(He^3,d) Reaction on Ca^{42} and Ca^{44}†

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Energy levels in Sc^{43} and Sc^{45} have been studied using the $Ca^{42,44}(He^3,d)Sc^{43,45}$ reactions at 10 and 11 MeV. Twenty-nine levels in Sc^{43} and seventy-four levels in Sc^{45} were observed below an excitation energy of 6.3 MeV. Angular distributions of the reaction deuterons were measured out to a laboratory angle of 50°. The angular distributions of the more intense groups have been compared with the predictions of a distorted-wave Born-approximation calculation, and angular momentum transfers of $l=0$, $l=1$, $l=2$, and $l=3$ have been identified. Most of the available $1f_{7/2}$ and $2p$ single-particle transition strength has been observed.

INTRODUCTION

DURING recent years, a great deal of work, both experimental and theoretical, has been devoted to the study of the $1f_{7/2}$ shell nuclei. The ground states of most of the calcium, scandium, and titanium isotopes have been described[1] by assuming active nucleons only in the $1f_{7/2}$ shell. The excited states arising from the interaction of several particles in this shell usually extend over a region of several MeV in energy. Excited states arising from particles in the $2p$ shell occur in the same energy region, so that extensive configuration mixing may be expected even in rather low-lying states.

In previous work, the energy-level structure of Sc^{43} has been observed in the reactions $Ca^{43}(p,n)Sc^{43}$,[2] $Ca^{40}(\alpha,p)Sc^{43}$,[3,4] $Ti^{46}(p,\alpha)Sc^{43}$,[5] and $Ca^{42}(p,\gamma)Sc^{43}$.[6] Levels in Sc^{45} have been observed in the reactions $Sc^{45}(p,p')Sc^{45}$ [7] and $Ti^{46}(d,He^3)Sc^{45}$.[8]

In the present work, levels in Sc^{43} and Sc^{45} have been studied with the $Ca^{42}(He^3,d)Sc^{43}$ and $Ca^{44}(He^3,d)Sc^{45}$ reactions, which are expected to preferentially excite states consisting largely of a single proton coupled to the target ground state. The results have been analyzed using distorted-wave calculations to determine the orbital angular momentum of the transferred particle and spectroscopic factors for a number of excited states in each nucleus.

EXPERIMENTAL PROCEDURE

Measurements were carried out using the facilities of the tandem Van de Graaff accelerator at Argonne National Laboratory. Deuterons from the reaction were recorded in nuclear emulsions in the focal surface of a broad-range magnetic spectrograph of the Browne-Buechner type. Kodak type-NTB emulsions, 100 μ in thickness, were used for the measurements. Emulsions were covered with aluminum absorber sufficient to reduce the residual range of the deuteron to about 100 μ in the emulsion, allowing easy discrimination between proton and deuteron tracks in the emulsion.

Targets were prepared by decomposing enriched $CaCO_3$ in a hot tantalum tube and evaporating the calcium onto the target backing. The calcium was evaporated onto backings of carbon and Formvar about 30 $\mu g/cm^2$ or gold about 200 $\mu g/cm^2$ in thickness. The calcium target material was about 75 $\mu g/cm^2$ thick. To minimize oxidation of the calcium, targets were kept in a vacuum lock which permitted transfer from evaporator to target chamber without exposure to air. Ca^{42} targets enriched to 66% and 92% were used to allow discrimination of deuteron groups from the $Ca^{40}(He^3,d)Sc^{41}$ reaction. Ca^{44} targets were enriched to 94%.

Angular distributions were taken over the range 7.5° to 50° with 10-MeV He^3 on Ca^{44}, and 5° to 50° with 11- and 12-MeV He^3 on Ca^{42}. In the latter case, exposures were made at 12 MeV as well as 11 MeV to produce a greater separation between the calcium elastic peak and the $T=\frac{3}{2}$, $2p_{3/2}$ energy level (its expected position having been calculated from the known position of its analog in Ca^{43}). At the more forward angles of 5° to 15°, the targets with C^{12} backings were used to minimize the background from elastic scattering. At all other angles, targets with the gold backing were used to minimize the reaction groups from C^{12}. To facilitate the separation of C^{12}, C^{13}, and O^{16} reaction groups, several exposures were made with the same beam incident on the carbon and Formvar backings alone.

