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ONE- NUCLEON TRANSFER REACTIONS ON DEFORMED NUCLEI

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ONE- NUCLEON TRANSFER REACTIONS ON DEFORMED NUCLEI

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1. Introduction

In the last years the one-nucleon transfer reactions caused by medium and low-energy particles (nucleons, deuterons, tritons and so forth) were applied more and more frequently for the analysis of the nuclear structure. Many of the obtained experimental data have been successfully described by the distorted wave Born approximation (DWBA), under the assumption that the transition takes place directly from the incident to the exit channel, without any intermediate excitations. But it is well known that for instance collective excitations may well play a role /1/.

In ref. /2/ the one-nucleon transfer reaction on deformed nuclei is treated in terms of the DWBA, where, using the adiabatic approximation the contributions of the rotational levels of the initial and final nucleus on the differential cross section was taken into account. In the same notation as in ref. /2/ we obtained for the differential cross section

$$
\begin{aligned}
\sigma(\theta) = {} & C^2 [16\pi (2s_n+1)(1+\delta_{OK_A})]^{-1} \sum_{JL} (2L+1)^{-1} (J_A J\, K_A \Omega | J_B\, K_B)^2 \times \\
& \times \sum_{m'} \Big| \sum_{n\ell'' jv} C_{n\ell'' j} (L\, s_n\, \Omega - v\, v | J\, \Omega)(\ell''\, s_n\, \Omega - v\, v | j\, \Omega) \times \\
& \times \sum_{\ell' \bar{\ell}' \ell \bar{\ell} m \bar{m}} I \begin{pmatrix} \ell' \ell m, & \ell'' \\ \bar{\ell}' \bar{\ell} \bar{m}, & \end{pmatrix} \hat{\ell} \hat{\bar{\ell}} \hat{\ell}'' (\ell \bar{\ell}\, 0\, 0 | \ell'' 0) \times \qquad (1) \\
& \times (\ell \bar{\ell}\, m m | \ell''\, \Omega - v)(\ell' \bar{\ell}'\, m m | L\, \Omega - v) \times \\
& \times (\ell' \bar{\ell}'\, m' 0 | L m') \, Y^*_{\ell' m'} (\theta, \phi) \Big|^2 ,
\end{aligned}
$$

where

$$I = \int_0^{R_{max}} \bar{R}_{\bar{\ell}'\bar{\ell}\bar{m}} \; R_{n\ell' j} R_{\ell'\ell m} \, r^2 \, dr \qquad (2)$$

is the overlap integral of the radial functions of the relative motion and the bound state. In the deformed nuclear field one immediately obtains coupled channel equations for the radial functions of the relative motion.

The bound state wave function in the deformed Saxon-Woods potential /3/ is given by

$$\Psi_\Omega(\vec{r}) = \sum_{n\ell j} C_{n\ell j} R_{n\ell j} \sum_v (\ell s \, \Omega - v \, v \,|\, j \Omega) \, Y_{\ell \Omega - v} \; * \sum_{v'} D^s_{vv'}(\theta_i) \, X_{sv'} \, , \qquad (3)$$

where the $R_{n\ell j}$ are the exact solutions of the radial Schroedinger equation with the spherical Saxon-Woods potential. In eq. (3) the spin function was transformed in the laboratory system.

The selection rules for the angular momentum transfer J and its projection $\Omega = K_B - K_A$ into the nuclear symmetry axis follow from eq. (1).

In this work only methodical investigation of the influences of coupled channel equations, of the deformed Saxon-Woods potential for the bound state wave function and of the change of the deformation parameter on the differential cross section has been performed.

2. Results and Discussion

In spite of the fact that our results refer, to the pick-up reaction $^{160}Gd(d,t)^{159}Gd$ at 12.1 MeV /4/ and to the stripping reaction $^{24}Mg(d,p)^{25}Mg$ at 15 MeV /5,1/ a comparison of the experimental data with the theoretical predictions is not carried out, because at present we are only in qualitative effects of our considerations. Therefore, the optical parameters, listed in table 1, were not fitted to the experimental data. For Gd the coefficients $c_{n\ell j}$ of the deformed Saxon-Woods bound state wave function were taken from ref. /3/ and for Mg were used the ordinary Nilsson coefficients. Detailed calculations with respect to the experimental data are in preparation.

