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ABSTRACT

Deuteron stripping reactions are considered. Due to the strong repulsion between nucleons at very short distances, we have investigated the nuclear short-range correlations. The neutron-proton nuclear potential in the deuteron is taken as a short-range repulsive core surrounded by a long-range attractive potential. The neutron-proton potential is taken as the Tabakin separable potential to take into account the short-range correlations. The differential cross-sections for deuteron stripping reactions have been calculated in two different cases by taking Yamaguchi or Breit et al. type parameters for the Tabakin potential used. The angular distributions for different (d,p) stripping reactions on the different target nuclei ^{28}Si, $^{32,34}S$, ^{36}Ar, $^{40,48}Ca$, $^{50,52,54}Cr$ have been calculated using the DWBA calculations. Our present theoretical calculations for the angular distributions of the different reactions considered have been fitted to the experimental data, where good agreement is obtained. The extracted spectroscopic factors from the present work are found to be more reliable.

I. INTRODUCTION

Deuteron stripping reactions have been found to be a valuable tool of nuclear spectroscopy in obtaining information about nuclear structure in nuclei. The theory of deuteron stripping reactions had been considered firstly by Butler [1] on a simple plane wave theory. It has been found that all the fine effects of the deuteron stripping are included in the form factor integral over the deuteron bound state wave function and the neutron-proton nuclear potential. The plane wave theory is reconsidered by many authors [2)-4)] to include finite-range effects which were found to reduce the cross-sections more than the zero-range theory uniformly over the whole angular range. Huby, Refai and Satchler [5] developed the plane-wave theory and presented the distorted-wave theory of stripping nuclear reactions in a rather general form.

Recently, it was found that the nucleon-nucleon interaction becomes strongly repulsive at very short distances. Due to this strong repulsion at small distances, the nucleon-nucleon interaction is represented by a short-range repulsive core surrounded by a long-range attractive potential. Taking a gaussian form for each part of the nuclear neutron-proton potential, reasonable and reliable values have been extracted [6)-11)] for the binding energies and the spectroscopic factors in different nuclear processes. A more realistic nucleon-nucleon potential has been suggested by Tabakin [12] as an effective potential for the nucleon-nucleon interaction calculations. The suggested potential matches the different partial wave nucleon-nucleon phase parameters. It is defined as a set of separable potentials in a suitable form to produce a smooth two-body wave function. The Tabakin potential introduces a good interaction model because it lacks realistic short-range correlations which, however, are implicitly assumed to be of little importance for low-lying levels of nuclei. The two parts of the defined model of the Tabakin potential are taken to be non-local but separable potential of the Yamaguchi [13] type or of the Breit et al. [14] type. Osman and Goumry [15] found that the repulsive core effects in (d,p) stripping reactions using a Tabakin potential are important.

In the present work we must consider the short-range correlations effect in nucleon-nucleon interaction on deuteron stripping reactions. We considered a neutron-proton potential as a short-range repulsive core surrounded by a long-range attractive potential. To include these short-range correlations, we used for the neutron-proton potential the model previously defined by Tabakin [12]. In our present calculations we take two

different cases for the two parts of the used Tabakin potential according to the Yamaguchi [13] type or the Breit et al. [14] type. In each case we calculated the angular distributions for the (d,p) stripping nuclear reactions on the different target nuclei ^{28}Si, $^{32,34}S$, ^{36}Ar, $^{40,48}Ca$, $^{50,52,54}Cr$. The present calculations of the differential cross-sections have been carried out using the DWBA calculations. Fitting our present theoretical calculations of the angular distributions with the experimental data, we extracted the spectroscopic factors for each reaction in each case.

In Sec.II we introduced expressions for the differential cross-sections of the deuteron stripping reactions using a Tabakin neutron-proton potential. Results of the DWBA calculations of the angular distributions together with the extracted spectroscopic factors are presented in Sec.III. Sec.IV is dedicated to discussion.

II. DIFFERENTIAL CROSS-SECTIONS

The theory of deuteron stripping reactions has been widely studied and analysed using the DWBA [5),16),17)]. The most important features of deuteron stripping reactions lie in the integral

$$B_{\ell m} = i^{-\ell} (2\ell+1)^{-\frac{1}{2}} \iint \overset{*}{\psi}{}_p^{(-)} (\underset{\sim}{R} + \tfrac{1}{2} \underset{\sim}{r}) \, \overset{*}{\psi}_n (\underset{\sim}{R} - \tfrac{1}{2} \underset{\sim}{r}) \, V_{np}(r) \, \varphi_d(r) \, \psi_d^{(+)}(\underset{\sim}{R}) \, d\underset{\sim}{r} \, d\underset{\sim}{R} \quad , \qquad (1)$$

where the relative and centre-of-mass co-ordinates are used as $\underset{\sim}{r} = \underset{\sim}{r}_p - \underset{\sim}{r}_n$ and $\underset{\sim}{R} = \frac{1}{2} (\underset{\sim}{r}_p + \underset{\sim}{r}_n)$, respectively.

Finite-range effects are considered, included and taken into account by many authors [2)-4)]. If both $\overset{*}{\psi}{}_p^{(-)}(\underset{\sim}{R} + \frac{1}{2} \underset{\sim}{r})$ and $\overset{*}{\psi}_n(\underset{\sim}{R} - \frac{1}{2} \underset{\sim}{r})$, presented in the integral given by Eq.(1), are expanded around the centre-of-mass co-ordinate $\underset{\sim}{R}$, then we obtain

$$B_{\ell m} = i^{-\ell} (2\ell+1)^{-\frac{1}{2}} \int I_\ell^m \, \overset{*}{\psi}{}_p^{(-)}(\underset{\sim}{R}) \, \overset{*}{\psi}_n(\underset{\sim}{R}) \, \psi_d^{(+)}(\underset{\sim}{R}) \, d\underset{\sim}{R} \quad , \qquad (2)$$

where

$$I_\ell^m = \int e^{\frac{1}{2} \underset{\sim}{r} \cdot (\underset{\sim}{\nabla}_p - \underset{\sim}{\nabla}_n)} \, V_{np}(r) \, \varphi_d(r) \, d\underset{\sim}{r} \qquad (3)$$

$\psi_d^{(+)}(\underset{\sim}{R})$ and $\overset{*}{\psi}_p^{(-)}(\underset{\sim}{R})$ are the distorted wave functions in the initial and final channels due to the nuclear optical potentials $V_d(R)$ and $V_p(R)$, respectively. $\overset{*}{\psi}_n(\underset{\sim}{R})$ is the bound state wave function for the captured neutron in the residual nucleus with the nuclear potential $V_{nT}(R)$.

