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## A STUDY OF THE ( $^3\text{He},t$ ) CHARGE-EXCHANGE REACTION AT $E(^3\text{He})=200$ MeV

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The ( $^3\text{He},t$ ) charge-exchange reaction has been studied at a bombarding energy of 200 MeV on 12 targets ranging from  $^{12}\text{C}$  to  $^{244}\text{Pu}$  including  $^{90}\text{Zr}$ ,  $^{120}\text{Sn}$ ,  $^{208}\text{Pb}$  and five radioactive actinide targets. The objective of this work was to establish the feasibility of taking data at zero degrees with the K600 spectrometer and to determine the sensitivity of this charge-exchange reaction to spinflip and non-spinflip transitions. The results could then be compared to the ( $^3\text{He},t$ ) charge-exchange reaction at higher bombarding energies<sup>1</sup> and to (p,n) charge exchange<sup>2</sup>. The selectivity to non-spinflip L=0 transitions is of particular interest for the observation of isobaric analog states (IAS) and certain isovector giant resonances. In a particular application, properties of IAS were measured with emphasis on heavy nuclei.

The experiment was carried out with the K600 magnetic spectrometer at zero degrees. The  $^3\text{He}^{++}$  beam entered the spectrograph and hit a beam stop inside the first dipole magnet. The beam stop was electrically insulated so that the beam current could be read directly from it. Background in the focal plane detector due to particles originating from the beam stop and from beam halo was low when proper precautions were taken. Singly-ionized  $^3\text{He}^+$  particles produced in the target with an intensity on the order of  $10^{-8}$  compared to the incident beam reached the focal plane where they increased the event rate by approximately 30% unless eliminated with an absorber in front of the focal plane detector. Spectra were measured mostly in singles mode, but preliminary coincidence spectra were also obtained in a few instances. In this case, decay protons from unbound states were detected in the scattering chamber at backward angles with two large-area Li-drifted Si detectors.

Figures 1, 2 and 3 display spectra obtained for targets of natural carbon,  $^{120}\text{Sn}$  and  $^{208}\text{Pb}$ , respectively. All measurements were made at identical magnetic field settings. The energy resolution is better than 50 keV. Spectra for the light targets  $^{12}\text{C}$ ,  $^{16}\text{O}$  and  $^{28}\text{Si}$  with very negative Q-values were used primarily for energy calibration but have also intrinsic interest. The spectra for  $^{90}\text{Zr}$ ,  $^{120}\text{Sn}$ ,  $^{181}\text{Ta}$ ,  $^{208}\text{Pb}$  and 5 radioactive actinide targets were obtained to observe IAS. Energies, hence Coulomb displacement energies, total widths, and cross sections were determined. Information about the IAS of the actinide nuclei is quite limited. The widths  $\Gamma$  are of particular interest in the context of the various decay modes. Figure 3 shows as an example the IAS from  $^{208}\text{Pb}$  which has a Lorentzian line shape with  $\gamma \simeq 300$  keV.

Isobaric analog states decay by isospin-allowed and isospin-violating decay modes. The latter account for the so-called spreading width which is due to isospin mixing via the Coulomb force with  $T_<$  doorway states mediated by coupling to the  $(T_0-1)$ -component of the giant isovector monopole resonance<sup>3</sup>. Only recently has it become possible to quantitatively describe the dependence of the experimentally observed spreading widths of IAS on nucleon number and neutron excess<sup>4</sup> by introducing global trends for certain properties of isovector monopole resonances. In particular, mixing with the isovector quadrupole resonance had to be postulated for deformed nuclei. Information about the total and partial widths of IAS beyond  $^{208}\text{Pb}$  is very limited, and additional measurements have therefore been carried out in the meantime<sup>5</sup> at  $E(^3\text{He})=75$  MeV on 5 radioactive actinide targets. Proton decay from the IAS has been measured which will permit us to separate the observed total widths into the two components for comparison with the predicted values.

