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J DEPENDENCE FOR $l = 1$ NUCLEON TRANSFER*

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The J dependence for $l = 1$ nucleon-transfer reactions at an incident-deuteron energy of 23 MeV is qualitatively reproduced by distorted-wave claculations. Considerably greater damping of contributions from the interior of the nucleus is required than previously thought necessary in (d,p) reactions. This may imply that the energy dependence of the real potential for protons is stronger than the dependence previously obtained for neutrons.

The experimentally observed angular distributions for the (d,p) reaction at 23 MeV show the J dependence qualitatively predicted by distorted-wave theory. This is in contrast with the large discrepancy between experiment and theory observed at lower energies.

Lee and Schiffer[1] have observed a very pronounced J dependence in (d,p) reactions for p-wave neutron transfer at backward angles. These experiments in the region of incident-deuteron energies around 12 MeV show a very sharp minimum for $p_{1/2}$ neutron transfers near 120° and a relatively flat angular distribution for $p_{3/2}$ neutrons in that angular range. Such an effect is not predicted by the distorted-wave theory, and attempts to reproduce the experimental angular distribution have been unsuccessful. Recently Johnson and Santos[2] have considered the effect of the D component of the deuteron internal wave function and have shown that for $l = 3$ the corrections resulting from the inclusion of the D component are important. However, inclusion of the D component does not produce an appreciable effect for $l = 1$ transfers at backward angles.

In an investigation of the (d, He^3) reaction on the molybdenum isotopes,[3] we have observed a significant experimental difference between the angular distributions corresponding to $p_{1/2}$ proton pickup and those corresponding to $p_{3/2}$ proton pickup. Representative angular distributions are shown in Fig. 1. The J dependence consists in the difference in the depth of the minimum near 18°. That this difference cannot be assigned to Q dependence is established by its observation over a sufficiently large range of Q values in the Zr and Mo isotopes. The distorted-wave calculations[4] reproduce the effect satisfactorily. The calculations show that the main contribution to the J-dependence effect is due to the spin-orbit term of the deuteron potential. Furthermore, if one uses sharp cutoffs of the radial integrals, the effect persists up to a cutoff radius of 6 F. On the other hand, the (d,t) reactions on these same isotopes do not show a significant J dependence in the angular distributions corresponding to $p_{1/2}$ and $p_{3/2}$ neutron pickup, and none is predicted by the distorted-wave calculations.

Since the J dependence for $l = 1$ pickup is correctly given by the distorted-wave calculations for the (d, He^3) and (d,t) experiments, which were done at an incident-deuteron energy of 23 MeV, it seemed of interest to investigate the (d,p) reaction at this same energy. A pronounced J dependence has been found[5] for the

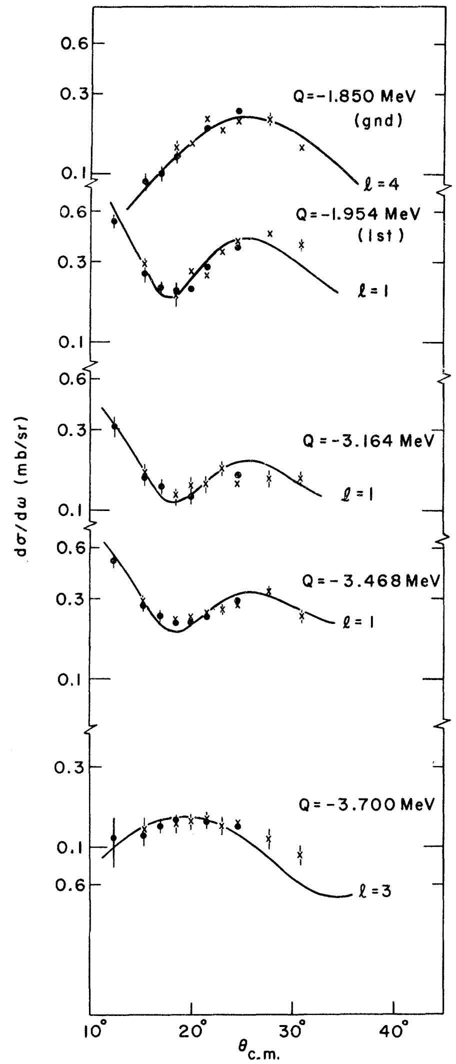

FIG. 1. Angular distributions from the reaction $Mo^{92}(d,He^3)Nb^{91}$ at $E_d = 23$ MeV. The solid lines are the result of distorted-wave (zero-range) calculations.

