THE (^{3}He,t) REACTION AT 200 MeV

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Analysis has proceeded on the (^{3}He,t) data taken during 1981.[1] Although no further experiments were performed in 1982, we will report on progress in our understanding of the existing data.[2]

Analogs of the Giant Dipole Resonance (GDR) have been seen on all the targets investigated — ^{12}C, ^{24}Mg, ^{28}Si and ^{40}Ca. The GDR structures seen in the (^{3}He,t) reaction on ^{12}C and ^{40}Ca closely resemble the photoabsorption spectra, which trace out the classic GDR, after correction for the Coulomb energy difference. In the case of ^{28}Si, there is some difference between the shape of the classic GDR in ^{28}Si and its analog in ^{28}P, which is seen in the ^{28}Si(^{3}He,t) reaction.

This difference between the GDR and its charge exchange analog is greatest for ^{24}Mg/^{24}Al, as shown in Fig. 1. The GDR lies closest to peak "D" in the charge-exchange spectrum, but there is considerable structure in the photoabsorption curve, shown in the inset. Peaks "D" and "E" may correspond to the two

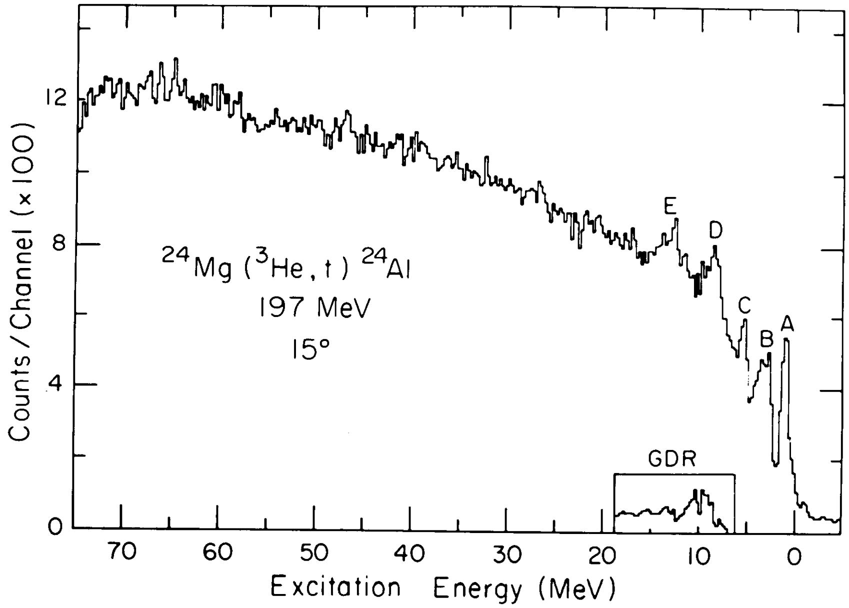

Figure 1. Spectrum of the ^{24}Mg(^{3}He,t)^{24}Al reaction at E_{lab} = 197 MeV and θ_{lab} = 15°. The inset traces the photoabsorption curve.

strongest GDR peaks. At present it is not clear what gives rise to those differences between the GDR and its analog. Deformation may play a role since the effect is greatest for the most deformed nuclei. On the other hand, spin degrees of freedom may be excited in the (^{3}He,t) reaction and not in photoabsorption. Some encouraging theoretical work has started[3] on the question of GDR analogs and more experimental work is also needed.

It is well known that the (^{3}He,t) reaction does not proceed by a one-step direct reaction mechanism at low (24-36 MeV) energies.[4] We have examined this question for the 200 MeV ^{40}Ca(^{3}He,t)^{40}Sc data by means of a microscopic double-folding analysis. The code ALLWRLD[5] has been modified to generate the appropriate form factors by integrating the effective nucleon-nucleon interaction over the nucleons in the projectile (assuming a simple wavefunction) as well as the target.