It is clear that all the finite-range effects and the short-range repulsive core effects are included in the integral I_ℓ^m given by Eq.(3). The repulsive core effects in (d,p) stripping reactions are studied in the integral I_ℓ^m given by Eq.(3), by considering the neutron-proton potential $V_{np}(r)$ as composed of a short-range repulsive core surrounded by a long-range attractive potential. Also, the short-range correlations in the nuclei are introduced in the same integral by considering that the different wave functions are correlated to become zero within the soft core of the potential. Recently, Tabakin [12] suggested an effective potential for nucleon-nucleon interaction calculations which matches the different partial wave nucleon-nucleon phase parameters. In the present work, we used for the neutron-proton potential V_{np} the model potential suggested by Tabakin which is a non-local separable potential defined as

$$V_{np}(\underset{\sim}{r},\underset{\sim}{r}') = \lambda \sum_{\alpha MLL'} \left[-g_{\alpha L}(r)\, g_{\alpha L'}(r') + h_{\alpha L}(r)\, h_{\alpha L'}(r')\right] \mathcal{Y}_{\alpha L}^{M}(\hat{\underset{\sim}{r}})\, \mathcal{Y}_{\alpha L'}^{M}(\hat{\underset{\sim}{r}}') , \tag{4}$$

where α denotes the quantum numbers JTS, and $\lambda = \frac{\hbar^2}{m}$ (m is the nucleon mass). The symbols $g_{\alpha L}(r)$ and $h_{\alpha L}(r)$ refer to the attractive and repulsive parts of the potential, respectively. The function $\mathcal{Y}_{\alpha L}^{M}(\hat{\underset{\sim}{r}})$ is a normalized eigenstate of total angular momentum J and its z component M ; it is a combination of an orbital angular momentum state $Y_L^{M_L}(\hat{\underset{\sim}{r}})$ and a total spin state $\chi_S^{M_S}$.

Also the short-range correlations are introduced in the deuteron wave function. In that sense, the deuteron wave function is taken in the momentum representation as

$$\psi_d(k') = N \left[\frac{1}{k'^2 + \alpha^2} - \frac{1}{k'^2 + \beta^2}\right] , \tag{5}$$

where

$$N^2 = \pi^{-2}\, \frac{\alpha\beta(\alpha + \beta)}{(\beta-\alpha)^2} \tag{6}$$

and

$$\alpha = \left(\frac{M\varepsilon_d}{\hbar^2}\right)^{1/2} , \tag{7}$$

where M and ε_d are the reduced nucleon mass and the deuteron binding energy, respectively.

Now, the deuteron quantum numbers J,T,S and L are understood to have the values (J = 1, T = 0, S = 1 and L = 0,2). Thus the deuteron wave function is composed of S- and D-state components. The probability of the D-state component has not been accurately determined. Many authors, however, have adopted the value of 4% for the D-component probability. The smallness of this quantity justifies treating the deuteron as an S state. Consequently, the interaction V_{np} will be considered as a central S-state potential.

In the present work, the attractive and the repulsive parts of the potential $g_0(k)$ and $h_0(k)$ are represented in their momentum representation in two different cases. In the first case we choose for both the attractive function $g_0(k)$ and the repulsion function $h_0(k)$ the Yamaguchi [13] form

$$g_0(k) = \gamma(k^2 + a^2)^{-1} , \tag{8}$$

$$h_0(k) = \mu(k^2 + c^2)^{-1} , \tag{9}$$

with ranges (1/a, 1/c) and "equivalent strengths" ($V_\gamma = \lambda\gamma^2/a$ and $V_\mu = \lambda\mu^2/c$). In the second case,we choose for the attraction function $g_0(k)$ the Yamaguchi form given by Eq.(8), and for the repulsion function $h_0(k)$ the suggested Breit _et al._ [14] form

$$h_0(k) = \frac{\mu' k^2}{[(k-d)^2 + b^2]\,[(k+d)^2 + b^2]} , \tag{10}$$

with range 1/b and "equivalent strength" ($V_{\mu'} = \lambda\mu'^2/b$) and where d is the soft-core radius.

The integral given by Eq.(3) carries all the repulsive core effects and short-range correlations. This form factor has been calculated in the present work using the Tabakin potential for the neutron-proton interaction V_{np} . This form factor as given by the integral (3) is denoted here by F^{RC}, just for convenience, and to be consistent with the same notation which we used before as F^{RC} . After a lengthy mathematical procedure which has no place here, we calculated this form factor in two different cases.

In the first case, we calculated the form factor by taking for the attractive and repulsive parts of the potential, $g_{\alpha L}(r)$ and $h_{\alpha L}(r)$, a Yamaguchi [13] form as given by Eqs.(8) and (9), respectively. In this case, by using Yamaguchi parameters for the Tabakin potential, we obtain for the form factor an expression given by

$$F_1^{RC}(R) = I_{AT}(R) + I_{RP}(R) \quad , \tag{11}$$

where

$$I_{AT}(R) = \frac{4\pi H}{a^2} \bigcap_a(R) \tag{12}$$

and

$$I_{RP}(R) = \frac{4\pi G}{c^2} \bigcap_c(R) \quad . \tag{13}$$

In Eqs.(12) and (13) we have

$$H = -\sqrt{\frac{\pi}{2}}\, \lambda\!\!\!^{-} N \gamma^2 \left[-\frac{a}{\alpha^2 - a^2} + \frac{\alpha}{\alpha^2 - a^2} + \frac{a}{\beta^2 - a^2} - \frac{\beta}{\beta^2 - a^2} \right] \tag{14}$$

and

$$G = \sqrt{\frac{\pi}{2}}\, \lambda\!\!\!^{-} N \mu^2 \left[-\frac{c}{\alpha^2 - c^2} + \frac{\alpha}{\alpha^2 - c^2} + \frac{c}{\beta^2 - c^2} - \frac{\beta}{\beta^2 - c^2} \right] \quad . \tag{15}$$

Also, we have for $\bigcap_a(R)$ and $\bigcap_c(R)$ the expressions

$$\bigcap_a(R) = 1 - \frac{V_d(R) - V_n(R) - V_p(R) - \varepsilon_d}{(a^2/\alpha^2)\, \varepsilon_d} \tag{16}$$

and

$$\bigcap_c(R) = 1 - \frac{V_d(R) - V_n(R) - V_p(R) - \varepsilon_d}{(c^2/\alpha^2)\, \varepsilon_d} \quad , \tag{17}$$

where $V_d(R)$ and $V_p(R)$ are the distorting optical potentials in the initial and final channels and $V_n(R)$ is the potential of the captured bound neutron in the residual nucleus.

