where

$$F_j = [1-(M_j/M_\tau)^2]^2[1+2(M_j/M_\tau)^2].$$

We can use two independent measures for $B(\tau\to\rho\nu_\tau)$ to evaluate (2). Tsai[7] has calculated $B(\tau\to\rho\nu_\tau) = (21.5\pm1.8)\%$ assuming the conserved-vector-current hypothesis and the measurement[8] $\Gamma(e^+e^-\to\rho^0) = 5.8\pm0.5$ keV, where the error in $B(\tau\to\rho\nu_\tau)$ reflects the uncertainty in $\Gamma(e^+e^-\to\rho^0)$. For $\tan^2\theta_C = 0.05$ and $M_\tau = 1.782$ GeV/c^2, one obtains[9] $B(\tau\to K^*\nu_\tau) = (1.0\pm0.1)\%$. Alternatively we can use the Mark-II measurement[2] $B(\tau\to\rho\nu_\tau) = (20.5\pm4.1)\%$ to obtain $B(\tau\to K^*\nu_\tau) = (0.95\pm0.19)\%$. The experimental measurement presented in this Letter agrees well with both these predictions.

The work was supported in part by the Department of Energy under Contract No. DE-AC03-76SF00515 and No. W-7405-ENG-48. Support for individuals came from the listed institutions in addition to Deutsche Akademische Austauschdienst, Bonn, Germany, and Ecolê Polytechnique, Paris, France.

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[1]The notation $\tau^-\to\rho^-\nu_\tau$ and $\tau^-\to K^{*-}\nu_\tau$, used throughout the text, imply also the charge-conjugate reactions $\tau^+\to\rho^+\bar{\nu}_\tau$ and $\tau^+\to K^{*+}\bar{\nu}_\tau$.

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Investigation of the (d,p) Stripping Reaction around 700 MeV

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(Received 14 January 1980)

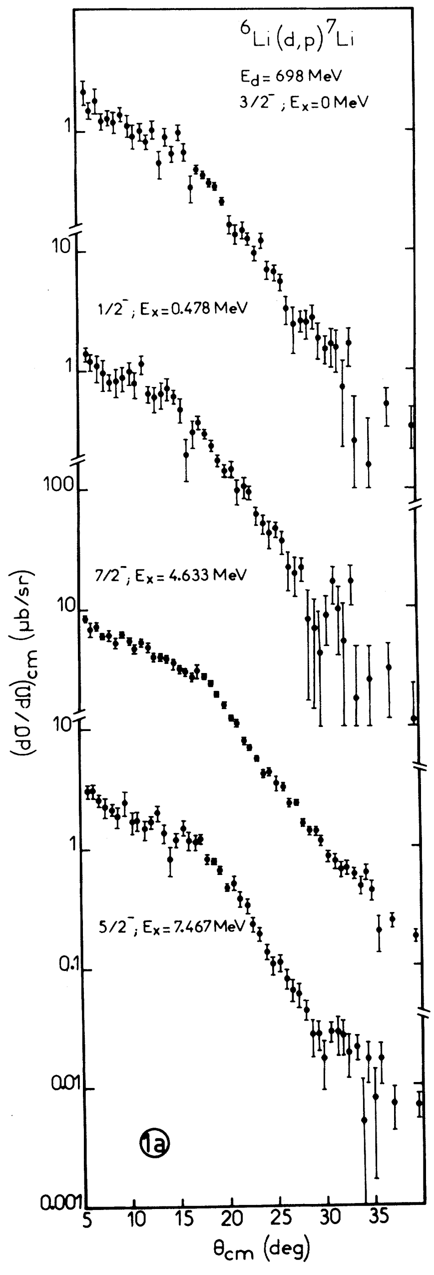
First results for the (d,p) reaction on ^{6}Li, ^{9}Be, and ^{16}O are presented for a scattering energy T_d = 698 MeV at momentum transfers 2 fm$^{-1}\le q\le 5$ fm^{-1}. Simple distorted-wave Born-approximation and rescattering calculations stress the need for a more comprehensive analysis by explicitly including both the stripping amplitude and mesonic degrees of freedom.

PACS numbers: 25.40.Gr, 24.10.-i

In recent years there has been constantly increasing interest in one-nucleon–transfer reactions at intermediate energies and at momentum transfers q of typically $q\ge 2$ fm^{-1} as they might provide information on high-momentum components in wave functions of bound nucleons[1] and on virtual or real isobar degrees of freedom in nuclei.[2] Presently, however, such processes are only understood qualitatively on a microscopic level.[1-5] To remedy this unsatisfactory situation—which dominantly reflects the lack of detailed experimental information—we present and discuss in this note results on the (d,p) stripping reaction on various light nuclei at the scattering energy $T_d = 698$ MeV.

