(d, p) REACTIONS TO THE GROUND STATES OF ^{41}Ca AND ^{49}Ca†

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Abstract

Calculations for (d, p) stripping on the doubly magic calcium nuclei ^{40}Ca and ^{48}Ca leading to the ground states of ^{41}Ca and ^{49}Ca have been carried out on the basis of the sudden approximation method of deuteron stripping developed by Butler, Hewitt, McKellar, and May. The use of realistic form factors found by Philpott, Pinkston, and Satchler to generate the bound state wavefunction for the neutron captured by the ^{40}Ca core improves the agreement with experimental proton angular distributions arising from the ^{40}Ca(d, p)^{41}Ca g.s. reaction. For both reactions, good agreement is obtained where incident deuteron energies are above the Coulomb barrier. The spectroscopic factor for the $1f_{7/2}$ ground state of ^{41}Ca is found to be $0 \cdot 60 \pm 0 \cdot 10$ whilst that of the $2p_{3/2}$ ground state of ^{49}Ca is $0 \cdot 78$.

I. INTRODUCTION

The sudden approximation theory of Butler, Hewitt, McKellar, and May (1967; hereafter referred to as BHMM) was proposed as an alternative to the more usual distorted wave Born approximation (DWBA) approach. Other calculations (King and McKellar 1970*a*, 1970*b*) have shown the BHMM theory to be in good accord with experimental data.

In the BHMM approach to deuteron stripping, the differential cross section is related to a matrix element M_S by

$$\mathrm{d}\sigma/\mathrm{d}\Omega = \{S/(1-S)^2\}\,|\,M_S\,|^2, \qquad S \neq 1\,. \tag{1}$$

The calculation of this matrix element requires optical potentials for proton and neutron elastic scattering from the target nucleus but does not require the potential for deuteron scattering. Proton potentials are required at the energies of the outgoing proton channels, and elastic scattering data are available at energies near these. Neutron potentials are required for a range of energies (approximately 0–100 MeV) but data are scarce. The only available data are at low energies ($\lesssim$ 20 MeV) and parameters here affect only the forward stripping angles. Because of this and the compound elastic complications that occur, only average neutron potentials were used. However, the angular shape of the stripping cross sections is fairly insensitive to the neutron potential although the spectroscopic factors extracted from the same experimental data can vary by up to about $\pm 0 \cdot 1$.

Experimental data for (d, p) reactions on ^{40}Ca are available at several energies and at two energies for the ^{48}Ca(d, p)^{49}Ca reaction, thereby providing a good test for the BHMM theory. Because of the dependence of the cross section on the spectroscopic factor (equation (1)) the extracted spectroscopic factors are less sensitive to the

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normalization of experimental data and to the potential parameters than are those found from distorted wave calculations.

In our calculations it has been found that a combination of the Rosen *et al.* (1965) average neutron potential and a proton potential fitted to elastic scattering data at the energy nearest that of the outgoing proton channel produces the best results. In the case of the ^{48}Ca(d, p)^{49}Ca g.s. reaction the bound state wavefunction of the captured neutron is taken as the product of the spectroscopic amplitude with a single-particle wavefunction which has been generated by a Woods–Saxon well to produce the correct neutron binding energy. In the case of the ^{40}Ca(d, p)^{41}Ca g.s. reaction, however, the agreement with experiment is much improved by the use of a neutron wavefunction (G. R. Satchler, personal communication) generated with the more realistic form factors of Philpott, Pinkston, and Satchler (1968).

The effects of different scattered neutron, scattered proton, and bound neutron wavefunctions are estimated for calculations on the ^{40}Ca(d, p)^{41}Ca g.s. reaction by varying one of these three sets of input data at a time from the best-fit combination.

In the following section we discuss in more detail the optical parameters used. In Section III we present our main results and discuss their sensitivity on these parameters. We also discuss the spectroscopic factors extracted from the data by this method.

