(t,^{3}He) Reaction; new tool for studying GT$_+$ states

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Initial experiments were carried out to study spin-isospin transitions in nuclei using (t,^{3}He) measurements at National Superconducting Cyclotron Laboratory (NSCL). In the present (t,^{3}He) experiment, the first half of the A1200 system played the role of a beam transport system for the secondary triton beam. The second half was set to bend ^{3}He^{++} particles. It played the role of a spectrometer for measurements of (t,^{3}He) reactions.

The dispersion matching method was applied to obtain good energy resolution despite the significant energy spread of the incident tritons. The achromatic properties of the A1200 system made it possible to obtain high-resolution (t,^{3}He) spectra at θ=0° with a resolution of ΔE/E=0.002 (ΔE=780 keV).

Energy spectra obtained for the (t,^{3}He) reactions at θ=0° on targets of ^{12}C and ^{10}B are shown in Figs. 1 and 2. The energy acceptance covered by the focal-plane detector system was 13 MeV. In the off-line analyses, the kinematic shift was corrected in getting the final (t,^{3}He) spectra. The narrow peaks in the spectra corresponds to well-known discrete states in ^{12}B and ^{10}Be. The resolution obtained was 780 keV for the full-width at half maximum (FWHM) for the (t,^{3}He) experiment at 381 MeV. About half of this resolution is caused by the energy loss differences between tritons and ^{3}He particles in the target. The present results show that (t,^{3}He) spectra with good energy resolution can be achieved for the secondary beam; the energy spread of $\sim$23 MeV of the triton beam is corrected by the dispersion matching of the spectrometer system. A momentum resolving power was p/Δp$\approx$1000 for the A1200 system for the (t,^{3}He) spectra at θ=0°.

As an achromatic spectrometer system, a momentum resolution of p/Δp=2000 is expected for the A1200 system. However, the observed value was only about half of the expected value. This is partly due to the limited position resolution of the CRDC counter. Unfortunately, the ray-tracing technique for obtaining the final (t,^{3}He) spectra could not used. Improved resolution is expected if a more sophisticated position counter system can be employed which allows ray-tracing.

The results of peak fitting are presented by the solid curves in the (t,^{3}He) spectra

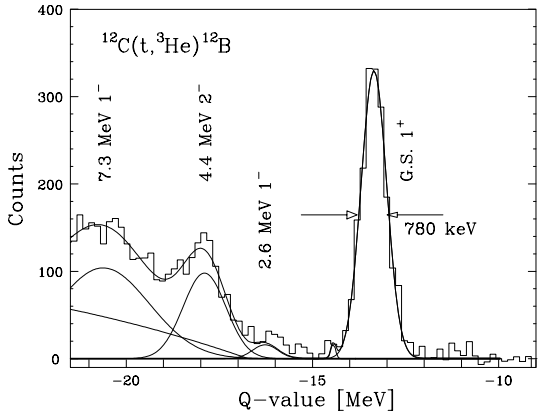

Figure 1: A ^{12}C(t,^{3}He) spectrum at zero degrees taken with a triton beam of 381 MeV. The dispersion matching method is applied to correct the energy width of ∼23 MeV for the initial triton beam from the breakup (^{4}He,p-t) reaction. The solid curves are the results of peak fitting.

in Figs. 1 and 2. Experimental background was determined by measuring a ^{3}He spectrum with a blank target. This background was constant over the detected ^{3}He range. The peak height ratio of the ground state of ^{12}B to the underlying background was found to be ∼150. In the process of spectrum fitting, Gaussian line shapes were assumed for the peaks, and a quasi-free shape was assumed for the non-resonant background. The latter was successfully used in fitting (^{3}He,t) spectra with the semi-phenomenological function given in Ref. [1].

The 1^+ ground state of ^{12}B is strongly excited in the ^{12}C(t,^{3}He)^{12}B spectrum at 381 MeV. The present ^{12}C(t,^{3}He)^{12}B spectrum was compared with those from the the (d,^{2}He) reaction [2] and the (^{7}Li,^{7}Be) reactions [3, 4].