The present experiment was performed at Saclay with a deuteron beam of 698 MeV kinetic energy, produced by the SATURNE synchrotron. The outgoing protons were identified and counted with the energy-loss spectrometer SPES I, which uses as a standard detection system, a combination of plastic scintillators and drift chambers to identify and to measure the position of a particle along the focal plane. In this experiment the trigger system was supplemented by three Čerenkov counters which were sensitive only to protons in order to reject deuterons with the same momentum as the protons detected.

With this system, the reactions ^{6}Li$(d,p)^7$Li in the angular range $5.7° < \theta_{c.m.} < 39.6°$ and for the excitation of the four lowest-lying levels, ^{9}Be$(d,$



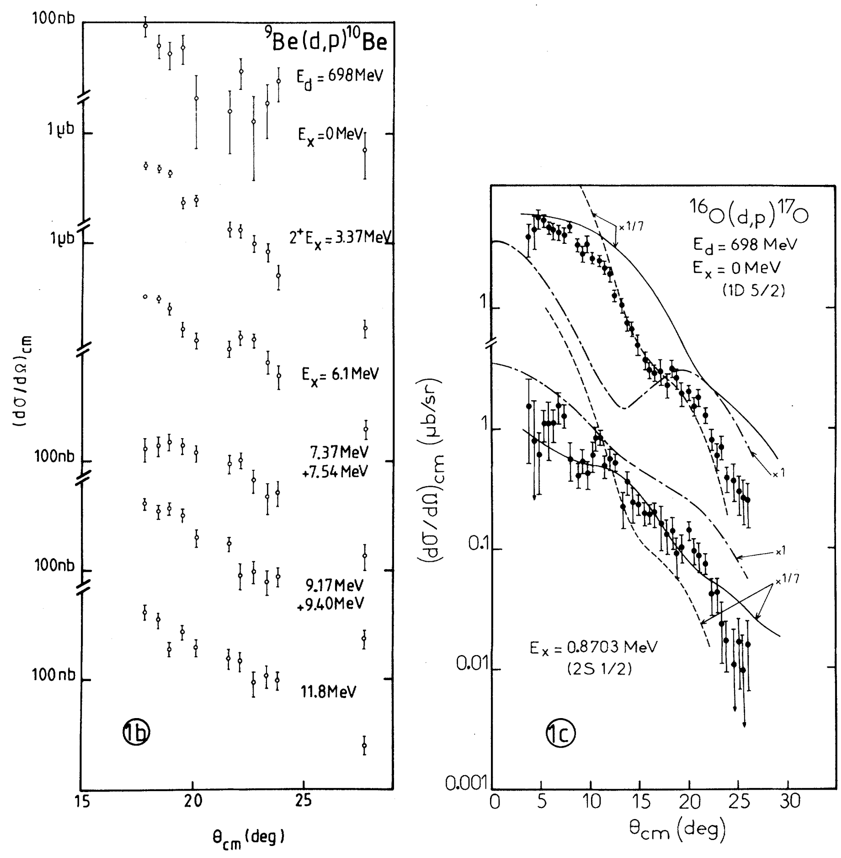


FIG. 1. (a) Differential cross section for the reaction ^{6}Li$(d,p)^7$Li(J^π) at $T_d = 698$ MeV. Compared are the angular distributions for the excitation of the four lowest states in ^{7}Li (their total angular momentum J, their parity π, and their binding energy E_x are indicated). (b) As in (a), but for ^{9}Be$(d,p)^{10}$Be(J^π). (c) As in (a), but for ^{16}O$(d,p)^{17}$O(J^π). Shown are the DWBA results from the stripping model, either with a folded potential (solid lines) or a phenomenological potential (dashed lines) for the deuteron (see the text for details). Note that these predictions are renormalized by a factor $\frac{1}{7}$. Dotted-dashed lines give the results of a calculation based on the rescattering diagram 2(b), including distortions in the eikonal approximation (see the text for further details). There is no renormalization factor for this last calculation.

$p)^{10}$Be (between 17.8° and 27.7° for six levels) and ^{16}O$(d,p)^{17}$O (between 3.8° and 26° for two levels) were measured. The results are presented with the statistical errors in Fig. 1; uncertainties in the beam flux and the target thickness (mainly for the iced-water target for ^{16}O) result in an overall scaling error of 20%. We should note that, in order to facilitate a theoretical interpretation of the transfer reaction, data on elastic deuteron scattering on ^{6}Li and ^{16}O were taken at the same scattering energy (the tabulated cross sections can be found[6]).