In the second case, we calculated the form factor by taking for the attractive part of the potential $g_{\alpha L}(r)$ a Yamaguchi [13] form as given by Eq.(8), while we use for the repulsive part of the potential $h_{\alpha L}(r)$ a Breit et al. [14] form as given by Eq.(10). In this case by using Breit et al. parameters for the Tabakin potential, we obtain for the form factor an expression given by

$$F_2^{RC}(R) = I_{AT}(R) + I_{RP_1}(R) + I_{RP_2}(R) \quad , \tag{18}$$

where $I_{AT}(R)$ is given by Eq.(12), while $I_{RP_1}(R)$ and $I_{RP_2}(R)$ are given by

$$I_{RP_1}(R) = \frac{4\pi G_1}{h^2} \bigcap_h(R) \tag{19}$$

and

$$I_{RP_2}(R) = \frac{4\pi G_2}{f^2} \bigcap_f(R) \tag{20}$$

h, f, G_1 and G_2 are given by

$$h^2 = (b^2 - d^2) + 2ibd \quad , \tag{21}$$

$$f^2 = (b^2 - d^2) - 2ibd \quad , \tag{22}$$

$$G_1 = \sqrt{\frac{\pi}{2}}\, \lambda\!\!\!^{-} \mu'^2 NSA \tag{23}$$

and

$$G_2 = \sqrt{\frac{\pi}{2}}\, \lambda\!\!\!^{-} \mu'^2 NSB \quad , \tag{24}$$

where

$$A = \frac{2bd - i(b^2 - d^2)}{4bd} \tag{25}$$

and

$$B = \frac{2bd + i(b^2 - d^2)}{4bd} \quad . \tag{26}$$

Also, in Eqs.(19) and (20), we have the following expressions for $\bigcap_h(R)$ and $\bigcap_f(R)$ as:

$$\bigcap_h(R) = 1 - \frac{V_d(R) - V_n(R) - V_p(R) - \varepsilon_d}{(h^2/\alpha^2)\, \varepsilon_d} \tag{27}$$

and

$$\bigcap_f(R) = 1 - \frac{V_d(R) - V_n(R) - V_p(R) - \varepsilon_d}{(f^2/\alpha^2)\, \varepsilon_d} \quad . \tag{28}$$

In expression (2), by expanding the distorted wave functions $\psi_d^{(+)}(\underset{\sim}{R})$ and $\overset{*}{\psi}{}_p^{(-)}(\underset{\sim}{R})$ in partial waves, taking for $\overset{*}{\psi}_n(\underset{\sim}{R})$ a harmonic oscillator wave function and integrating over the angular part Ω_R, we finally obtain for the differential cross-section of the (d,p) stripping reactions the expression

$$\frac{d\sigma}{d\Omega} = \frac{\overset{*}{m}_d\, \overset{*}{m}_p}{(2\pi\hbar^2)^2}\, \frac{k_p}{k_d}\, \frac{(2I_R+1)}{(2I_T+1)} \Big| \sum_{\ell j m} \textcircled{H}(\ell, j)$$

$$\cdot\, 2 \left\{ \frac{\pi (2\nu)^{\ell+\frac{3}{2}} (n-1)!}{[\Gamma(n+\ell+\frac{1}{2})]^3} \right\}^{\frac{1}{2}} \sum_{\lambda\mu} i^{\lambda-\mu-\ell} (2\mu+1)$$

$$\cdot \left\{ \frac{(\mu-m)!}{(\mu+m)!} \right\}^{\frac{1}{2}} P_{\ell}^{m}(\cos\theta)\ (\ell\, m\, \mu\, {-m}|\lambda 0)(\ell 0\, \mu 0|\lambda 0)$$

$$\cdot \int dR\, R^2\, \psi_{\lambda}(R)\, \psi_{\mu}(R)\, \overset{*}{u}_{n\ell}(R)\, F^{RC}(R) \Big|^2 \ . \tag{29}$$

In expression (29) the factor $F^{RC}(R)$ is the form factor which carries all the short-range correlations and repulsive core effects in the deuteron stripping reactions. This repulsive core form factor is calculated here in two cases. Firstly, by taking for the neutron-proton potential $V_{np}(r)$ a Tabakin form with Yamaguchi parameters: it is denoted and expressed in this case by $F_1^{RC}(R)$ and is given explicitly by Eq.(11). Secondly, by taking for $V_{np}(r)$ a Tabakin potential with Breit <u>et al</u>. parameters; it is denoted and expressed in this case by $F_2^{RC}(R)$ given explicitly by Eq.(18).

III. RESULTS OF THE DWBA CALCULATIONS

In the present work, short-range correlations in nuclei are taken into account. The short-range correlations together with the repulsive core effects are studied here via the deuteron stripping reactions. We considered the nucleon-nucleon interaction as a short-range repulsive core surrounded by a long-range attractive potential. A suitable representation for the neutron-proton potential which we used in the present work to take into account the repulsive core effects and the short-range correlations is the Tabakin potential. The Tabakin potential used for the neutron-proton potential V_{np} is a separable but non-local potential and is represented by Eq.(4). The deuteron bound-state wave function is given by Eq.(5). In the present calculations, we used two different cases for the two parts of the Tabakin potential used. The first case is that in which we used, for the attractive and repulsive parts of the Tabakin potential, the Yamaguchi [13] type as given by expressions (8) and (9). In the second case we considered for the attractive part of the Tabakin potential, the Yamaguchi [13] form given by Eq.(8), while for the repulsive part of the potential we used the Breit <u>et al</u>. [14] form expressed by Eq.(10). We shall refer here to the first case as Tabakin 1 while the second case will be referred to as Tabakin 2. The parameters of the Tabakin [12] neutron-proton potential in the two cases of the Yamaguchi [13] form and the Breit <u>et al</u>. [14] form which are used [15] in the (d,p) stripping reactions and will be used in the present numerical calculations are listed in Table I.

For numerical calculations of the DWBA for the deuteron stripping reactions, a Woods-Saxon form for the optical potentials is suggested as

$$V_{opt.}(R) = -V(1 + e^{x})^{-1} - i\left\{W - W_d \left(\frac{d}{dx'}\right)\right\}(1 + e^{x'})^{-1} + V_c , \tag{30}$$

where

$$x = (R - r_r A^{1/3})/a_r \quad ; \quad x' = (R - r_i A^{1/3})/a_i \tag{31}$$

and V_c is the Coulomb potential with radius $r_c A^{1/3}$.

The parameters of the proton and deuteron optical potentials $V_p(R)$ and $V_d(R)$ are listed in Table II [17)-20)].

Different deuteron stripping nuclear reactions are studied in the present work. We studied the nuclear reactions $^{28}Si(d,p)^{29}Si$, $^{32}S(d,p)^{33}S$, $^{34}S(d,p)^{35}S$, $^{36}Ar(d,p)^{37}Ar$, $^{40}Ca(d,p)^{41}Ca$, $^{48}Ca(d,p)^{49}Ca$, $^{50}Cr(d,p)^{51}Cr$, $^{52}Cr(d,p)^{53}Cr$ and $^{54}Cr(d,p)^{55}Cr$. These reactions are studied at different incident deuteron energies. Angular distributions are obtained for different cases leaving the residual nuclei in different excited states. The experimental data for the first four reactions are taken from Mermaz <u>et al</u>. [18] for a deuteron incident with the same energy on different targets with different mass numbers. The experimental data for the fifth reaction are taken from Lee <u>et al</u>. [17] for a deuteron incident with different energies on the same target nucleus. The experimental data for the last five reactions are taken from Brown <u>et al</u>. [20] for a deuteron incident with the same energy on target nuclei with different mass numbers and also on target nuclei with the same mass numbers but leaving the residual nuclei in different excited states. The choice of the present data serves to give a survey of all possible studies to make one constant and changing the others of the possible experimental variables, i.e. the incident deuteron energy, the mass number of the target nuclei and the excited state of the residual nuclei.

