# Gamow-Teller Transitions in the $^{37}$Cl($^3$He,$t$)$^{37}$Ar Reaction


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In charge exchange (CE) reactions at intermediate energies and at 0°, it is known that the cross sections are essentially proportional to the Gamow-Teller (GT) strengths $B$(GT) observed in $\beta$ decays [1, 2]. However, exceptionally in transitions exciting $j_<^{+1} j_<^{-1}$ configurations in odd mass nuclei, it has been reported that the proportionality has a large ambiguity [3]. The $A = 37$ nuclei are suited to investigate the question on this ambiguity because, in a naive shell model, valence nucleons are in a $j_<$ shell, i.e., the $d_{3/2}$ shell. Assuming that there is no isospin mixing, the $B$(GT) distributions should be the same in transitions from the ground state of $^{37}$Cl to the excited states of $^{37}$Ar and from that of $^{37}$Ca to those of $^{37}$K. If the cross sections in CE reactions are proportional to the $B$(GT) values, the distribution of the differential cross sections from the $^{37}$Cl($p,n$)$^{37}$Ar or $^{37}$Cl($^3$He,$t$)$^{37}$Ar reactions should be identical to the $B$(GT) distribution from the $^{37}$Ca $\rightarrow$ $^{37}$K $\beta$-decay. Both $^{37}$Cl($p,n$)$^{37}$Ar [5] and $^{37}$Ca($\beta_+$)$^{37}$K [6, 7, 8] experiments were intensively performed, because the data are important as a parameter to estimate the solar neutrino flux by a $^{37}$Cl detector [4]. In deriving the $B$(GT) values from the $^{37}$Cl($p,n$)$^{37}$Ar, it was assumed that the observed cross section of the transition to the ground state of $^{37}$Ar corresponded to the $B$(GT) value determined in the $^{37}$Ar $\beta$-decay to the ground state of $^{37}$Cl. The obtained $B$(GT) distribution was rather different from the results of the $^{37}$Ca $\beta$-decay measurements. As the origin of the disagreement, it was pointed out that the proportionality was not valid in the $^{37}$Cl($p,n$)$^{37}$Ar experiment especially for the ground state transition [6, 7]. Unfortunately, the ($p,n$) reaction data cannot be compared with the $\beta$-decay data on level-by-level base because of its poor resolution of 200-300 keV.

In order to realize level-by-level comparison, we performed a high-resolution ($^3$He,$t$) experiment. A 140 MeV/u $^3$He beam from the RCNP Ring Cyclotron was dispersively transported by the WS beam line. The spectrometer Grand Raiden set at 0° was used for the momentum analysis of tritons. A newly developed foil target made by calcium chloride ($^{40}$Ca$^{37}$Cl$_2$) and polyvinylalcohol (PVA) was used [9]. With the dispersion matching method compensating the energy spread of the beam, we achieved a resolution of 30 keV (FWHM), the world record resolution of the CE reactions at intermediate energies.

Our spectrum is compared with the $B$(GT) distribution from the $^{37}$Ca $\beta$-decay experiment in Fig. 1. In the $^{37}$Ca $\beta$-decay data shown in the upper part, the $B$(GT) in the IAS is not shown because of its large error due to the mixture of the Fermi strength. If we neglect the corresponding IAS in the ($^3$He,$t$) spectrum, we can see similarities between these two figures. A closer look of the spectrum shows, however, that there are obvious disagreements over the error bars for the states in the 2-5 MeV region. Since the ($d_{3/2}^{+1} d_{3/2}^{-1}$) configuration is expected to be dominant at the lower excitations, it is suggested that the disagreements originate from the lack of proportionality.