As a first attempt to understand the gross feature of these data, a rough analysis was performed for the excitation of the ground and the first excited state in ^{16}O$(d,p)^{17}$O(J^π). As in previous analyses,[3,4] a calculation was performed within the stripping model [Fig. 2(a)] based on the conventional distorted-wave Born approximation (DWBA) yielding the transition amplitude

$$T_{(d,p)}{}^{S}(\vec{k}_d,\vec{k}_p) \simeq \int \chi_p^*(\vec{k}_p,\vec{r}_p)\psi_\alpha^*(\vec{r}_n)V_{pn}(\vec{r}_{pn})\varphi_d(\vec{r})\chi_d(\vec{k}_d,\vec{R})\,d^3r_p\,d^3r_n \qquad (1)$$

with $\vec{R}=\frac{1}{2}(\vec{r}_p+\vec{r}_n)$ and $\vec{r}=\vec{r}_p-\vec{r}_n$ for the excitation of a pure single-particle state $|\alpha\rangle$ (i.e., with a spectroscopic factor equal to 1). The corresponding form factor was taken from Cooper *et al.*[7] To treat the S and D states of the deuteron (in this model the latter strongly dominates at the momentum transfers considered), we made the "local-momentum approximation." For the derivation of the distorted wave $\chi_d(\vec{k}_d,\vec{R})$ of the deuteron, two choices for the optical potential were tested:

First, employing the Johnson and Soper prescription[8]

$$V_d(R)=\frac{\int\{V_p(|\vec{R}+\frac{1}{2}\vec{r}|)+V_n(|\vec{R}-\frac{1}{2}\vec{r}|)\}V_{pn}(\vec{r})\varphi_d(\vec{r})d^3r}{\int V_{pn}(\vec{r})\varphi_d(\vec{r})\,d^3r}. \qquad (2)$$

Here V_p and V_n denote the optical potentials for the proton and the neutron for elastic scattering on ^{16}O at half of the deuteron energy, which, as for the outgoing proton, were derived from a calculation in the Kerman-McManus-Thaler formalism by Chaumeaux, Layly, and Schaeffer.[9]

Second, using a purely phenomenological deuteron optical potential as extracted from a fit of the elastic ^{16}O$(d,d)^{16}$O data at the same scattering energy (the corresponding parameters for a simple volume Woods-Saxon form are listed in Table I).

The results of this analysis are shown in Fig. 1(c). Most strikingly it is found that the data are overestimated by nearly one order of magnitude for both choices of the deuteron potential. Though rough qualitative agreement is found for the angular distributions, in particular for the deuteron potential based on the Johnson-Soper prescription, we feel that both our results and other findings[3,4,10] indicate that an important part of the physics of the (d,p) reaction is missed in the conventional DWBA. This idea is supported from a comparison with other one-nucleon transfer reactions, i.e. (p,π^+)[11,12] and (γ,p)[13]: There is evidence that at scattering energies between 200 and 600 MeV both reactions are dominated by π-induced $\Delta(1236)$ excitation, particularly at scattering energies around the (3, 3) resonance. Consequently, we expect that the π-rescattering mechanism is of importance also for the (d,p) reaction at large momentum transfers and at scattering energies around 600 MeV[14] [as for the formulation of $V_\alpha(R)$ in Eq. (2), we thereby as-

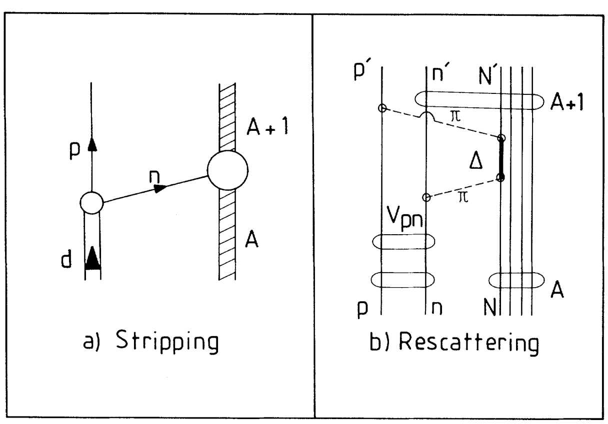


FIG. 2. (a) Schematical representation of the stripping amplitude. (b) Pion-rescattering contribution to the (d,p) reaction.