II. Optical Model Parameters

(a) *Definitions*

For the neutron and proton optical potentials we assume the form

$$V(r) = V_{\mathrm{C}}(r) - V_{\mathrm{r}}\, f_{\mathrm{r}}(r) - \mathrm{i}W_{\mathrm{V}}\, f_{\mathrm{i}}(r) - \mathrm{i}W_{\mathrm{S}}\, g_{\mathrm{i}}(r) - \lambda\!\!\!^{-}{}_{\pi}^{2}\, V_{\mathrm{so}}\, h_{\mathrm{so}}(r)\, \boldsymbol{l}\cdot\boldsymbol{\sigma}, \tag{2}$$

where $V_{\mathrm{C}}(r)$ is the Coulomb potential of the nucleon in the field of a charge Ze distributed uniformly throughout the sphere $r \leqslant R$, V_{r} is the depth of the real potential well, W_{V} and W_{S} are the strengths of the volume and surface absorptions respectively, and V_{so} is the spin–orbit potential strength. All well depths are measured in units of MeV. The dimensional factor $\lambda\!\!\!^{-}{}_{\pi}$ is the Compton wavelength of the pion and is taken to be exactly $\sqrt{2}$ f. The orbital angular momentum $\boldsymbol{l}$ and spin $\boldsymbol{\sigma}$ of the captured neutron are in units of $\hbar$.

Our form factors $f(r)$ are of the Woods–Saxon type, e.g.

$$f_{\mathrm{r}}(r) = [1+\exp\{(r-r_{\mathrm{r}}\,A^{\frac{1}{3}})/a_{\mathrm{r}}\}]^{-1}, \tag{3}$$

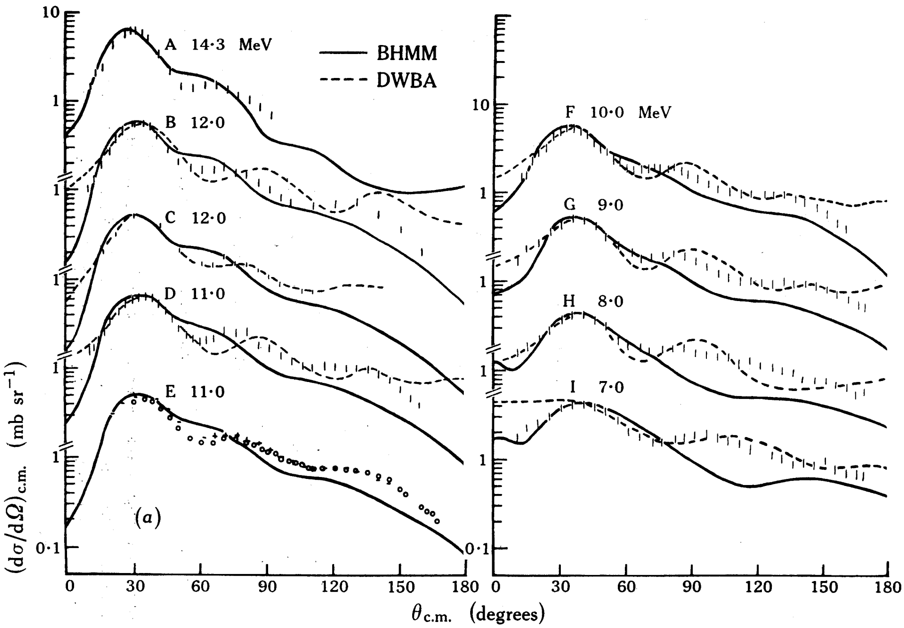
where the parameters a_{r} and $r_{\mathrm{r}}\,A^{\frac{1}{3}}$ are the diffuseness and radius of the well respectively.