In order to investigate the influences of the change of the deformation parameter on the differential cross section we varied it in the distorted waves (β_{DW}) and in the bound state wave function (β_{BS}), independently. In figures 1 to 6 are displayed the differential cross sections calculated with the following deformation parameters:

$\beta_{DW} = 0$	$\beta_{BS} = 0$	denoted in the fig. by (0/0)
$\beta_{DW} = 0.3$	$\beta_{BS} = 0$	(0.3/0)
$\beta_{DW} = 0$	$\beta_{BS} = 0.3$	(0/0.3)
$\beta_{DW} = 0.3$	$\beta_{BS} = 0.3$	(0.3/0.3) .

We will compare two cases in the following examples. i) First, we consider how the differential cross section varies depending on whether the deformation is considered or not. (The curves assigned with (0/0) and (0.3/0) are compared). ii) Second, we consider how the differential cross section varies depending both on the deformation in the coupled channel equations and on the bound state deformation. (The curves assigned with (0.3/0) and (0.3/0.3) are compared).

2.1. $^{160}Gd(d,t)^{159}Gd$

In this reaction we considered states with spins $J=1/2$, 3/2 and 5/2. The corresponding angular distributions are displayed, in figures 1 to 3. Besides the asymptotic quantum numbers $\Omega^{\pi}[Nn_z\Lambda]$, the quantum numbers of the spherical case $\beta_{BS}=0(n\ell j)$ are given in the figures, too. Now we consider case i). As is seen, past 60° the two curves are very similar. However, the (0.3/0) angular distribution has a smoother slope than that with (0/0). In addition to these changes in the shape the differential cross section with(0.3/0) at angles greater than 60° is larger than that with (0/0). It means that the absolute values of the angular distribution increase when taking into account the indirect contributions. The ratio of the absolute values of the cross section amounts to about a factor 1.5 to 3.

At the forward angles up to 60° some of the differential cross sections are strongly affected by the inclusion of the deformation. For instance, in fig. 1 the minimum is shifted about 10° to the left.

Next we shall consider case ii).

As is seen, the shape of the two curves is very similar. It means, that the inclusion of the deformed state wave function influences only the absolute values of the differential cross section. However, the ratio of the absolute values is not the same for the curves (0/0) and (0/0.3). This effect can be explained by the fact, that including the deformation in the distorted waves the coupling possibilities for the deformed bound state wave function increase.

2.2. $^{24}Mg(d,p)^{25}Mg$

First we consider the stripping to the 5/2 $5/2^+$ [202] ground state. The Nilsson coefficient for this state is unity. The angular distributions are displayed in fig. 4. The comparison of the differential cross sections indicates that the inclusion of the coupled channel equations changes the shape as well as the absolute value of the cross section. The maxima and minima are shifted to the right and the (0.3/0) cross section is larger than the (0/0) cross section for angles up to 120°. The ratio amounts to about a factor 2 at the peak. Similar results have also been obtained in ref. /1/.

Next we shall consider the stripping to the $K=1/2$ band, with the spins $J=1/2$, 3/2 and 5/2. The cross section to the 1/2 $1/2^+$[211] state are displayed in fig. 5. We consider again the case i). First as is seen, the shapes of the two curves are very similar but the (0.3/0) curve is smaller than the (0/0) curve. This means that in this case the absolute value of the cross section decreases when taking into account the indirect contributions. This result is in contradiction with that obtained for the ground state and also with those of ref. /1/.

If we now consider the case ii), we can see, that the effect of the coupled channel equations becomes larger when taking into account the deformation in the bound states, Finally, we will consider the stripping to the 3/2 $1/2^+$ [211] and 5/2 $1/2^+$ [211] states. The cross section are given in fig. 6. In order to investigate the J-dependence of the cross section we compare the (0.3/0.3) cross sections with that denoted by (0/0.3). The (0/0.3) cross section for $J=5/2$ agrees with that for $J=3/2$ because we renormalized the curves in this figures by the coefficients $c_{1d5/2}$ and $c_{1d3/2}$, respectively. Figure 6 shows, that only the absolute values of the differential cross sections are effected by the different J. Noticeable is the fact that the ratios of the absolute values of the (0/0.3) curve to the (0.3/0.3) curves depend strongly on the coefficients $c_{n\ell j}$.