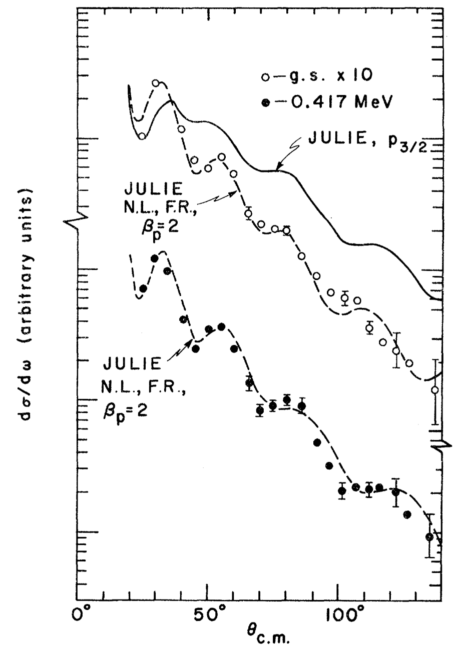

FIG. 2. $Fe^{54}(d,p)Fe^{55}$ angular distributions for the transitions to the ground state and first excited state. The ordinate of the curve and points for the 0.417-MeV level have been shifted downward one decade. The solid line is the zero-range calculation, the dashed lines are nonlocal finite-range calculations.

reaction $Fe^{54}(d,p)Fe^{55}$ to the ground state $(\frac{3}{2}^-)$ and first excited state $(\frac{1}{2}^-)$ at 10 MeV. The experimental results at 23 MeV for these two transitions are shown in Fig. 2. In contrast to the low-energy work, there are no dramatic differences between the two angular distributions. The flat regions in the angular distributions are at somewhat larger angles for the $p_{1/2}$ transition than for the $p_{3/2}$ transition. The distorted-wave curves have been calculated with the potentials listed in Table I. The deuteron potential was obtained from Bassel[6] and the proton potential was taken from Satchler's analysis of the scattering of 30-MeV protons.[7] It is clear that the zero-range JULIE calculation does not give a sufficiently rapid decrease of cross section with angle. Therefore a local-energy approximation to nonlocality and finite-range effects[8] was made with a program written by Perey.[9] In earlier work on the energy dependence of the real potential V for neutrons, Perey and Buck[10] suggested that $\Delta V = -0.3E$. This value corresponds to $\beta \approx 0.9$ for neutrons. In his analysis of proton scattering, Perey[11] found evidence that ΔV

Table I. Optical-model potential parameters for Fe^{54}.

	V	W	r_0	a	V_s	W_s	r'	a'	W'	r_c
$Fe^{54}+d$	105.0	0.0	1.02	0.86	6.0	0	1.42	0.65	60.0	1.3
$Fe^{54}+p$	52.4	3.0	1.12	0.75	6.4	0	1.33	0.58	22.56	1.12

$=-0.55E$. This difference is partly due to the use of backward angles in the latter analysis and perhaps to its neglect of core excitations. We have found that the decrease of cross section with angle requires $\beta=2$ for protons and $\beta=1$ for deuterons. This larger value of β increases the damping of contributions from the interior and may imply a considerably higher rate of energy dependence of the real potential than suggested by the work of Buck and Perey.

The J dependence for $l=1$ particle-transfer reactions at $E_d=23$ MeV appears to be qualitatively in good agreement with the distorted-wave predictions. This suggests the possibility that the $l=1, J=l-\frac{1}{2}$ effect of Lee and Schiffer may be due to the interference of direct reaction with some other type of reaction mechanism.

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EVIDENCE FOR THE ISOBARIC SPLITTING OF THE GIANT RESONANCE FROM THE REACTION $^{89}Y(p,\gamma_0)^{90}Zr$†

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A small but well-defined resonance was found in ^{90}Zr near the predicted $T_>$ component of the giant dipole resonance.

Several years ago, Fallieros, Goulard, and Ventner[1] suggested that the giant dipole resonance in nuclei is split into two components: The larger component occurs at lower energy and has the same isospin as the target (i.e., $T_<$). The $T_>$ counterpart was predicted to be about 5 MeV higher in energy for ^{90}Zr. Although an excess of photoneutrons above a classical Lorentz line shape has been reported[2] above the giant dipole resonance in ^{90}Zr, an obvious resonant cross section near the predicted location of the $T_>$ component has not been identified. This paper identifies the position and width of what is probably the $T_>$ resonance. It would be interesting if experiments sensitive to other decay modes of ^{90}Zr could be performed in order to provide additional information about the $T_>$ state.

The $^{89}Y(p,\gamma_0)^{90}Zr$ cross section at 90°, shown in Fig. 1, and obtained at the Los Alamos Scientific Laboratory tandem facility, shows a definite resonance centered at an excitation energy of 21.0 ± 0.15 MeV with a full width at half-maximum of about 0.6 MeV.

The integrated (p,γ_0) cross section in this small resonance is 1.5 MeV μb/sr corresponding to a (γ,p_0) integrated cross section of 0.75 MeV mb/sr. This integrated cross section is considerably smaller than the predicted partition of dipole strength would imply if the (p,γ_0) cross section were equally sensitive to the $T_>$ and $T_<$ giant resonance components. How-