It was observed that the excitation strengths of the ground state and the 2^- state at 4.4 MeV in ^{12}B are almost equal in both the (t,^{3}He) and (d,^{2}He) reactions. The excitation strength for the wide bump located at 7.3 MeV is stronger and wider than that obtained by the (d,^{2}He) reaction at 100 MeV/nucleon [2]. Thus, it appears that there exist at least two components in the region around 7.3 MeV. One seems to be the spin-flip component which is measured in the (d,^{2}He) reaction, and the other is inferred to be the non spin-flip component which spreads over the wider energy region. The present result is consistent with the results obtained from the (^{7}Li,^{7}Be) and (^{7}Li,^{7}Be-γ) reactions at 65 MeV/nucleon [3].

For the ^{10}B(t,^{3}He)^{10}Be reaction at θ=0°, three peaks are clearly visible (see Fig. 2). The ground state of ^{10}Be is outside the measured energy range. The ground state was found to be very weakly excited at θ=0°. This result is expected since the spin-parity of the ground state of ^{10}B is 3^+ and the spin-parity of the ground state of ^{10}Be is 0^+. The transition from ^{10}B(g.s.) to ^{10}Be(g.s.) is therefore a forbidden Gamow-Teller transition. The observed spectrum is very similar to that obtained by the (d,^{2}He) reaction at θ=0°, which has been independently measured using the 200 MeV deuteron beam at RCNP. Thus, these three states in ^{10}Be are identified as spin-flip (ΔS=1) states.

Two known 2^+ states (E_x = 3.37 MeV, 5.96 MeV) are excited in ^{10}Be. In the DWBA

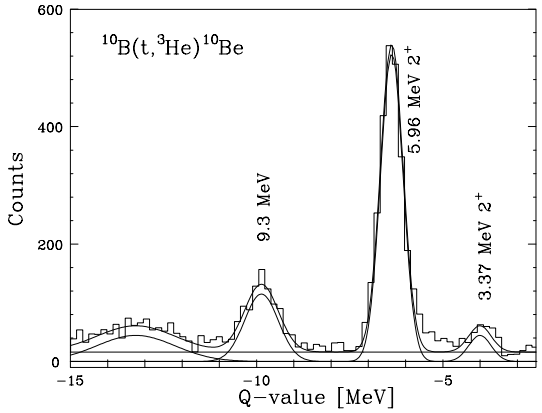

Figure 2: A ^{10}B(t,^{3}He) spectrum at zero degrees taken with a triton beam of 381 MeV. The dispersion matching method is applied to correct the energy width of ∼23 MeV for the initial triton beam from the breakup (^{4}He,p-t) reaction. The solid curves are the results of peak fitting.

analyses of the $2^{+}_{1,2}$ states (E_x = 3.35 and 5.3 MeV) in ^{10}C observed in the mirror ^{10}B(p,n)^{10}C reaction at E_p=186 MeV [5], the transitions to these two states are shown to be dominated by $\Delta J^{\pi}=1^{+}$ transition. In the (t,^{3}He) reaction at forward angles, ΔL=0 transitions are dominant. Thus, we conclude that these two 2^{+} states in ^{10}Be are due to Gamow-Teller transitions and are probably the isobaric analog states of the $2^{+}_{1,2}$ states in ^{10}C.

In conclusion, we have demonstrated that the radioactive triton beam produced as a secondary beam from a breakup reaction can be used to study spin-isospin characteristics of states in nuclei. Since new radioactive beam facilities are scheduled for construction, and since high-intensity radioactive beams will become available in the near future, the present result demonstrates that radioactive beams can be widely used in the future for many nuclear structure studies with good energy resolution on the basis of the dispersion matching principle in nuclear reactions. The present results are published elsewhere [6, 7]

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