The form factors $g_{\mathrm{i}}(r)$ and $h_{\mathrm{so}}(r)$ are given as derivative Woods–Saxon shapes with the usual normalizations,

$$g_{\mathrm{i}}(r) = -4a_{\mathrm{i}}\,\mathrm{d}\big(f_{\mathrm{i}}(r)\big)/\mathrm{d}r, \qquad h_{\mathrm{so}}(r) = r^{-1}\,\mathrm{d}\big(f_{\mathrm{so}}(r)\big)/\mathrm{d}r. \tag{4}$$

(b) *Neutron Potential*

The parameters of the neutron optical potential are required for a range of neutron energies approximately $0 \leqslant E_{\mathrm{n}} \leqslant 100$ MeV in the cases considered. As mentioned above, data are scarce and so it was not possible to obtain best-fit potentials. The optical potentials of Rosen *et al.* (1965), Perey and Buck (1962), and



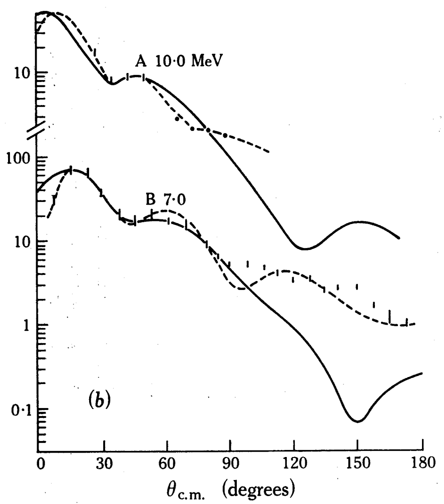


Fig. 1.—Comparison of BHMM theoretical proton angular distributions with experimental data and DWBA predictions for the reactions (*a*) $^{40}Ca(d,p)^{41}Ca$ g.s. and (*b*) $^{48}Ca(d,p)^{49}Ca$ g.s. at the indicated bombarding energies. The BHMM parameters and references to data and DWBA fits are given in Table 2.

Becchetti and Greenlees (to be published; quoted from Batty, Friedman, and Greenlees 1969) were used. We refer to these average parameter sets as $\mathscr{U}_n^R$, $\mathscr{U}_n^{PB}$, and $\mathscr{U}_n^{BG}$ respectively; they are given in Table 1(*a*).

(*c*) *Proton Potential*

The results of optical analyses on proton elastic scattering data are given in Table 1(*b*). Proton potentials are available at many energies and those nearest the required energy (that of the outgoing proton channel in the (d, p) reaction considered) were extrapolated to this required energy by assuming an energy dependence such as that involved in the average proton potential of Rosen *et al.* ($\mathscr{U}_p^R$). In this

TABLE 1

PARAMETERS FOR ELASTIC SCATTERING

Targets	Parameter Set	Reference*	V† (MeV)	W_v† (MeV)	W_s† (MeV)	V_{so} (MeV)	r_r (f)	r_i (f)	r_{so} (f)	r_C (f)	a_r (f)	a_i (f)	a_{so} (f)
(a) Neutron Parameters													
^{40}Ca, ^{48}Ca	$\mathscr{U}_n^R$	1	$49\cdot3-0\cdot33\,E_n$[a] $41\cdot4-10\cdot8\ln(E_n/24\cdot0)$[b]	0·0	5·75	5·5	1·25	1·25	1·25	—	0·65	0·70	0·65
^{40}Ca, ^{48}Ca	$\mathscr{U}_n^{PB}$	2	$48\cdot0-0\cdot29\,E_n$[a] $41\cdot0-10\cdot8\ln(E_n/24\cdot0)$[b]	0·0	9·6	7·2	1·27	1·27	1·27	—	0·66	0·47	0·66
^{40}Ca only	$\mathscr{U}_n^{BG}$	3	$56\cdot3-0\cdot32\,E_n$[c] $40\cdot3-10\cdot8\ln(E_n/50\cdot0)$[d]	$-1\cdot56+0\cdot22\,E_n$[e] 9·88[f]	$13\cdot0-0\cdot25\,E_n$[e] 0·0[f]	6·2	1·17	1·26	1·01	—	0·75	0·58	0·75
(b) Proton Parameters													
^{40}Ca, ^{48}Ca	$\mathscr{U}_p^R(E_p)$	1	$53\cdot8-0\cdot33\,E_p$	0·0	7·5	5·5	1·25	1·25	1·25	1·25	0·65	0·70	0·65
^{40}Ca	$\mathscr{U}_p^{21\cdot0}(21\cdot0)$	4	46·2	0·0	8·2	4·6	1·25	1·25	1·10	1·25	0·65	0·65	0·53
	$\mathscr{U}_p^{18\cdot3}(18\cdot3)$	4	48·0	0·0	5·4	3·8	1·25	1·25	1·10	1·25	0·65	0·65	0·34
	$\mathscr{U}_p^{17\cdot0}(17\cdot0)$	4	47·9	0·0	5·2	4·2	1·25	1·25	1·10	1·25	0·65	0·65	0·25
	$\mathscr{U}_p^{14\cdot5}(14\cdot5)$	4	48·4	0·0	5·2	5·0	1·25	1·25	1·10	1·25	0·65	0·65	0·37
^{48}Ca	$\mathscr{U}_p^{10\cdot0}(10\cdot0)$	5	50·0	0·0	13·75	7·5	1·25	1·25	1·25	1·25	0·65	0·47	0·65