The output of a solid-state detector mounted at 90° in the scattering chamber was used to monitor the elastic scattering from the calcium during each exposure, and all exposures were normalized to this elastic peak. Absolute cross sections were determined by assuming that the elastic scattering of He^3 from Ca^{42} and Ca^{44} is the same as from Ca^{40} at the energies used in these measurements. The elastic scattering of He^3 from Ca^{40} has been measured[9] at 8.5, 9.5, and 12 MeV, and 90° cross sections at 10 and 11 MeV were interpolated from these measurements. Absolute cross sections are ex-

* Research supported in part by the U. S. Atomic Energy Commission.
[1] J. D. McCullen, B. F. Bayman, and Larry Zamick, AEC Technical Report No. NYO-9891 (1964) (unpublished).
[2] G. J. McCallum, A. T. G. Ferguson, and G. S. Mani, Nucl. Phys. **17**, 116 (1960).
[3] N. O. Lassen and Clive Larsen, Nucl. Phys. **42**, 183 (1963).
[4] B. Čujec, Nucl. Phys. **81**, 523 (1966).
[5] H. S. Plendl, L. J. Defelice, and R. K. Sheline, Nucl. Phys **73**, 131 (1965).
[6] L. Broman and J. Dubois, Nucl. Phys. **72**, 529 (1965).
[7] W. W. Buechner and M. Mazari, Rev. Mex. Fís. **7**, 117 (1958).
[8] J. L. Yntema and G. R. Satchler, Phys. Rev. **134**, 976 (1964).
[9] D. Cline, W. P. Alford, and L. M. Blau, Nucl. Phys. **73**, 33 (1965). See also R. W. Zurmühle, C. M. Fou, and L. W. Swenson, Nucl. Phys. **80**, 259 (1966).

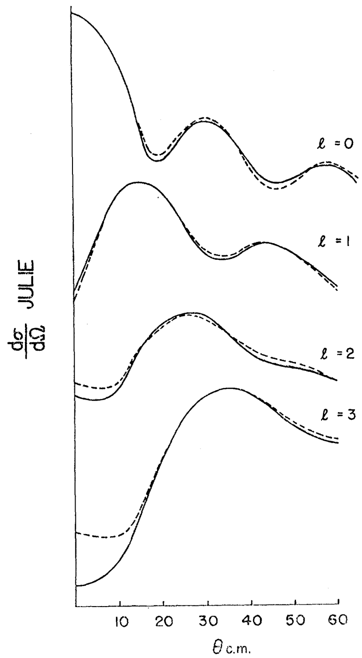

FIG. 1. Ca^{42}(He^3,d)-Sc^{43}; DWBA calculations with (dashed line) and without (solid line) lower cutoff at 4.090 F, for $l=0$, 1, 2, 3.

pected to have an uncertainty of about 25% in all measurements.

Sc^{43} RESULTS

In Table I are listed the observed energy levels of Sc^{43} together with the peak cross sections measured. In

TABLE I. Observed energy levels of Sc^{43} with peak cross sections.

Excitation (MeV)	$(d\sigma/d\Omega)_{\text{peak}}$ (mb/sr)
ground state	2.5
0.152±0.008	0.6
0.475±0.006	2.9
0.856±0.010	1.0
1.180±0.007	7.5
1.812±0.006	3.1
1.962±0.006	0.3
2.100±0.009	0.5
2.294±0.005	0.7
2.679±0.015	0.1
2.992±0.015	0.1
3.337±0.015	0.1
3.462±0.015	0.1
3.618±0.015	0.1
3.673±0.015	0.4
3.992±0.010	0.1
4.238±0.008	1.5
4.380±0.010	0.2
4.565±0.010	0.3
4.663±0.010	0.1
4.713±0.010	0.3
3.896±0.010	0.3
5.025±0.008	0.9
5.266±0.009	0.3
5.495±0.010	0.1
5.634±0.010	0.1
5.818±0.010	0.1
6.156±0.009	0.7
6.282±0.010	0.1

TABLE II. Optical-model expressions and parameters used in analysis of Ca^{42}(He^3,d)Sc^{43} and Ca^{44}(He^3,d)Sc^{45} data. Well depths are given in MeV and lengths in fermis.