We have performed our theoretical calculations for the differential cross-sections for these reactions taking into account the short-range correlations and repulsive core effects using the expression (29). The differential cross-sections for deuteron stripping reactions as given by expression (29) are numerically calculated using the DWBA calculations. We used the computer programme JULIE which is modified by Osman [8] to include the repulsive core effects in (d,p) stripping reactions. The optical potential parameters which we used in our present DWBA calculations are listed in Table II for the different reactions considered. Our theoretical DWBA calculations of the differential cross-sections, taking into account the repulsive core effects, for the different reactions considered are presented in Figs.1-7. The present calculated angular distributions of the different reactions are fitted to the experimental data as shown in Figs.1-7. The heavy points are the experimental data, while the curves represent our present calculations. The solid curves stand for our calculations using the Tabakin potential with Yamaguchi parameters and this case is referred to as Tabakin 1. The dashed curves represent the second case, referred to as Tabakin 2, which is obtained in our calculations by using the Tabakin potential with Breit et al. parameters.

Fitting our present calculations of the differential cross-sections, taking into account the short-range correlations with the experimental angular distributions, we obtain the spectroscopic factors for these reactions in both cases (Tabakin 1 and Tabakin 2). The extracted spectroscopic factors are introduced in Table III.

IV. DISCUSSION

One of the most important features which affect the theory of deuteron stripping reactionsare the short-range correlations. In the present work, we have considered the short-range correlations and the repulsive core effects. A more realistic representation which we used here is the Tabakin representation for the nucleon-nucleon interaction. From the present calculations, it is clear that the DWBA theory enables us to extract more reasonable values for the spectroscopic factors of the deuteron stripping reactions. A glance at Table III shows that by taking into account the short-range correlations in nuclei, more correct spectroscopic factors for the deuteron stripping reactions are extracted.

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Table I

Parameters of the neutron-proton potential

The Tabakin potential form	a^{-1} (fm)	c^{-1} (fm)	b^{-1} (fm)	d^{-1} (fm)	V_γ (MeV)	V_μ (MeV)
Tabakin 1 (Yamaguchi)	0.752	0.125	-	-	113.9	660.5
Tabakin 2 (Breit et al.)	0.834	-	0.801	0.694	115.9	235.6

Table II

Optical model parameters

Channel	Number of set	V (MeV)	r_r (fm)	a_r (fm)	W (MeV)	W_d (MeV)	r_i (fm)	a_i (fm)	r_c (fm)	Ref.
Proton	I	44.0	1.25	0.65	0.0	38.5	1.25	0.47	1.25	17,18
	II	50.3	1.20	0.65	0.0	44.0	1.20	0.47	1.25	17,18
	III	51.9	1.25	0.65	0.0	13.5	1.25	0.47	1.25	19,20
	IV	50.0	1.25	0.65	0.0	13.3	1.25	0.47	1.25	19,20
Deuteron	I	124.7	0.919	0.943	0.0	89.70	1.422	0.541	1.25	17,18
	II	112.0	1.000	0.900	0.0	72.00	1.550	0.470	1.25	17,18
	III	89.2	1.175	0.830	0.0	19.01	1.534	0.470	1.25	20
	IV	90.8	1.175	0.797	0.0	14.58	1.361	0.660	1.25	20
	V	83.3	1.175	0.823	0.0	19.08	1.411	0.603	1.25	20
	VI	87.2	1.175	0.792	0.0	17.17	1.402	0.658	1.25	20
	VII	85.5	1.175	0.821	0.0	17.84	1.366	0.688	1.25	20

Table III

Extracted spectroscopic factors from the DWBA calculations

Reaction	Incident energy (MeV)	Excitation energy (MeV)	ℓ	J^π	Spectroscopic factors present work Tabakin 1	Tabakin 2	previous work
$^{28}Si(d,p)^{29}Si$	18.0	0.0	0	$\frac{1}{2}^+$	0.8783	0.9974	0.53
		1.273	2	$\frac{3}{2}^+$	1.0879	1.0032	0.74
		2.032	2	$\frac{5}{2}^+$	0.5227	0.7618	0.12
		2.427	2	$\frac{3}{2}^+$	0.4119	0.6383	0.012
		3.069	2	$\frac{5}{2}^+$	0.7934	0.9219	0.06
		3.623	3	$\frac{7}{2}^-$	0.9314	0.9897	0.38
$^{32}S(d,p)^{33}S$	18.0	0.0	2	$\frac{3}{2}^+$	1.1006	1.0006	0.93
		1.968	2	$\frac{5}{2}^+$	0.7971	0.8993	0.002
		2.313	2	$\frac{3}{2}^+$	0.7714	0.8552	0.066
$^{34}S(d,p)^{35}S$	18.0	0.0	2	$\frac{3}{2}^+$	0.8327	0.9438	0.46
		1.992	3	$\frac{7}{2}^-$	0.9918	1.0004	0.63
		2.348	1	$\frac{3}{2}^-$	0.9384	0.9998	0.50
$^{36}Ar(d,p)^{37}Ar$	18.0	0.0	2	$\frac{3}{2}^+$	0.8261	0.9516	0.52
		1.409	0	$\frac{1}{2}^+$	0.7412	0.7889	0.10
		2.491	1	$\frac{3}{2}^-$	0.8337	0.9112	0.42
		2.796	2	$\frac{5}{2}^+$	0.5837	0.7196	0.04
		3.516	1	$\frac{3}{2}^-$	0.7813	0.8695	0.33
		4.466	1	$\frac{1}{2}^-$	0.7412	0.7998	0.14

cont......

Table III (cont.)

Reaction	Incident energy (MeV)	Excitation energy (MeV)	ℓ	J^π	Spectroscopic factors: present work, Tabakin 1	Spectroscopic factors: present work, Tabakin 2	Spectroscopic factors: previous work
$^{40}Ca(d,p)^{41}Ca$	7.0	0.0	3	$\frac{7}{2}^-$	0.8172	0.8994	0.742
	8.0	0.0	3	$\frac{7}{2}^-$	0.9176	0.9989	0.934
	9.0	0.0	3	$\frac{7}{2}^-$	0.8879	0.9578	0.891
	10.0	0.0	3	$\frac{7}{2}^-$	0.8241	0.9375	0.831
	11.0	0.0	3	$\frac{7}{2}^-$	0.9437	0.9996	0.957
	12.0	0.0	3	$\frac{7}{2}^-$	0.8216	0.9378	0.832
$^{40}Ca(d,p)^{41}Ca$	10.0	0.0	3	$\frac{7}{2}^-$	0.7918	0.8864	
		1.95	1		0.9036	0.9918	
$^{48}Ca(d,p)^{49}Ca$	10.0	0.0	1		0.8138	0.9446	
$^{50}Cr(d,p)^{51}Cr$	10.0	0.74	1		0.9219	0.9956	
$^{52}Cr(d,p)^{53}Cr$	10.0	1.01	3		0.7618	0.8572	
$^{54}Cr(d,p)^{55}Cr$	10.0	0.0	1		0.8117	0.9394	