* References: 1, Rosen *et al.* (1965), average parameters; 2, Perey and Buck (1962), average parameters; 3, Becchetti and Greenlees (quoted from Batty, Friedman, and Greenlees 1969), average parameters; 4, Boschitz (1966), data fit parameters; 5, Kashy *et al.* (1964), data fit parameters.

† Alternative values are for: a, $E_n \leqslant 24\cdot0$ MeV; b, $E_n > 24\cdot0$ MeV; c, $E_n \leqslant 50\cdot0$ MeV; d, $E_n > 50\cdot0$ MeV; e, $E_n \leqslant 52\cdot0$ MeV; f, $E_n > 52\cdot0$ MeV.

procedure all parameters are held constant except the real well depth $V_{\rm r}$, which depends linearly on the proton energy $E_{\rm p}$, that is,

$$\Delta V_{\rm r} = -0\cdot33\,\Delta E_{\rm p}\,. \tag{5}$$

The parameter set found by optical analysis of data for elastic scattering from the

Table 2

PARAMETERS AND REFERENCES FOR MAIN STRIPPING RESULTS

The letters in columns 3 and 4 refer to the curves in Figures 2 and 1 respectively

(1) References to Stripping Data	(2) $E_{\rm d}$ (MeV)	(3) Polarization Graph	(4) Cross Section Graph	(5) BHMM Proton Parameter Set
^{40}Ca(d, p)^{41}Ca g.s. (Figs 1(*a*) and 2)				
Boschitz (1963)	21·0	A	—	$\mathscr{U}_{\rm p}^{21\cdot0}(26\cdot78)$
Hjorth, Saladin, and Satchler (1965)	14·3	B	A	$\mathscr{U}_{\rm p}^{21\cdot0}(20\cdot24)$
Pasechnik, Saltykov, and Tambovtsev (1962)	13·8	C	—	$\mathscr{U}_{\rm p}^{21\cdot0}(19\cdot75)$
Lee *et al.* (1964), Seth *et al.* (to be published)	12·0	—	B,C	$\mathscr{U}_{\rm p}^{18\cdot3}(18\cdot00)$
Lee *et al.* (1964)	11·0	—	D	$\mathscr{U}_{\rm p}^{17\cdot0}(17\cdot02)$
Kato *et al.* (1965), C. C. Foster and D. W. Miller (personal communication), Seth *et al.* (to be published)	11·0	—	E*	$\mathscr{U}_{\rm p}^{17\cdot0}(17\cdot02)$
Kato *et al.* (1965), Kelley *et al.* (to be published)	10·9	D	—	$\mathscr{U}_{\rm p}^{17\cdot0}(16\cdot92)$
Bercaw and Shull (1964), Lee *et al.* (1964)	10·0	E	F	$\mathscr{U}_{\rm p}^{17\cdot0}(16\cdot05)$
Lee *et al.* (1964)	9·0	—	G	$\mathscr{U}_{\rm p}^{14\cdot5}(15\cdot07)$
Lee *et al.* (1964)	8·0	—	H	$\mathscr{U}_{\rm p}^{14\cdot5}(14\cdot09)$
Lee *et al.* (1964)	7·0	—	I	$\mathscr{U}_{\rm p}^{14\cdot5}(13\cdot12)$
^{48}Ca(d, p)^{49}Ca g.s. (Fig. 1(*b*))				
Andersen *et al.* (1968)	10·0	—	A	$\mathscr{U}_{\rm p}^{10\cdot0}(12\cdot78)$
Hjorth, Saladin, and Satchler (1965)	7·0	—	B	$\mathscr{U}_{\rm p}^{10\cdot0}(9\cdot84)$