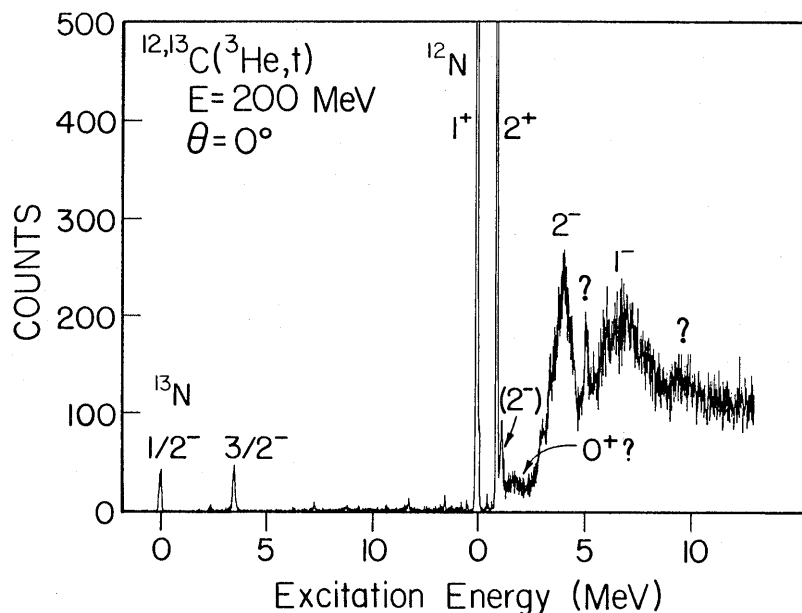
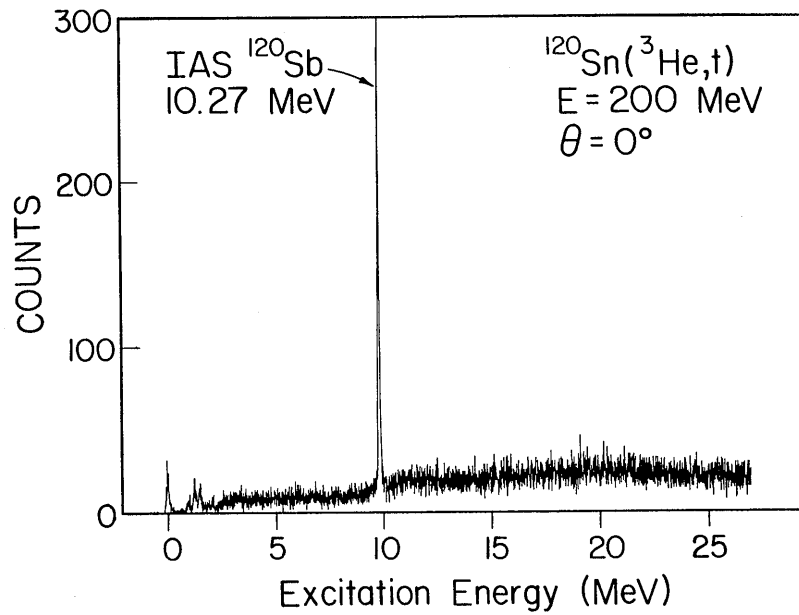
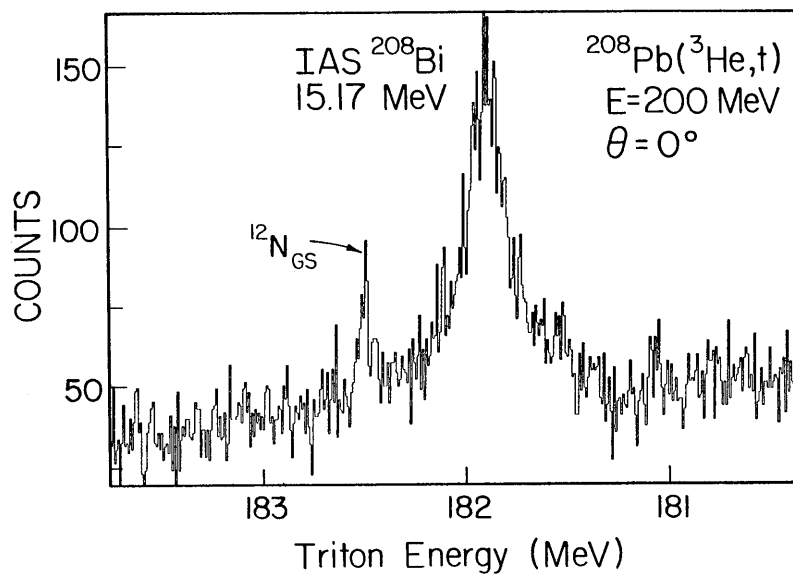


Figure 1. Triton energy spectrum for  $^{12,13}\text{C}(^3\text{He},t)^{12}\text{N}$ ,  $\theta=0^\circ$ ,  $E(^3\text{He})=200$  MeV.



**Figure 2.** Triton energy spectrum for  $^{120}\text{Sn}(^3\text{He},t)^{120}\text{Sb}$ ,  $\theta=0^\circ$ ,  $E(^3\text{He})=200 \text{ MeV}$ .