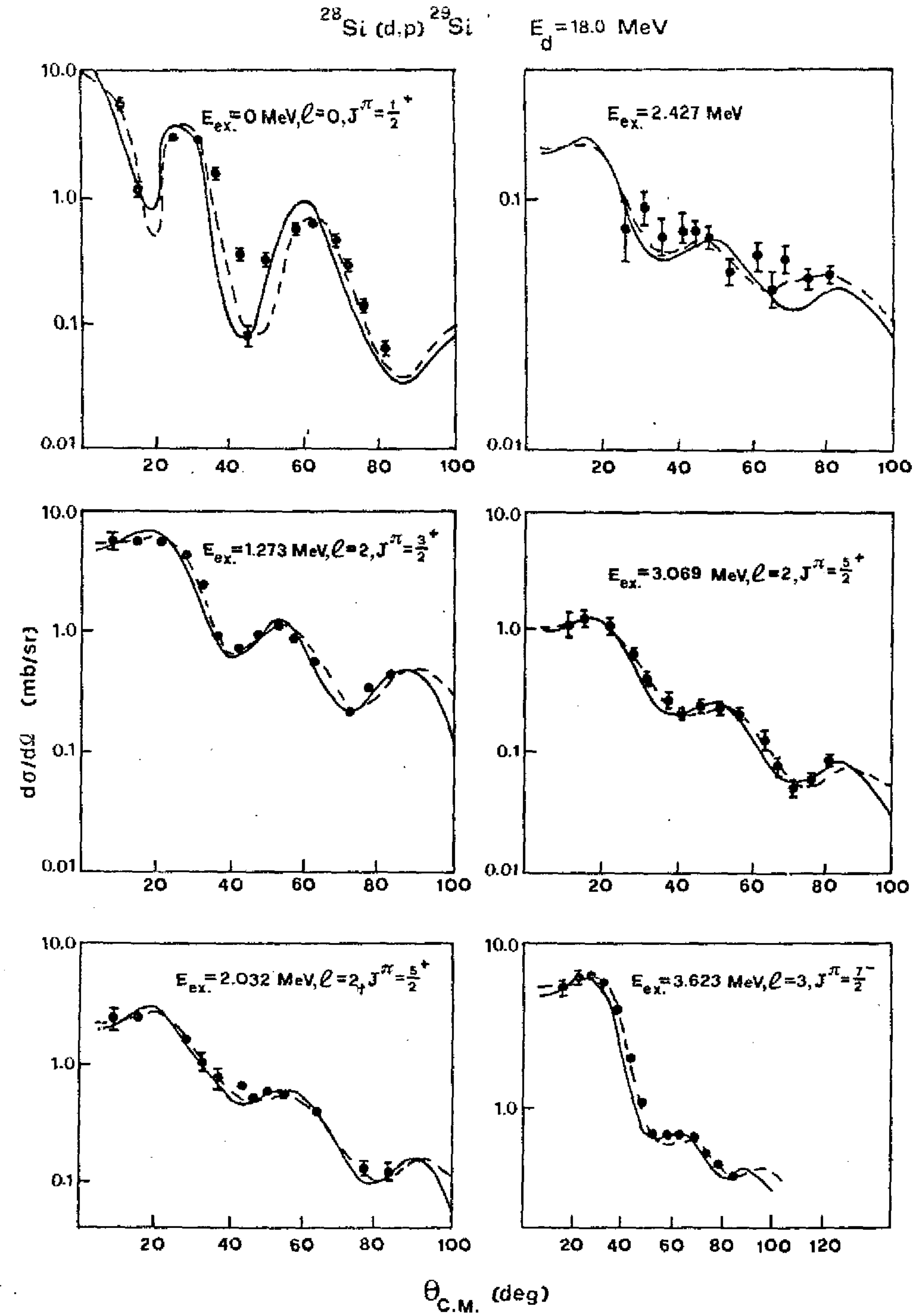


Fig 1

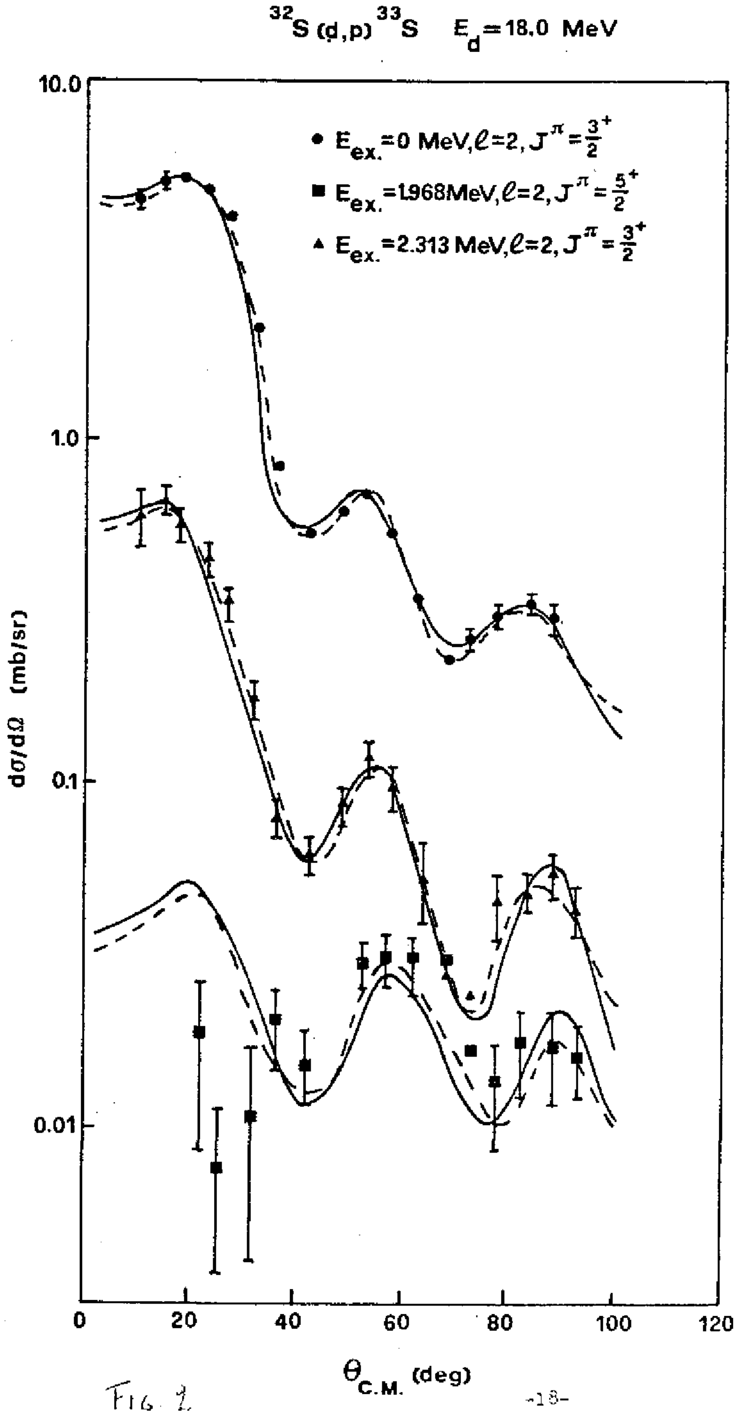

$^{32}S(d,p)^{33}S$ $E_d = 18.0$ MeV
• $E_{ex.} = 0$ MeV, $\ell = 2$, $J^{\pi} = \frac{3}{2}^{+}$
■ $E_{ex.} = 1.968$ MeV, $\ell = 2$, $J^{\pi} = \frac{5}{2}^{+}$
▲ $E_{ex.} = 2.313$ MeV, $\ell = 2$, $J^{\pi} = \frac{3}{2}^{+}$
10.0
1.0
0.1
0.01
$d\sigma/d\Omega$ (mb/sr)
0
20
40
60
80
100
120
$\theta_{C.M.}$ (deg)