* Experimental data of the three references in column 1 are plotted as horizontal marks, open circles, and vertical marks respectively for graph E in Figure 1(*a*).

appropriate nucleus at incident proton energy $E_{\rm p}$ we refer to as $\mathscr{U}_{\rm p}^{E_{\rm p}}(E_{\rm p})$. If this parameter set has been extrapolated to describe scattering at a new proton energy $E'_{\rm p}$ we refer to it as $\mathscr{U}_{\rm p}^{E_{\rm p}}(E'_{\rm p})$.

The validity of this extrapolation procedure for scattering from ^{208}Pb has already been shown (King and McKellar 1970*a*). In the present case the effect of extrapolation on the potentials (and ultimately on the stripping predictions) is also slight due to the small energy range over which extrapolation takes place.

TABLE 3

COMPARISON BETWEEN BHMM AND DWBA SPECTROSCOPIC FACTORS

The letters in columns 3 and 5 refer to the curves in Figure 1

(1) Final State	(2) E_d (MeV)	(3) BHMM Spectroscopic Factor Present	(4) BHMM Spectroscopic Factor Previous*	(5) DWBA Spectroscopic Factor
^{41}Ca g.s., $1f_{7/2}$	14·3	A 0·65	—	
	12·0	B 0·60	0·60	B 0·832
	12·0	C 0·59		C 0·76
	11·0	D 0·61	0·60	D 0·957
	11·0	E 0·575†		
	11·0	E 0·56‡		
	10·0	F 0·58	0·57	F 0·831
	10·0	0·53§		0·75§
	9·0	G 0·56	0·55	G 0·891
	8·0	H 0·53	0·52	H 0·934
	7·0	I 0·51	0·49	I 0·742
^{49}Ca g.s., $2p_{3/2}$	10·0‖	A 0·77	—	A 1·0
	7·0	B 0·78	—	B 1·03

* Butler, Hewitt, and Truelove (1967).
† Normalized to data from Kato *et al.* (1965).
‡ Normalized to data from Seth *et al.* (to be published).
§ Not shown in Figure 1(*a*); data from Andersen *et al.* (1968).
‖ Normalized to the second maximum because data on the main stripping peak are absent.

(*d*) *Bound State Neutron Potential*

In the analysis of the ^{48}Ca(d, p)^{49}Ca g.s. reaction, the usual "well-depth prescription" for the bound state wavefunction was used. Here the wavefunction (see BHMM) of the captured neutron is generated by a Woods–Saxon well

$$V_{\rm bs}(r) = -V'_{\rm r}\, f_{\rm r}(r) - \lambda_\pi^2\, V'_{\rm so}\, h_{\rm so}(r)\, \boldsymbol{l}\cdot\boldsymbol{\sigma}, \tag{6}$$

where the spin–orbit depth is chosen to be 25 times the Thomas term:

$$V'_{\rm so} = 25(m_\pi^2/4m_{\rm p}^2)\, V'_{\rm r} = 0\cdot 138\; V'_{\rm r}. \tag{7}$$

The real well depth $V'_{\rm r}$ is then chosen to give the correct neutron binding energy.

In the case of the ^{40}Ca(d, p)^{41}Ca g.s. reaction an improved bound state neutron wavefunction (G. R. Satchler, personal communication) calculated using the method of Philpott, Pinkston, and Satchler (1968) was used.

