° cross sections and B(GT) values, we are fairely certain that the reaction can be used as a probe of spin-flip transions.

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