FIG. 2

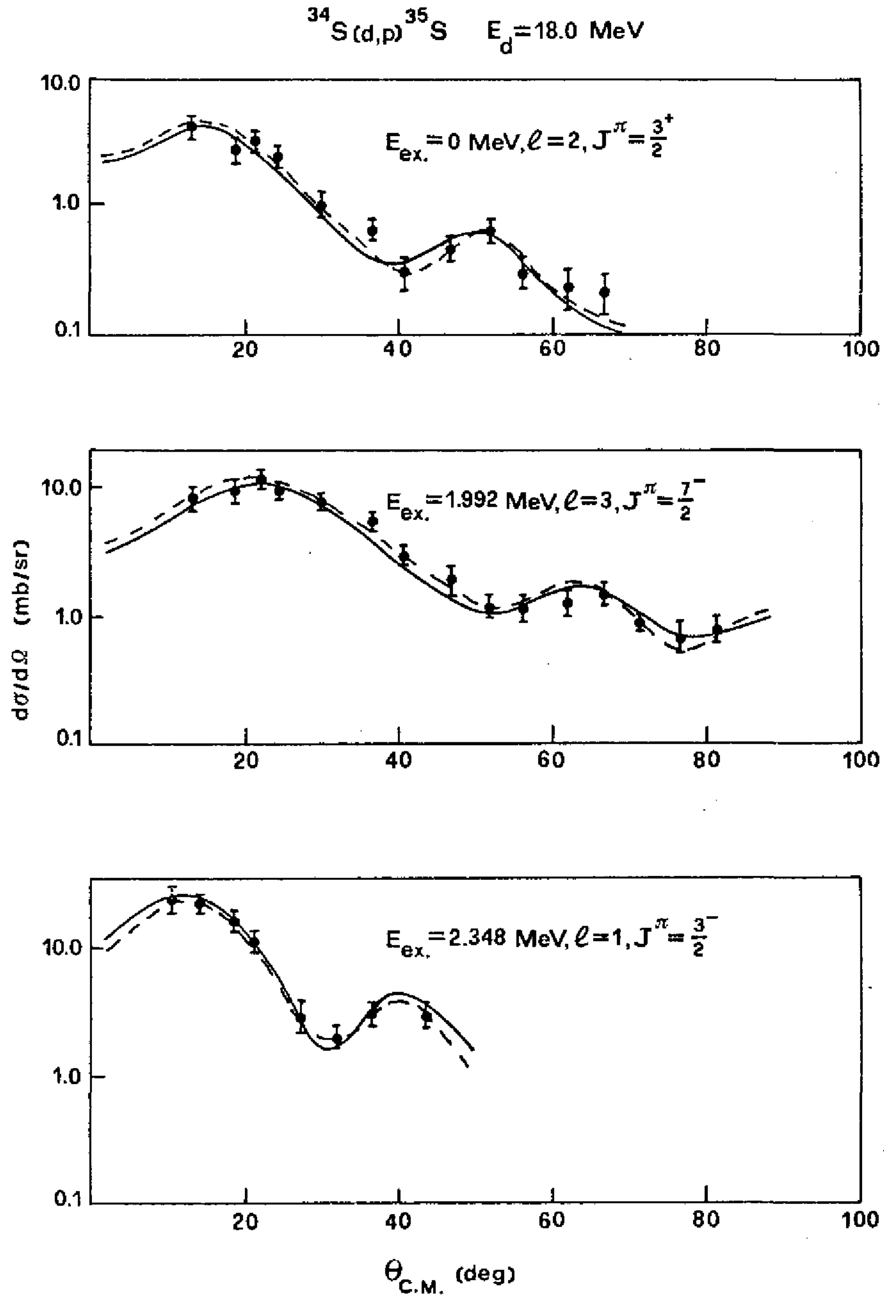

$^{34}S(d,p)^{35}S$ $E_d = 18.0$ MeV
$E_{ex.} = 0$ MeV, $\ell = 2$, $J^{\pi} = \frac{3}{2}^{+}$
$E_{ex.} = 1.992$ MeV, $\ell = 3$, $J^{\pi} = \frac{7}{2}^{-}$
$E_{ex.} = 2.348$ MeV, $\ell = 1$, $J^{\pi} = \frac{3}{2}^{-}$
10.0
1.0
0.1
$d\sigma/d\Omega$ (mb/sr)
20
40
60
80
100
$\theta_{C.M.}$ (deg)