Potential:

$$U(r)=-V(e^x+1)^{-1}-i\left(W-4W_d\frac{d}{dx'}\right)(e^{x'}+1)^{-1}+U_c(r)\,,$$

where

$$U_c(r)=(Z^2e^2/2R_c)(3-r^2/R_c^2)\,,\quad r<R_c$$
$$=Ze^2/r\,,\quad r\geqslant R_c$$
$$x'=(r-r'_0A^{1/3})/a',\qquad x=(r-r_0A^{1/3})/a.$$

Spin-orbit potential:

$$U_{\text{so}}(r)=\left(\frac{\hbar}{m\pi c}\right)^2(V_s+iW_s)\frac{1}{r}\frac{d}{dr}(e^x+1)^{-1}\mathbf{L}\cdot\mathbf{S}$$

	V	W	r_0	R_c	a	V_s	W_s	r_0'	a'	W_d
Entrance channel	168.0	17.0	1.07	1.4	0.854	0	0	1.81	0.592	0
Exit channel	112.0	0	1.0	1.3	0.900	0	0	1.55	0.470	18.0
Bound state			1.2	1.25	0.65	8.0				

the Ca^{40}(α,p)Sc^{43} reaction, additional levels have been observed[3,4] at energies of 0.880, 1.34, 1.41, 1.64, 1.88, and 1.91 MeV. An upper limit to the cross section for

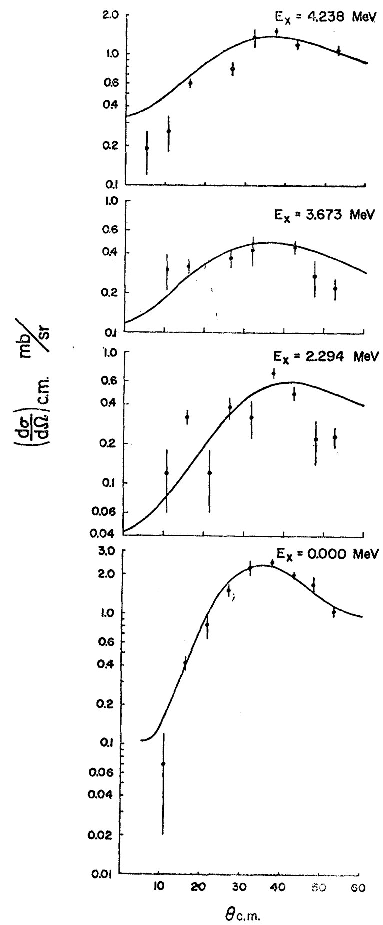

FIG. 2. Ca^{42}(He^3,d)-Sc^{43}; DWBA calculations and data on f-wave transitions. $E_{\text{He}^3}=11.00$ MeV. Solid line—JULIE, $l=3$.

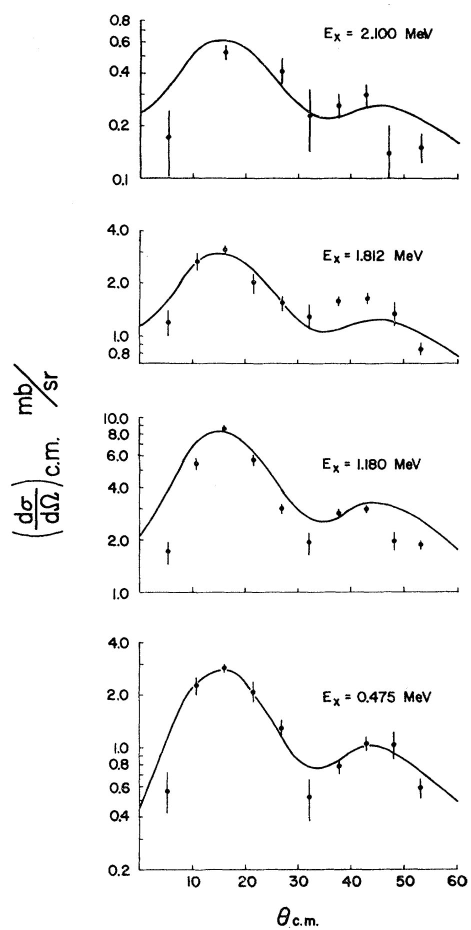

FIG. 3. $Ca^{42}(He^3,d)Sc^{43}$; DWBA calculations and data on transitions to the 0.475, 1.180, 1.812, and 2.100-MeV levels. $E_{He^3}=11.00$ MeV. Solid line—JULIE, $l=1$.

excitation of these levels in the $Ca^{42}(He^3,d)Sc^{43}$ reaction may be set at 0.02 mb/sr.