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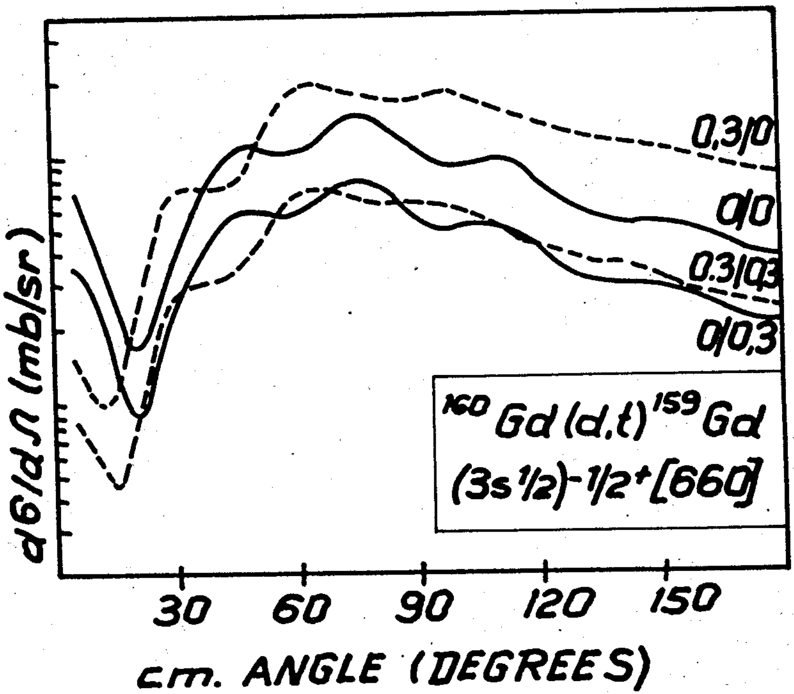

Fig. 1. Cross sections for the deformation parameters $\beta_{DW}=0$, 0.2 and $\beta_{BS}=0$, 0.3 to the (3s 1/2) - 1/2$^+$ [660] state in ^{159}Gd.

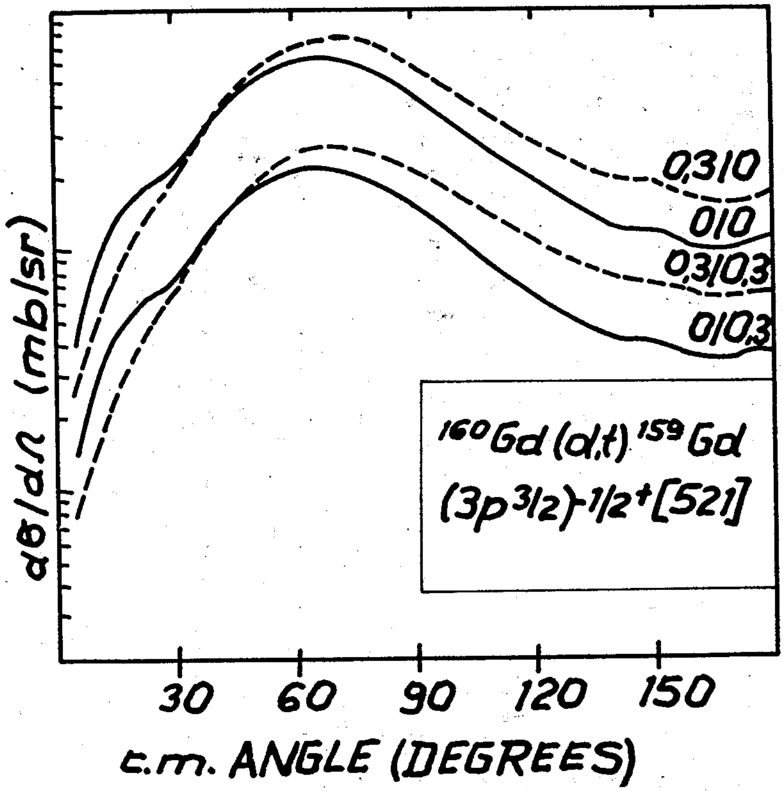

Fig. 2. Cross sections for the deformation parameters $\beta_{DW}=0$, 0.3 and $\beta_{BS}=0$, 0.3 to the (3p 3/2) - 3/2- [521] state in Gd.