III. RESULTS

Our main results for the stripping cross sections are given in Figures 1(*a*) and 1(*b*) using the bound state wavefunctions mentioned above, the Rosen *et al.* neutron potential, and proton parameters as listed in Table 2. References to DWBA fits and experimental data are also given in Table 2. In Table 3 we present the spectro-

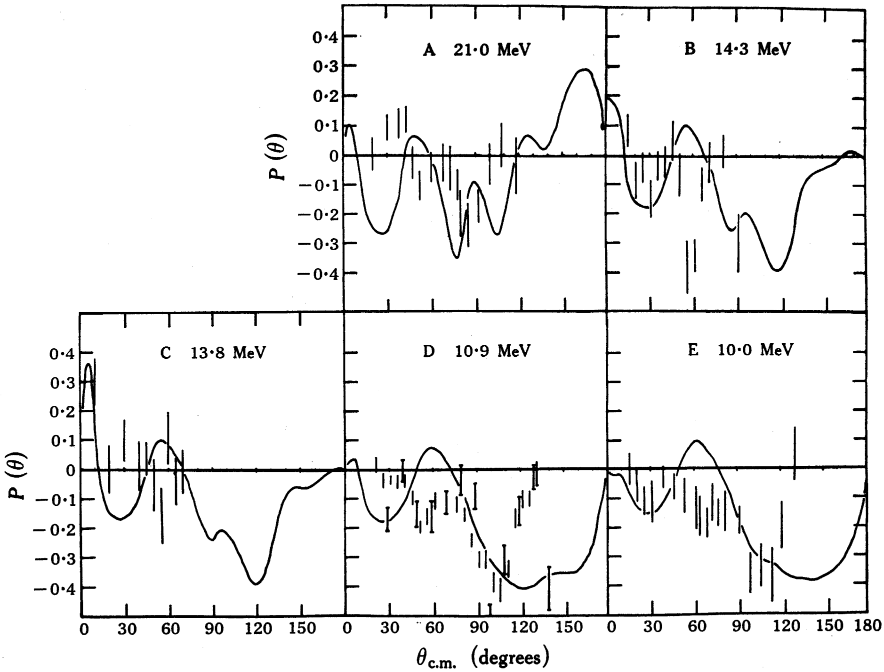


Fig. 2.—Comparison of BHMM predictions with the experimental angular dependence of proton polarizations $P(\theta)$ arising from the $^{40}Ca(d,p)^{41}Ca$ g.s. reaction with the indicated bombarding energies.

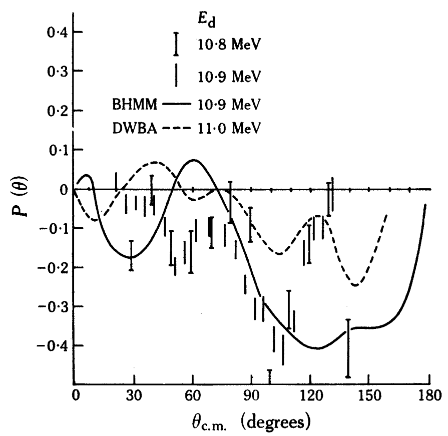


Fig. 3.—Comparison of the BHMM and DWBA theories with the experimental proton polarizations $P(\theta)$ arising from the $^{40}Ca(d,p)^{41}Ca$ g.s. reaction with an incident deuteron energy E_d of about 11 MeV.

scopic factors extracted from the data by these calculations and compare them with those obtained in a previous BHMM analysis of the $^{40}Ca(d,p)^{41}Ca$ g.s. reaction by Butler, Hewitt, and Truelove (1967) and with those extracted using the DWBA fits. In Figure 2 the BHMM predictions for the polarization $P(\theta)$ of the outgoing proton from the $^{40}Ca(d,p)^{41}Ca$ g.s. reaction are shown to be in qualitative agreement with experiment, as is characteristic of current stripping theories. In Figure 3, for example, we show the present BHMM curves and the predictions of a DWBA analysis

(Swandt and Haeberli 1969). Polarizations shown were measured at 10·8 MeV (Kelley *et al.*, to be published) and 10·9 MeV (Kato *et al.* 1965).