Measured angular distributions have been compared with the predictions of a distorted-wave Born-approximation (DWBA) calculation to obtain spectroscopic factors for a number of levels in Sc^{43}. Calculations were performed by R. H. Bassel at Oak Ridge National Laboratory using the DWBA code JULIE. The calculations were carried out as described by Bassel *et al.*[10] except that an Irving-Gunn wave function was used for the three-particle system in calculating the spectroscopic factor for the light particles. This re-

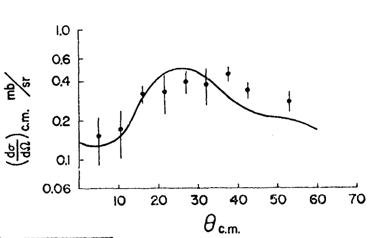

FIG. 4. $Ca^{42}(He^3,d)$-Sc^{43}; DWBA calculations and data on the transition to the 0.152-MeV level. $E_{He^3}=11.00$ MeV; $E_x=0.152$ MeV. Solid line—JULIE, $l=2$.

[10] R. H. Bassel, R. M. Drisko, and G. R. Satchler, Oak Ridge National Laboratory Report No. ORNL-3240 1962 (unpublished).

TABLE IV. Strengths of observed p-wave transitions to Sc^{43}. For $(J,T)=(J,\frac{1}{2})$, theoretical $\sum C^2S=0.67$.

E_{obs} (MeV)	C^2S for $J=\frac{3}{2}$
0.475	0.12
1.180	0.29
1.812	0.12
2.100	0.02

sulted in an increase of the calculated cross section by a factor of 4.4 as compared with that predicted using wave functions of the type described in the original report.

A Saxon-Woods potential was used for both the bound-state and optical potentials. A spin-orbit term was included in the bound state potential. The optical-model parameters used in the calculations are shown in Table II. The entrance-channel parameters were taken from $Ca^{40}(He^3,\alpha)Ca^{39}$ results[9] and the exit-channel parameters from $Ca^{40}(d,p)Ca^{41}$ results.[11,12] Thus, the parameters used were not obtained by best fits to these data but from independent sources. Calculations were made both with and without radial cutoff, and the results were virtually unchanged by the cutoff, both in shape and magnitude. This is illustrated in Fig. 1, where DWBA curves for $l=0$, 1, 2, 3 both with and without cutoff are plotted. All subsequent DWBA curves shown are those calculated without cutoff. The relationship between measured and calculated cross section is given by

$$\left.\frac{d\sigma}{d\omega}\right|_{\text{expt}}=\frac{2J_f+1}{2J_i+1}C^2S\left(4.4\frac{d\sigma}{d\omega}\right)_{\text{JULIE}},$$

where C is the appropriate isobaric spin Clebsch-Gordan coefficient and S the spectroscopic factor for the state in question.

Calculations of the levels arising from the $(f_{7/2})^3$ configuration have been carried out by McCullen *et al.*,[1] who predict levels with spin, parity, and isobaric spin $(J^\pi,T)=(\frac{7}{2}^-,\frac{1}{2})$ at 0, 3.25, and 5.43 MeV. The $(J^\pi,T)=(\frac{7}{2}^-,\frac{3}{2})$ analog to the Ca^{43} ground state is expected at 4.172 MeV. As shown in Fig. 2, the levels observed at excitation energies of 0, 2.294, 3.673, and 4.238 MeV have angular distributions consistent with those pre-

TABLE III. Calculated and observed Sc^{43} energy levels reached by f-wave transitions.

E_{calc}	J^π,T	E_{obs}	C^2S calc	C^2S obs.
0	$\frac{7}{2}^-,\frac{1}{2}$	0	0.58	0.68
3.25	$\frac{7}{2}^-,\frac{1}{2}$	3.67	0.16	0.07
4.17	$\frac{7}{2}^-,\frac{3}{2}$	4.238	0.25	0.22
5.43	$\frac{7}{2}^-,\frac{1}{2}$	not observed	0.01	...
		2.294	0	0.14

[11] R. H. Bassel, R. M. Drisko, G. R. Satchler, L. L. Lee, Jr., J. P. Schiffer, and B. Zeidman, Phys. Rev. 136, 960 (1964).