TABLE I. Optical-potential parameters fitting the deuteron elastic scattering at 698 MeV on ^{16}O. The notation is the same as in Ref. 9.

r_C (fm)	V (MeV)	r (fm)	a (fm)	W (MeV)	r_i (fm)	a_i (fm)
1.20	21.23	1.133	0.409	−15.45	1.217	0.428

sume that each nucleon in the deuteron carries approximately have of the scattering energy available].

Among the various exchange contributions estimated, the diagram in Fig. 2(b), which involves noncrossed double π rescattering together with intermediate Δ excitation yields the leading contribution. For practical purposes we cast it into a static, nonrelativistic transition potential. In evaluating the three-dimensional loop integration, only the singularity associated with the deuteron breakup was treated rigorously [to account for its large nonlocality $\lambda \simeq (m\,|E_d|)^{-1/2} \sim 4$ fm; E_d is the binding energy of the deuteron]. Approximating the other propagators in a zero-range form, we end up with a simple effective three-body transition potential

$$V(\vec{r}_p{}', \vec{r}_n{}', \vec{r}_N{}', \vec{r}_p, \vec{r}_n, \vec{r}_N; \vec{k}_d, \vec{k}_p)$$
$$= \frac{m}{64\pi}\left(\frac{f_\pi}{m_\pi}\right)^2\left(\frac{f_\pi{}^*}{m_\pi}\right)^2 \frac{\vec{\sigma}_p\cdot(\vec{k}_d - 2\vec{k}_p)\vec{S}_N\cdot(\vec{k}_d - 2\vec{k}_p)\vec{S}_N{}^\dagger\cdot\vec{k}_d\vec{\sigma}_n{}'\cdot\vec{k}_d\vec{\tau}_p\cdot\vec{T}_N{}^\dagger\vec{T}_N\cdot\tau_n{}'}{[\frac{1}{2}(\vec{k}_d-\vec{k}_p)^2+m_\pi{}^2](\frac{1}{4}k_d{}^2+m_\pi{}^2)[\vec{k}_d{}^2/8\mu_{N\Delta}+M_\Delta - M_N + \frac{1}{2}i\Gamma_\Delta T_d - T_d]}$$
$$\times V_{pn}(\vec{r}_p - \vec{r}_n)\frac{[\exp(m\,|E_d|)^{1/2}|\vec{r}_n{}' - \vec{r}_n|]}{|\vec{r}_n{}' - \vec{r}_n|}\,\delta(\vec{r}_p{}' - \vec{r}_p)\delta(\vec{r}_N{}' - \vec{r}_N)\delta(\vec{r}_n{}' - \vec{r}_p)\delta(\vec{r}_p - \vec{r}_N); \quad (3)$$

off-shell corrections are incorporated via form factors in the πNN and the $\pi N\Delta$ coupling constant f_π and $f_\pi{}^*$, respectively; $V_{pn}(\vec{r})$ with $\vec{r} = \vec{r}_p - \vec{r}_n$ represents the complete pn potential. The structure of the nuclear transition amplitude is then given as

$$T_{(d,p)}{}^R(\vec{k}_d, \vec{k}_p) = \sum_\beta \int \chi_p{}^*(\vec{k}_p, \vec{r}_p{}')\psi_\alpha{}^*(\vec{r}_n{}')\psi_\beta{}^*(\vec{r}_N{}')$$
$$\times V(\vec{r}_p{}', \vec{r}_n{}', \vec{r}_N{}', \vec{r}_p, \vec{r}_n, \vec{r}_N; \vec{k}_d, \vec{k}_p)\chi_d(\vec{k}_d, \vec{r})\varphi_d(\vec{r})\psi_\beta(\vec{r}_N)d^3r_p d^3r_n d^3r_N d^3r_p{}' d^3r_n{}' d^3r_N{}', \quad (4)$$

with the sum over β including all nucleons in ^{16}O.

The results of the calculation are included in Fig. 1(c). Comparing with the DWBA the overall shape of the angular distributions predicted is of comparable quality, while the absolute normalization is reproduced more correctly. However, the calculation is not able to reproduce the experimental ratio for the excitation of the ground state versus the first excited state, which is nicely given by the DWBA calculation.

In view of such inconsistencies in our rough analysis, we have to be careful in drawing conclusions. The only firm statement we would like to make is that for the (d,p) process mesonic and baryonic degrees of freedom seem to be important at energies above the (3, 3) resonance. This is in line with findings from the (p,π) and the (γ,p) reaction, where conventional distortions are not sufficient to reproduce the data, and where exchange currents (in the widest sense) are an important ingredient of any microscopic theory.[11-14] Including internal degrees of freedom consistently seems to provide a basis for a unified understanding of one-nucleon–transfer processes in particular and of high–momentum-transfer reactions in general.

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