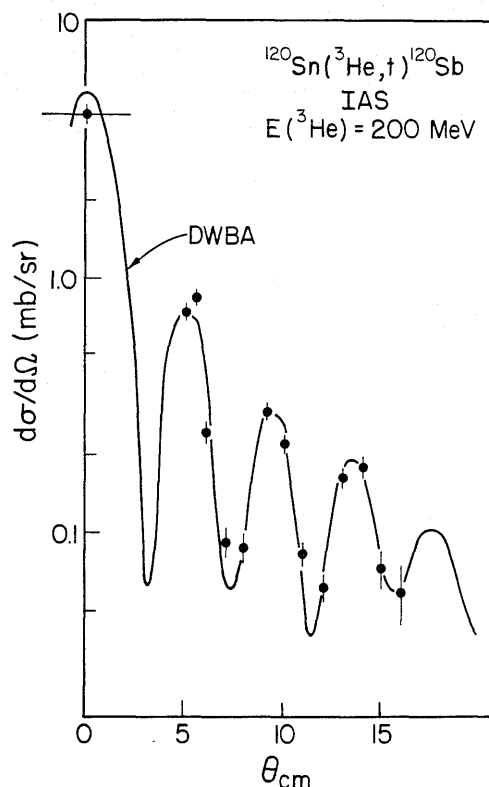


**Figure 3.** Triton energy spectrum (expanded scale) for  $^{208}\text{Pb}(^3\text{He},t)^{208}\text{Bi}$ ,  $\theta=0^\circ$ ,  $E(^3\text{He})=200 \text{ MeV}$ .

It is interesting to compare the zero-degree spectrum of Fig. 1 for  $^{12}\text{C}$  with that obtained at 81 MeV (Ref. 6). The absence of the  $0^+$  state at 2.42 MeV is noteworthy and not understood, and an additional resonance near 10 MeV seems to be indicated. Equally interesting are the cross sections for the transitions to the  $(1/2)^-$  ground and  $(3/2)^-$  3.51 MeV states in  $^{13}\text{N}$  resulting from the 1.1% isotopic abundance of  $^{13}\text{C}$  in natural carbon. The ratio of these cross sections has been used by Bergquist et al.<sup>1</sup> to determine the ratio of the squares of the spinflip (Gamow-Teller) to non-spinflip (Fermi) matrix elements based on the fact that the transition to the ground state is primarily a non-spinflip, whereas the transition to the excited state is a spinflip, transition. Compared to the  $(^3\text{He},t)$  results at higher energies, the ground state transition is much more favored at our bombarding energy leading to a greatly reduced ratio of spinflip to non-spinflip matrix elements on the order of unity. The enhancement of non-spinflip charge-exchange transitions is apparent in all observed spectra.

The IAS at 10.27 MeV dominates the spectrum observed for the  $^{120}\text{Sn}$  target, Fig. 2. Nevertheless, the spectrum also seems to show some Gamow-Teller strength near  $E_x=12$  MeV<sup>7</sup>. Similarly, the spectrum for the  $^{90}\text{Zr}$  target (not shown) displays the IAS at 5.03 MeV but also Gamow-Teller strength to a sharp state at 2.1 MeV and a weak and broad resonance centered near 8.7 MeV. The  $^{120}\text{Sn}$  spectrum received special attention because future attempts to observe components of the isovector monopole resonance will initially concentrate on this target. Figure 4 shows the angular distribution from  $0^\circ$  to  $16^\circ$  measured for the transition to the IAS. The analysis of the data point at  $0^\circ$  is incomplete. A slit aperture was employed which will make it possible to obtain by ray tracing a slightly

**Figure 4.** Angular distribution for  $^{120}\text{Sn}(^3\text{He},t)^{120}\text{Sb}(\text{IAS})$  at  $E(^3\text{He})=200$  MeV. The solid line is from a DWBA calculation using microscopic wave functions and an effective interaction.



averaged angular distribution over the entire  $3^\circ$  to  $4^\circ$  interval. The angular distribution displays a strongly diffractive pattern with a sharp maximum at zero degrees and the first minimum at  $3.5^\circ$ . The observed distribution was found to be in excellent agreement with DWBA calculations using an effective interaction (Yukawa shape) and microscopic BCS wave functions. The absolute values for the cross sections are overestimated at our higher bombarding energy suggesting an energy-dependence in the strength of the effective interaction.

The expected sharp maximum at  $0^\circ$  will be used in future attempts to observe and identify a broad  $L=0$  resonance near 40 MeV excitation energy. The cross sections can now reliably be estimated, and the need for making the measurements at  $0^\circ$  are quite obvious. The continuous background observed up to excitation energies of 28 MeV (see Fig. 2) is expected to increase slowly towards higher excitation energies. This background is known to result primarily from breakup/pickup reactions on the target which are also forward peaked but to a lesser extent. Additional techniques may therefore become necessary to isolate this giant resonance, for example by measuring neutrons (or protons) in coincidence as has been done in the observation of the isoscalar monopole resonance<sup>7</sup>.

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