FIG. 3

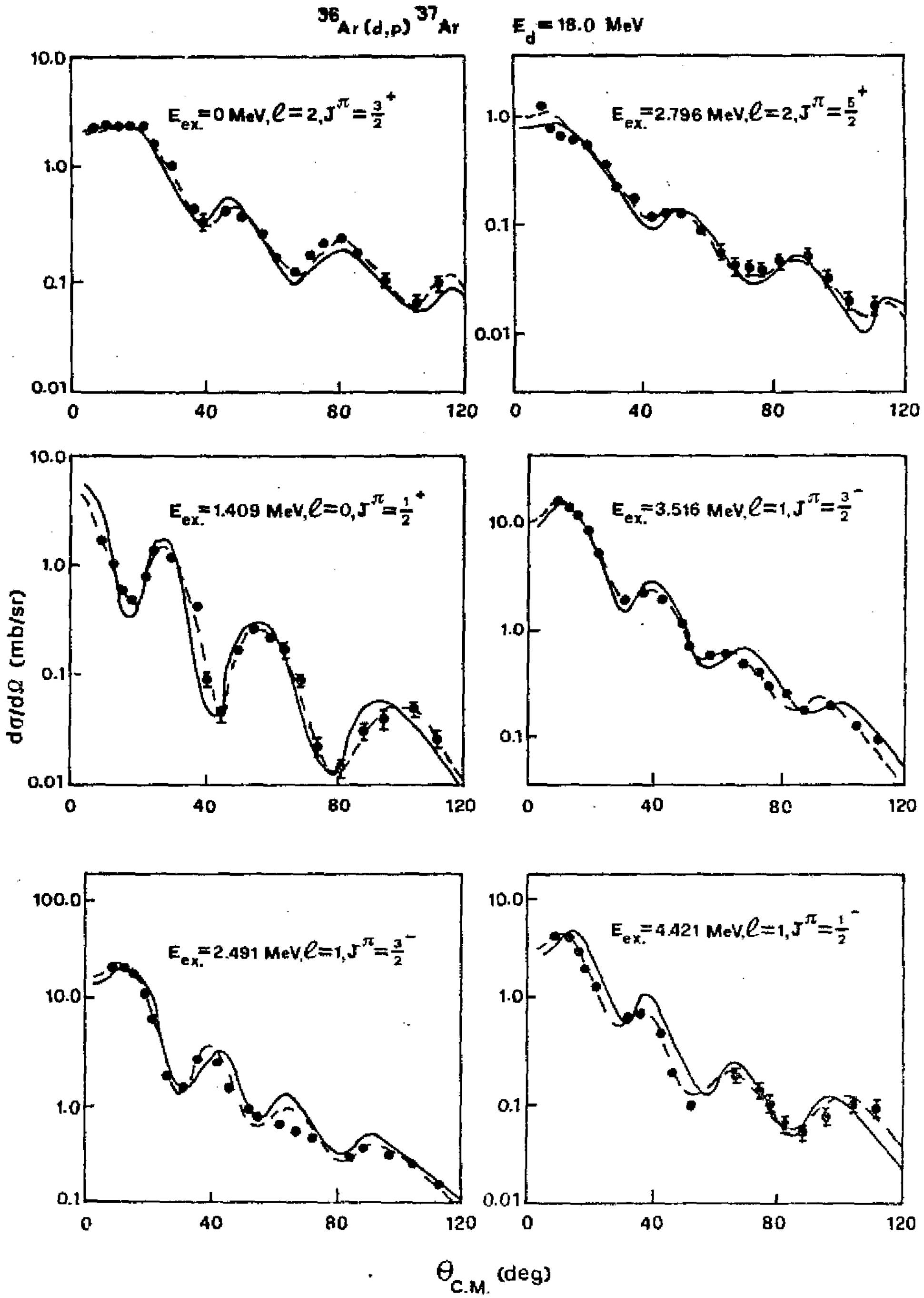

36Ar(d,p)37Ar
Ed = 18.0 MeV
Eex=0 MeV, ℓ=2, Jπ=3/2+
Eex=2.796 MeV, ℓ=2, Jπ=5/2+
Eex=1.409 MeV, ℓ=0, Jπ=1/2+
Eex=3.516 MeV, ℓ=1, Jπ=3/2−
Eex=2.491 MeV, ℓ=1, Jπ=3/2−
Eex=4.421 MeV, ℓ=1, Jπ=1/2−
dσ/dΩ (mb/sr)
θC.M. (deg)

Fig. 4

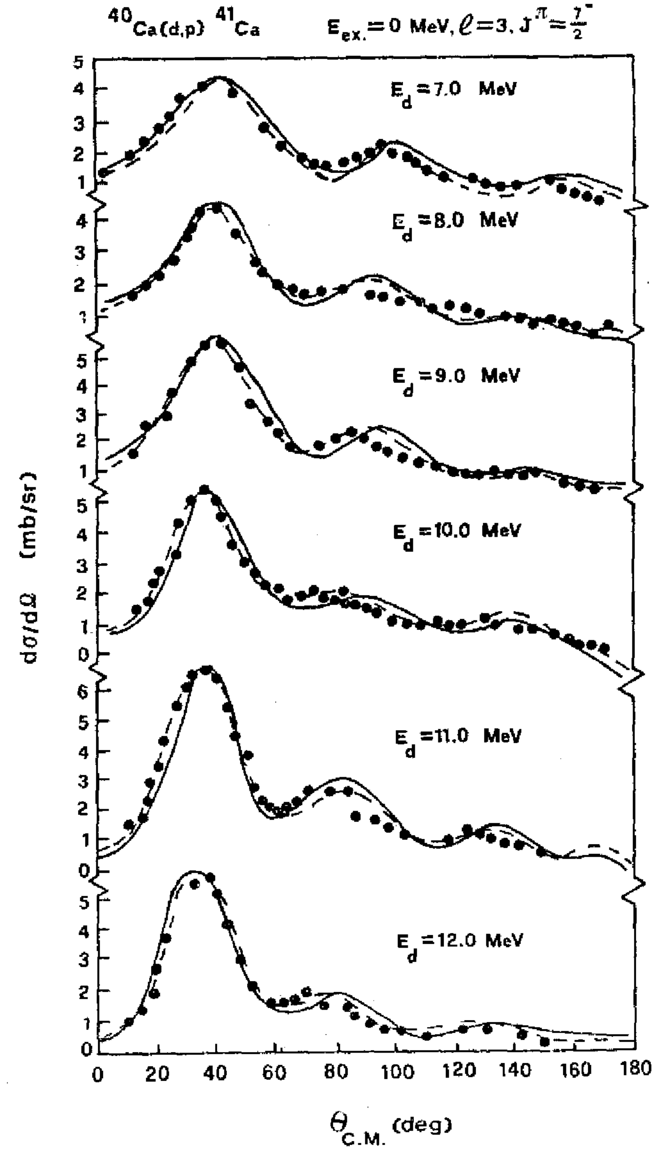
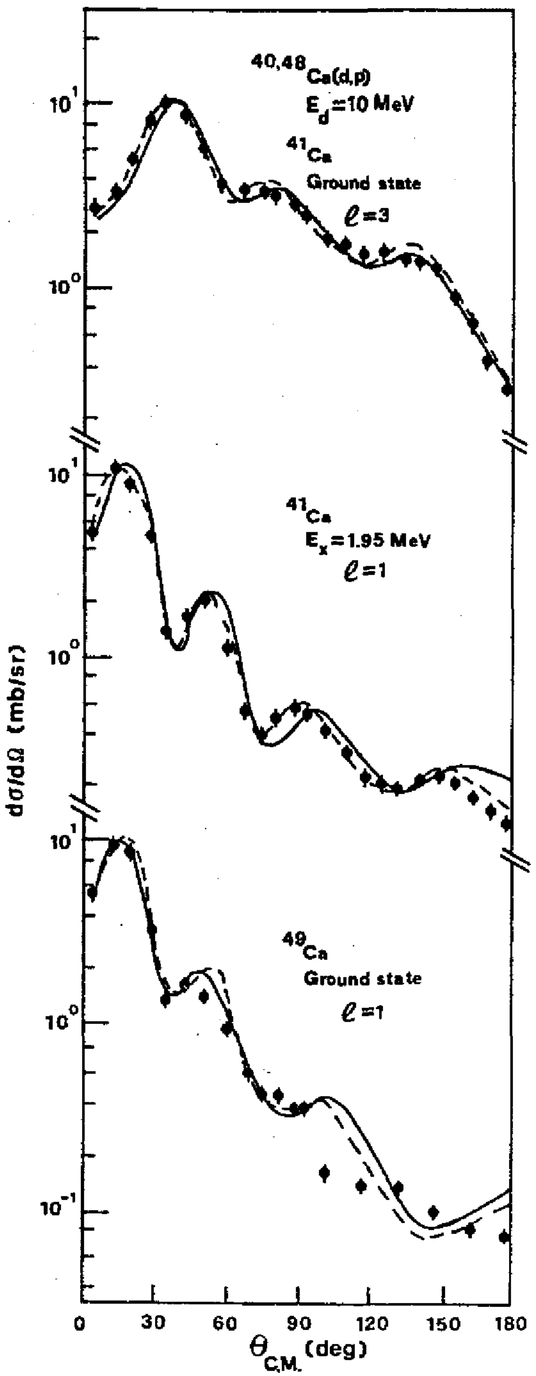
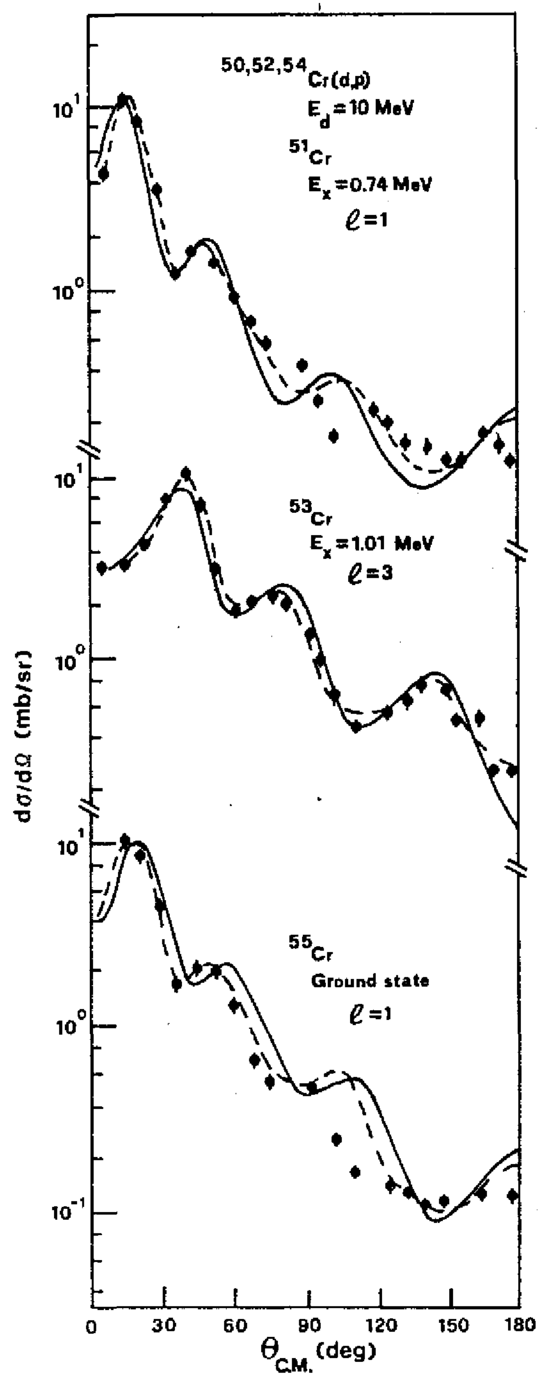