(*a*) *Effect of Neutron Potential*

The effect of using different average neutron parameters causes only small changes in the predicted angular distributions, as shown in Figure 4(*a*). The spectroscopic factors obtained with $\mathscr{U}_n^{PB}$ are similar to those obtained with $\mathscr{U}_n^{R}$, whereas those obtained using $\mathscr{U}_n^{BG}$ can differ by up to $+0\cdot1$ (see Table 4). This consistency, as well as the better angular distributions obtained, was the reason for favouring $\mathscr{U}_n^{R}$ and $\mathscr{U}_n^{PB}$ over $\mathscr{U}_n^{BG}$ in the analysis. There is no special reason for favouring the Rosen *et al.* potential over that due to Perey and Buck.

TABLE 4

EFFECT OF NEUTRON POTENTIAL, PROTON POTENTIAL, AND BOUND STATE WAVEFUNCTION ON BHMM SPECTROSCOPIC FACTORS

(1) Final State	(2) E_d (MeV)	(3) Best-fit Proton Parameter Set	(4) Spectroscopic Factors with: Neutron Potentials[a] $\mathscr{U}_n^R$	(5) $\mathscr{U}_n^{PB}$	(6) $\mathscr{U}_n^{BG}$	(7) Proton Potential[b] $\mathscr{U}_p^R$	(8) Bound State[c] (WDP)
^{41}Ca g.s., $1f_{7/2}$	14·3	$\mathscr{U}_p^{21\cdot0}(20\cdot24)$	0·65	0·64	0·72	0·65	0·52
	12·0[d]	$\mathscr{U}_p^{18\cdot3}(18\cdot00)$	0·60	0·58	0·68	0·63	0·47
	12·0[e]		0·59	0·57	0·67	0·62	0·46
	11·0[d]	$\mathscr{U}_p^{17\cdot0}(17\cdot02)$	0·61	0·60	0·69	0·64	0·50
	11·0[f]		0·575	0·56	0·66	0·61	0·45
	11·0[g]		0·56	0·54	0·64	0·59	0·44
	10·0	$\mathscr{U}_p^{17\cdot0}(16\cdot05)$	0·58	0·54	0·66	0·61	0·45
	9·0	$\mathscr{U}_p^{14\cdot5}(15\cdot07)$	0·56	0·54	0·64	0·59	0·44
	8·0	$\mathscr{U}_p^{14\cdot5}(14\cdot09)$	0·53	0·51	0·62	0·56	0·40
	7·0	$\mathscr{U}_p^{14\cdot5}(13\cdot12)$	0·51	0·50	0·60	0·54	0·39
^{49}Ca g.s., $2p_{3/2}$	10·0[h]	$\mathscr{U}_p^{10\cdot0}(12\cdot78)$	0·77	0·70	0·71	0·77	—
	7·0	$\mathscr{U}_p^{10\cdot0}(9\cdot84)$	0·78	0·71	0·67	0·78	—

[a] Calculated using best-fit proton parameters and Satchler's bound state wavefunction.

[b] Calculated using $\mathscr{U}_n^{R}$ and Satchler's bound state wavefunction. The values are to be compared with the spectroscopic factors in column 4 where best-fit proton parameters were used.

[c] Calculated using the well-depth prescription for the bound state wavefunction. The values are to be compared with column 4 where Satchler's bound state wavefunction was used.

[d] Normalized to data from Lee *et al.* (1964).

[e] Normalized to data from Seth *et al.* (to be published).

[f] Normalized to data from Kato *et al.* (1965).

[g] Normalized to data from C. C. Foster and D. W. Miller (personal communication).

[h] Normalized to second maximum.

(*b*) *Effect of Proton Potential*

If, instead of the best-fit proton potential, the average Rosen *et al.* proton potential is used, the calculations show only slight changes (Fig. 4(*b*), Table 4). This result was also found in the case of the ^{208}Pb(d, p)^{209}Pb g.s. reaction (King and McKellar 1970*a*).

(c) *Effect of Bound State Wavefunction*

The bound state wavefunction found by the well-depth prescription, although satisfactory in our analysis of stripping on ^{48}Ca, was not as good for analysis on ^{40}Ca as the more realistic wavefunction due to Satchler; the comparison is shown in Figure 5. In the analysis of $^{40}Ca(d, p)^{41}Ca$ g.s. due to Butler, Hewitt, and Truelove (1967) the bound state was described using the well-depth prescription, although the agreement with experiment was improved by using an average neutron potential modified in such a way as to provide a more realistic description of available (n, n) data.