Here we tentatively use a new normalization. The differential cross sections of the $^{37}$Cl($^3$He,$t$)$^{37}$Ar measurement were normalized to the $^{37}$Ca $\rightarrow$ $^{37}$K $\beta$-decay data by the total strength in the region 5.05-8.65 MeV in which the contribution of the $(d_{3/2}^{+1} d_{5/2}^{-1})$ configuration was expected to be larger. The $B(\mathrm{GT})$ values were integrated as a function of excitation energy and compared with that of the $^{37}\mathrm{Ca} \rightarrow {}^{37}\mathrm{K}$ in Fig. 2, where the IAS was neglected because the ambiguity was large in both data of $^{37}\mathrm{Cl}(^{3}\mathrm{He},t)^{37}\mathrm{Ar}$ and $^{37}\mathrm{Ca}$ $\beta$ decay. In order to make the curves match at 5.05-8.65 MeV in Fig. 2, the $y$ axis of the $^{37}\mathrm{Cl} \rightarrow {}^{37}\mathrm{Ar}$ was moved upward. With this shift, these two curves are in good agreement, indicating that the proportionality between the cross sections and the $B(\mathrm{GT})$ values in the $(^{3}\mathrm{He},t)$ reaction is good, probably owing to the larger fraction of the $(d_{3/2} d_{5/2}^{-1})$ configuration in the higher excitation region. Additionally, we see little effects by the isospin mixing as for the averaged strengths. On the other hand, a small gap, which was about 5% of the integrated value up to 8.65 MeV, appeared at 0 MeV. The gap indicates that, at lower excitation region, the fraction of the $(d_{3/2}^{+1} d_{3/2}^{-1})$ configuration is rather large and the proportionality becomes ambiguous.

Through the present study, we find that the $(^{3}\mathrm{He},t)$ data taken at intermediate energy and $0^{\circ}$ are useful for the extraction of the $B(\mathrm{GT})$ values in a wider excited-energy region. At the same time one should take into account the lack of proportionality between the cross section and $B(\mathrm{GT})$ in $j_< \rightarrow j_<$ transitions.

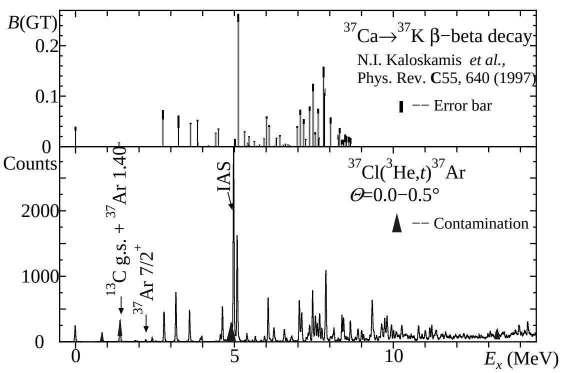


Figure 1: Comparison of the $^{37}\mathrm{Cl}(^{3}\mathrm{He},t)^{37}\mathrm{Ar}$ energy spectrum and the $B(\mathrm{GT})$ distribution from $^{37}\mathrm{Ca}$ $\beta$-decay. The vertical scales are adjusted so that the 5.11 MeV states have the same height.

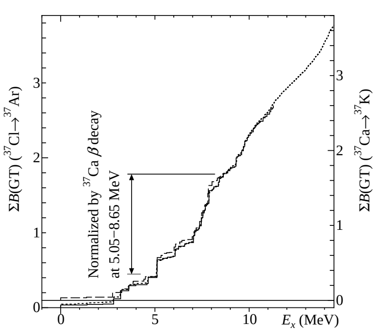


Figure 2: Integral $B(\mathrm{GT})$ distributions from the $^{37}\mathrm{Cl} \rightarrow {}^{37}\mathrm{Ar}$ and $^{37}\mathrm{Ca} \rightarrow {}^{37}\mathrm{K}$ GT transitions. The $B(\mathrm{GT})$ values extracted from $^{37}\mathrm{Cl}(^{3}\mathrm{He},t)^{37}\mathrm{Ar}$ are normalized to the $^{37}\mathrm{Ca}$ $\beta$-decay data in the region 5.05-8.65 MeV. The solid line shows the strength only of the discrete states in the $^{37}\mathrm{Cl}(^{3}\mathrm{He},t)^{37}\mathrm{Ar}$ spectrum, while doted line shows the strength including the continuous part of the spectrum. The dashed line shows the strength of $^{37}\mathrm{Ca} \rightarrow {}^{37}\mathrm{K}$ $\beta$-decay.

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