[12] L. L. Lee, Jr., J. P. Schiffer, B. Zeidman, G. R. Satchler, R. M. Drisko, and R. H. Bassel, Phys. Rev. 136, 971 1964.

dicted for $l=3$ stripping. A comparison of measured and predicted spectroscopic factors for these states is shown in Table III. Three of the predicted levels are observed with strengths in good agreement with the calculations. Several levels are observed near the predicted position of the fourth level at 5.43 MeV, but none of them can be clearly identified as arising from $l=3$ stripping. The level observed at 2.294 MeV does not correspond to any predicted level and may be a component of the $f_{5/2}$ strength.

TABLE V. Observed energy levels of Sc^{45}; with peak cross sections.

Excitation (MeV)	$(d\sigma/d\Omega)_{peak}$ (mb/sr)	Excitation (MeV)	$(d\sigma/d\Omega)_{peak}$ (mb/sr)
0	1.4		
0.015±0.003	0.2	4.664±0.015	0.3
0.378±0.015	1.5	4.713±0.015	0.2
0.714±0.010	0.2	4.739±0.015	0.2
0.944±0.015	1.0	4.774±0.015	0.2
1.067±0.015	1.8	4.801±0.015	0.2
1.410±0.015	0.2	4.826±0.015	0.2
1.553±0.015	1.6	4.869±0.015	0.2
1.889±0.015	0.2	4.917±0.015	0.2
2.304±0.015	0.2	4.959±0.015	0.2
2.349±0.015	0.6	5.009±0.015	0.2
2.750±0.015	0.5	5.049±0.015	0.2
2.980±0.015	1.3	5.084±0.015	0.2
3.022±0.015	2.0	5.125±0.015	0.2
3.104±0.015	0.2	5.169±0.015	0.2
3.119±0.015	0.2	5.219±0.015	0.2
3.150±0.010	0.2	5.254±0.015	0.2
3.189±0.015	0.2	5.309±0.015	0.2
3.354±0.015	0.2	5.374±0.015	0.2
3.407±0.015	0.4	5.419±0.015	0.2
3.484±0.015	1.0	5.444±0.015	0.4
3.609±0.015	0.2	5.504±0.015	0.2
3.724±0.015	0.8	5.574±0.015	0.2
3.779±0.015	0.2	5.604±0.015	0.3
3.881±0.015	0.9	5.684±0.020	0.2
3.926±0.015	2.2	5.774±0.020	0.4
3.989±0.015	0.2	5.810±0.020	0.2
4.034±0.015	0.2	5.834±0.020	0.4
4.129±0.015	0.3	5.931±0.020	0.2
4.179±0.015	0.3	5.964±0.020	0.3
4.249±0.015	0.3	5.971±0.020	0.2
4.309±0.015	0.3	6.004±0.020	0.2
4.360±0.015	0.2	6.031±0.020	0.2
4.424±0.015	0.2	6.136±0.020	0.2
4.464±0.015	0.2	6.179±0.020	0.2
4.505±0.015	0.7	6.202±0.020	0.2
4.549±0.015	0.2	6.244±0.020	0.2
4.619±0.015	0.2	6.319±0.020	0.2
		6.434±0.020	0.2

Angular distributions leading to other bound states with peak cross sections greater than 0.5 mb/sr have been compared with DWBA calculations and spectroscopic factors obtained. Levels at 0.475, 1.180, 1.812, 2.100 MeV show angular distributions characteristic of stripping with $l=1$, as shown in Fig. 3. It is expected that $p_{1/2}$ states will lie at excitation energies of about 4 MeV, and it is consequently assumed that these four levels all have $J^\pi=\frac{3}{2}^-$. With this assumption, it is found that 80% of the $p_{3/2}$ single-particle strength with $T=\frac{1}{2}$ is located in these four levels. (See Table IV.) The assignment of $J^\pi=\frac{3}{2}^-$ to the 0.475-MeV level is consist-