It is clear that the results of such double folding calculations are simultaneously a test of this reaction model and the interaction and densities used in it. We have adopted a systematic approach in which the existing electron and proton scattering data are used to determine the transition density, so that the ^{3}He data indicate whether these reactions scale with one another. The same nucleon-nucleon interaction is used for both the 35 MeV proton and the 66 MeV/nucleon ^{3}He calculations.

All calculations for a given transition use the same shell model wavefunction, listed in column 2 of Table 1, usually a simple particle-hole state, with the oscillator constant fixed at $\alpha = 0.500$. For the three cases where electron scattering data[6-9] were available, the normalization of the wave function was adjusted by the factors given in the third column of Table 1 to reproduce these data.

The nucleon-nucleon interaction for the hadron reactions was taken from entries 1,4,7,8,11,14,16 and 17 of Table I of Ref. 10, a choice which is slightly different from what is usually known as the M3Y interaction. Calculations using the folding model with this interaction are shown with solid curves in Figs. 2 and 3. The dash-dot curve shows the effect of dropping

Table I. Wave functions and normalizations for the transition densities

State	Model Wavefunct.	Normalization used for			Scaling from
		e	p	^{3}He	p to ^{3}He
3- T=0	Kuo RPA	1.0[a)]	0.55	1.0	1.8
2- T=1	$f_{7/2}d_{3/2}^{-1}$	0.12	0.12	0.10	0.82
5- T=1	$f_{7/2}d_{3/2}^{-1}$	n/a	0.15	0.15[a)]	1.0
4- T=1	$f_{7/2}d_{3/2}^{-1}$	n/a	0.57	0.20	0.35
3- T=1	$f_{7/2}d_{3/2}^{-1}$	n/a	0.043	0.043[a)]	1.0
1+ T=1	see text	0.051	n/a	0.051[a)]	1.0[b)]
GDR	Gillet RPA	n/a	n/a	1.0	n/a

a) Value held fixed

b) Scaling from e to ^{3}He

the tensor part of this interaction for the abnormal parity (1^+, 2^-, 4^-) states. A dashed curve for the normal parity (1^-, 3^-, 5^-) states indicates the result when the imaginary collective term is omitted.

The proton scattering data[11] shown with the solid circles in Fig. 2 provide reasonably complete angular distributions with moderate resolution. A high resolution measurement[10] at two angles allows a separate normalization to be obtained for each of the states of interest. The calculations were adjusted so the solid curves would be consistent with both the high resolution measurements and the summed angular distributions of larger angles. The resulting normalizations are given in column 4 of Table I.

It can be seen from Fig. 3 that the shapes of the calculated angular distributions generally agree with the measured ones. The exception is the 1^+ state which falls off much faster than the prediction. The agreement in absolute magnitude can be examined in Table I. Of particular interest is the last column which shows the ratio of ^{3}He to p normalization factors. The agreement with proton scattering is generally within a factor of two, suggesting that the proton and ^{3}He induced reactions might be consistently explained by a simple direct reaction theory.