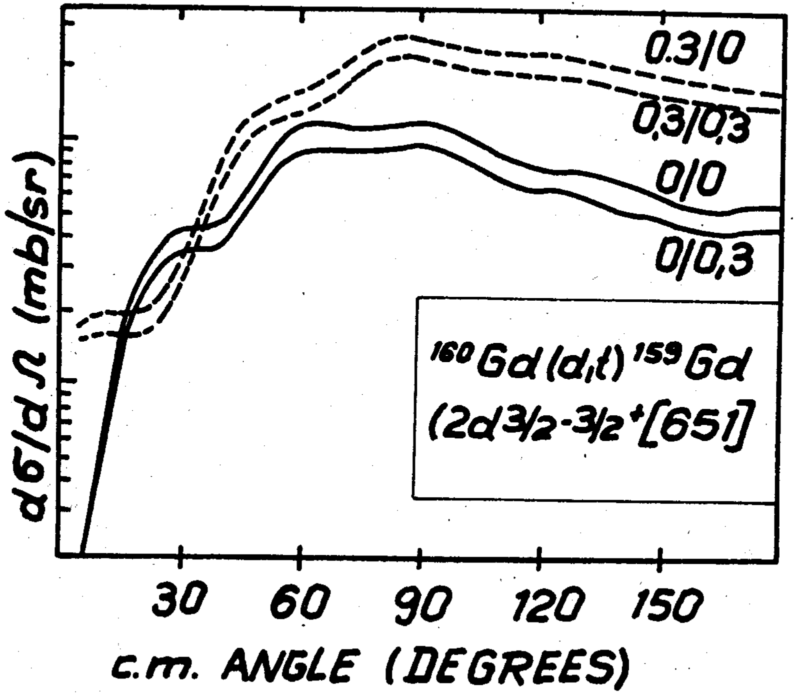

Fig. 3. Cross sections for the values of the deformation parameters $\beta_{DW}=0$, 0.3 and $\beta_{BS}=0$, 0.3 to the (2d 3/2) - 3/2+ [651] state in ^{159}Gd.

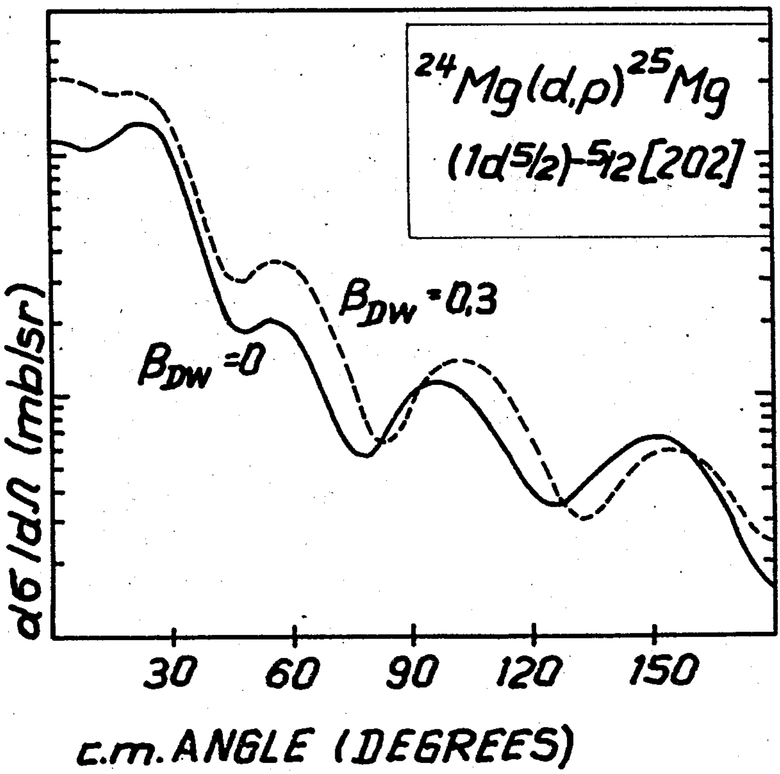

Fig. 4. Cross sections for the deformation parameter $\beta_{DW}=0$ and $\beta_{DW}=0.3$ to the ground tstate in ^{25}Mg .