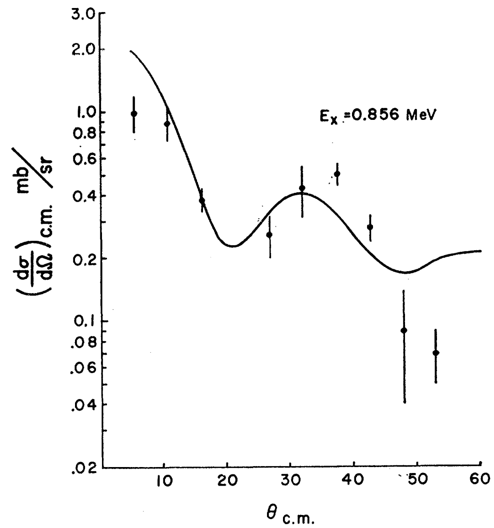

FIG. 5. $Ca^{42}(He^3,d)Sc^{43}$; DWBA calculations and data on the transition to the 0.856-MeV level. $E_{He^3}=11.00$ MeV. Solid line—JULIE, $l=0$.

ent with recent measurements of the angular correlation of the de-excitation gamma rays and conversion electrons from this level.[13]

The mean life of the first excited state at 0.152 MeV has been measured and found to be 628 μsec.[14] This lifetime is consistent with that expected for an inhibited $M2$ transition to the $J^\pi=\frac{7}{2}^-$ ground state, suggesting that this is the $d_{3/2}$ hole state in Sc^{43}. The measured angular distribution of deuterons leading to this state is shown in Fig. 4, along with the DWBA calculations for an $l=2$ transition. The fit and spectroscopic factor of 0.22 is in reasonable agreement with the identification of this as the $d_{3/2}$ hole state.

On the basis of its decay scheme, the 0.856-MeV level has recently been suggested to have spin $\frac{5}{2}$.[13] However,

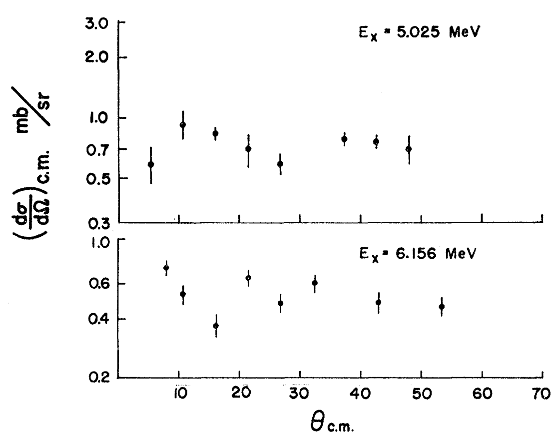

FIG. 6. $Ca^{42}(He^3,d)Sc^{43}$; data on transitions to the 5.025 and 6.156-MeV levels. $E_{He^3}=11.00$ MeV.

[13] W. R. Phillip, R. de la Pena, and T. A. Critchley, Bull. Am. Phys. Soc. 11, 406 (1966).
[14] R. E. Holland, F. J. Lynch, and K. E. Nysten, Phys. Rev. Letters 13, 241 (1964).

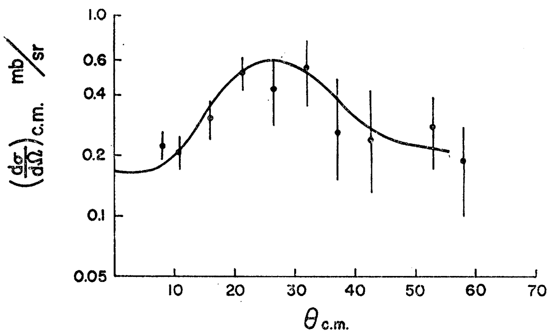

FIG. 7. $Ca^{44}(He^3,d)Sc^{45}$; DWBA calculations and data on the transition to the 0.013-MeV level of Sc^{45}. $E_{He^3}=10.00$ MeV; $E_x=0.013$ MeV. Solid line—JULIE, $l=2$.

as shown in Fig. 5, the angular distribution of deuterons leading to the 0.856-MeV state is consistent with the DWBA calculation for $l=0$, suggesting that this state may be the $s_{1/2}$ hole state. If $J^\pi=\frac{1}{2}^+$, the measured spectroscopic factor is 0.16, in good agreement with a value of 0.13 observed for the $s_{1/2}$ hole state in the $Ca^{42}(d,p)Ca^{43}$ reaction.[15] The measured energy difference of 704 keV between this state and the presumed $d_{3/2}$ hole state at 152 keV would also be in reasonable agreement with a difference of 969 keV observed for the separation of these states in Ca^{43}.