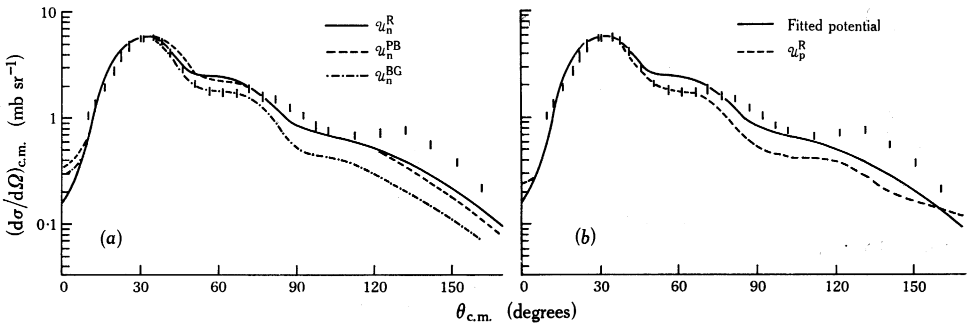


Fig. 4.—BHMM proton angular distributions for (*a*) three average neutron parameter sets and (*b*) best-fit and average proton potentials for the $^{40}Ca(d, p)^{41}Ca$ g.s. reaction and an incident deuteron energy of 12·0 MeV.

The use of Satchler's wavefunction increases the spectroscopic factor by about +0·13 but the resulting factor is approximately the same as that derived by Butler, Hewitt, and Truelove (see Tables 3 and 4).

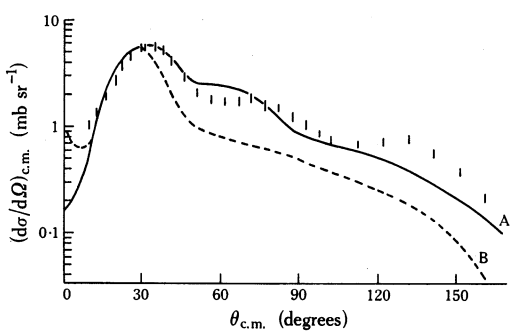


Fig. 5.—BHMM proton angular distributions from the $^{40}Ca(d, p)^{41}Ca$ g.s. reaction at 12·0 MeV bombarding energy using (A) the bound state wavefunction of Satchler and (B) the bound state wavefunction generated by the usual well-depth prescription. The figure shows the great improvement to the angular shape obtained by using a more realistic bound state for the captured neutron. Best-fit proton parameters and Rosen *et al.* average neutron parameters were used in both cases.

IV. Conclusions

It can be seen that the BHMM theory provides good agreement with experimental data. For a given set of data, the spectroscopic factors extracted by BHMM are characteristically about 30% smaller than those extracted by DWBA calculations. There is also an uncertainty in the absolute spectroscopic factor caused by uncertainties in the absolute experimental cross sections (approximately 20%). However, we note

(Table 5) that the BHMM ratios of the spectroscopic factors for ^{41}Ca g.s. and ^{49}Ca g.s. agree with the DWBA ratios (extracted from the same data) to within 10%.

TABLE 5

RATIOS OF SPECTROSCOPIC FACTORS FOR ^{41}Ca g.s. AND ^{49}Ca g.s.

E_d (MeV)	$R = S(^{41}\text{Ca g.s.})/S(^{49}\text{Ca g.s.})$ BHMM (R_B)	DWBA (R_D)	R_B/R_D	Data Graphs*
10·0	0·69	0·75	0·92	NS, A
10·0	0·755	0·831	0·91	F, A
7·0	0·655	0·72	0·91	I, B

* The letters refer to the curves in Figures 1(*a*), 1(*b*) respectively; NS indicates that the data are not shown in Figure 1(*a*) but are taken from Andersen *et al.* (1968).

V. Acknowledgments

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