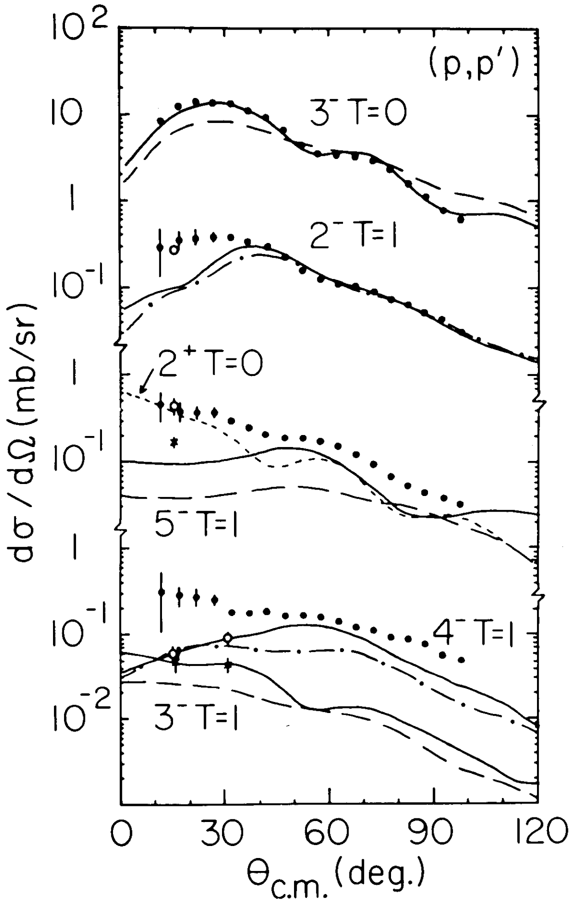

Figure 2. Proton scattering angular distributions on ^{40}Ca from ref. 9 (solid circles) and from ref. 10 (O's for even J, X's for odd J). From top to bottom the states are 3^- T=0 (3.74 MeV); 2^- T=1 (8.42 MeV); $4^-/3^-$ T=1 (7.67 MeV) doublet; and 2^+ T=0/5^- T=1 (8.56 MeV) doublet. The curves represent microscopic DWBA calculations as discussed in the text.

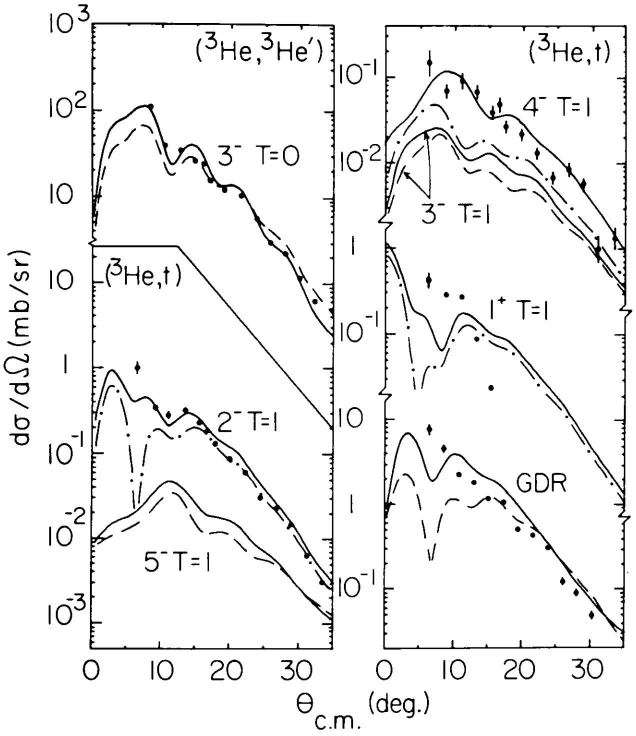

Figure 3. Angular distributions measured in the present experiment for the ^{40}Ca(^{3}He,^{3}He') and ^{40}Ca(^{3}He,t) reactions. On the left are the 3.74 MeV, 3^- T=0 state in ^{40}Ca and the 0.8 MeV $2^-/5^-$ T=1 doublet in ^{40}Sc. On the right are the 0 MeV, $4^-/3^-$ T=1 doublet; the 2.37 MeV 1^+ T=1 state; and the GDR at 12 MeV in ^{40}Sc. The curves represent microscopic DWBA calculations, as discussed in the text.

In summary, we have calculated angular distributions using a model in which the nucleon-nucleon interaction was folded with the appropriate projectile and target densities. The transition densities were calibrated with similar calculations for other reactions. This direct reaction theory reproduces the data quite well both in shape and magnitude, although scaling by reasonable factors is sometimes required. These results are quite promising and suggest that the reaction theory should be tested further by studying a target where a more complete set of complementary data is available.

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