40Ca(d,p)41Ca
Eex.=0 MeV, ℓ=3, Jπ=7/2−
Ed=7.0 MeV
Ed=8.0 MeV
Ed=9.0 MeV
Ed=10.0 MeV
Ed=11.0 MeV
Ed=12.0 MeV
dσ/dΩ (mb/sr)
θC.M. (deg)

Fig. 5



40,48Ca(d,p)
Ed=10 MeV
41Ca
Ground state
ℓ=3
41Ca
Ex=1.95 MeV
ℓ=1
49Ca
Ground state
ℓ=1
dσ/dΩ (mb/sr)
θC.M. (deg)

FIG. 6



50,52,54Cr(d,p)
Ed=10 MeV
51Cr
Ex=0.74 MeV
ℓ=1
53Cr
Ex=1.01 MeV
ℓ=3
55Cr
Ground state
ℓ=1
dσ/dΩ (mb/sr)
θC.M. (deg)

FIG. 7

FIGURE CAPTIONS

Fig.1 The angular distributions of the nuclear stripping reaction $^{28}Si(d,p)^{29}Si$ of incident deuteron energy 18.0 MeV leaving the residual nucleus ^{29}Si in different excited states. The solid curves are our present calculations. The optical model parameters used in our calculations are set I for protons and set I for deuterons as listed in Table II. The experimental data are taken from Ref.18.

Fig.2 The angular distributions of the nuclear stripping reaction $^{32}S(d,p)^{33}S$ of incident deuteron energy 18.0 MeV leaving the residual nucleus ^{33}S in different excited states. The solid curves are our present calculations. The optical model parameters used in our calculations are set I for protons and set I for deuterons as listed in Table II. The experimental data are taken from Ref.18.

Fig.3 The angular distributions of the nuclear stripping reaction $^{34}S(d,p)^{35}S$ of incident deuteron energy 18.0 MeV leaving the residual nucleus ^{35}S in different excited states. The solid curves are our present calculations. The optical model parameters used in our calculations are set I for protons and set I for deuterons as listed in Table II. The experimental data are taken from Ref.18.

Fig.4 The angular distributions of the nuclear stripping reaction $^{36}Ar(d,p)^{37}Ar$ of incident deuteron energy 18.0 MeV leaving the residual nucleus ^{37}Ar in different excited states. The solid curves are our present calculations. The optical model parameters used in our calculations are set I for protons and set I for deuterons as listed in Table II. The experimental data are taken from Ref.18.

Fig.5 The angular distributions of the nuclear stripping reaction $^{40}Ca(d,p)^{41}Ca$ at different energies for the incident deuteron and for the ground state of the residual nucleus ^{41}Ca. The solid curves are our present calculations. The optical model parameters used in our calculations are set II for protons and set II for deuterons as listed in Table II. The experimental data are taken from Ref.17.

Fig.6 The angular distributions of the nuclear stripping reactions $^{40,48}Ca(d,p)^{41,49}Ca$ of incident deuteron energy 10.0 MeV leaving the residual nuclei ^{41}Ca and ^{49}Ca in different excited states. The solid curves are our present calculations. The optical model parameters used in our calculations are set III for protons and sets III and IV for deuterons in the two cases of ^{40}Ca and ^{48}Ca, respectively, as listed in Table II. The experimental data are taken from Ref.20.

Fig.7 The angular distributions of the nuclear stripping reactions $^{50,52,54}Cr(d,p)^{51,53,55}Cr$ of incident deuteron energy 10.0 MeV leaving the residual nuclei ^{51}Cr, ^{53}Cr and ^{55}Cr in different excited states. The solid curves are our present calculations. The optical model parameters used in our calculations are set IV for protons and sets V, VI and VII for deuterons in the cases of ^{50}Cr, ^{52}Cr and ^{54}Cr, respectively, as listed in Table II. The experimental data are taken from Ref.20.

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