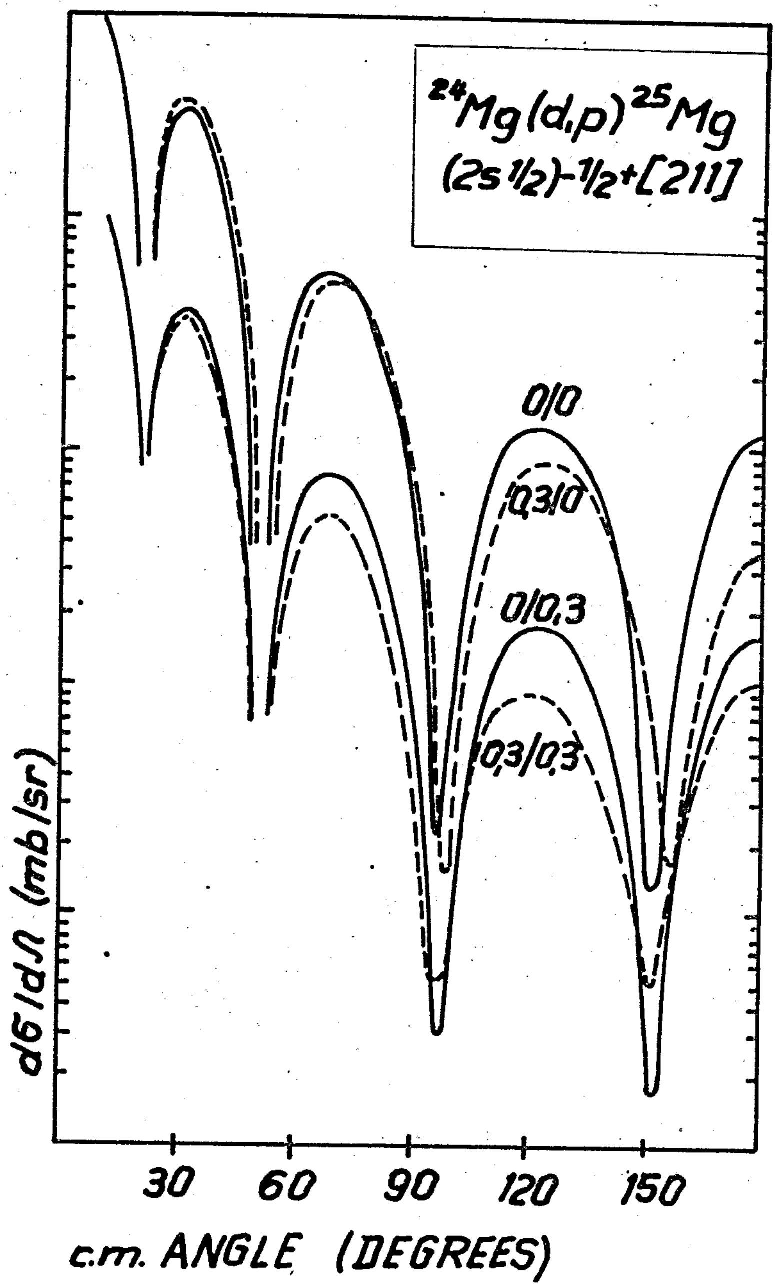

Fig. 5. Cross sections for the deformation parameters $\beta_{DW}=0$, 0.3 and $\beta_{BS}=0$, 0.3 to the J =1/2 level of the 1/2+ [211] band of ^{25}Mg .

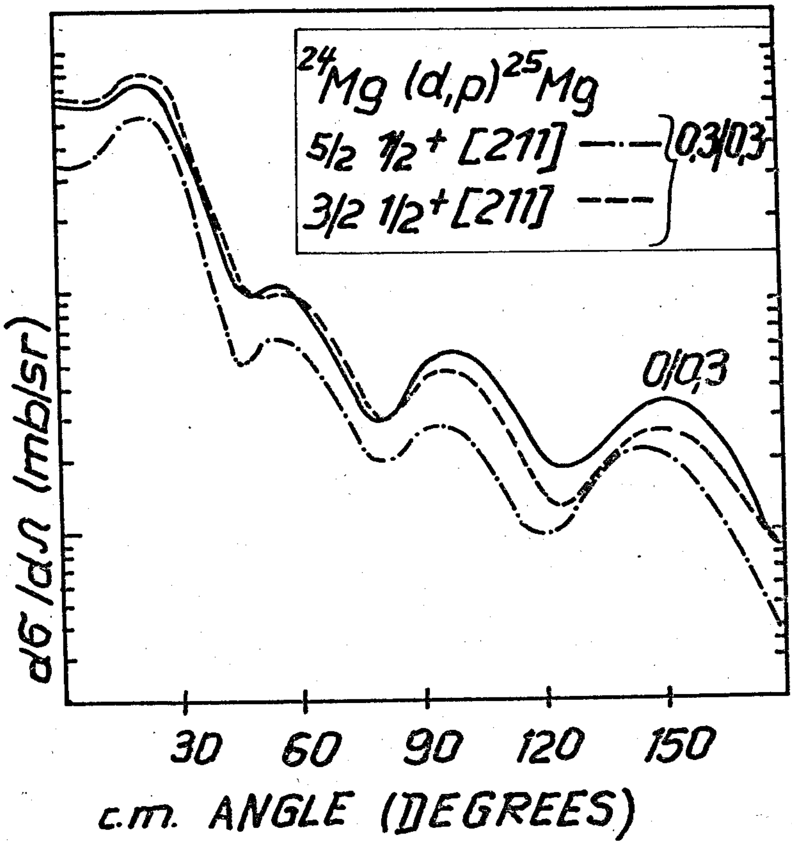

Fig. 6. Cross sections for the $J = 3/2$ and $5/2$ levels of the $1/2^+$ [211] band of ^{25}Mg.