Two unbound levels at 5.025- and 6.156-MeV excitation show comparatively large cross sections. (See Fig. 6.) The 6.156-MeV state may be the $(J^\pi,T)=(\frac{3}{2}^-,\frac{3}{2})$ analog of the $p_{3/2}$ state found in Ca^{43} at an excitation of 2.048 MeV. The identification of the 5.025-MeV state is not clear, although the shape of the angular distribution suggests that it may be a major component of the $p_{1/2}$ strength.

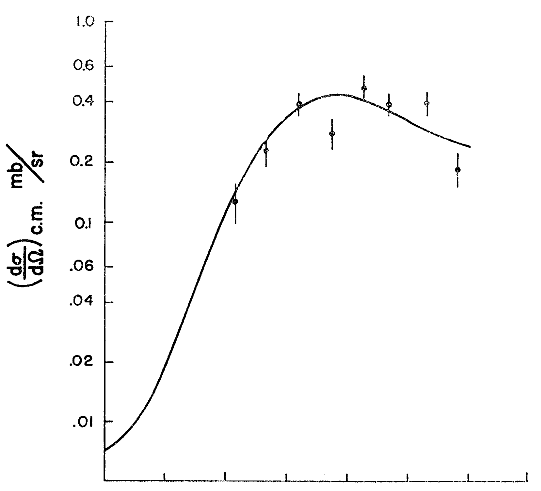

FIG. 8. $Ca^{44}(He^3,d)Sc^{45}$; DWBA calculations and data on the transition to the 2.750-MeV level of Sc^{45}. $E_{He^3}=10.00$ MeV; $E_x=2.75$ MeV. Solid line—JULIE, $l=3$.

[15] W. E. Dorenbusch, T. A. Belote, and O. Hansen, Phys. Rev. **146**, 734 (1966).

TABLE VI. Calculated and observed Sc^{45} energy levels reached by f-wave transition.

E_{obs} (MeV)	E_{calc} with $T=\frac{3}{2}$ (MeV)	C^2S expt	C^2S theory
0	g.s.	0.71	0.67
2.75	2.62	0.14	0.17
	3.22		0.006
	4.96		0.003
	5.52		0.04
	6.64		0.001

Sc^{45} RESULTS

In Table V are listed the observed energy levels of Sc^{45} together with the peak cross sections observed.

Distorted-wave Born approximation calculations were carried out by Bassel at Oak Ridge National Laboratory for all observed levels with a peak cross section in excess of 0.4 mb/sr. These consisted of the ground state, 0.378-, 0.944-, 1.067-, 1.553-, 2.349-, 2.750-, 2.980-, 3.022-, 3.407-, 3.484-, 3.724-, 3.881-, 3.926-, and 4.505-MeV levels. The code JULIE was used with the same potentials and parameters as described above for the analysis of Sc^{43} data.

The first excited state of Sc^{45} is known to lie at an excitation energy of 0.013 MeV. Measurements of the lifetime[13] of this state and of the $Ti^{46}(d,He^3)Sc^{45}$ reaction[8] leading to the unresolved ground and first excited state of Sc^{45} are consistent with the identification of this as the $d_{3/2}$ hole state. In the present measurements, this level was clearly resolved from the ground state at laboratory angles of 7.5°, 10°, and 15°. At these angles, the measured cross section for the transition to the ground state of Sc^{45}, assuming it to proceed by stripping of an $f_{7/2}$ proton, indicated a spectroscopic factor of 0.9 for the ground state. At other angles where the ground

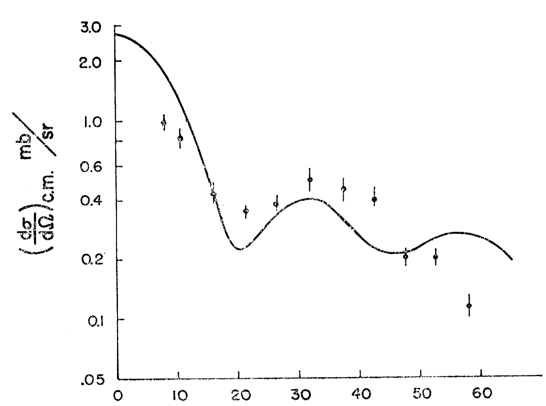

FIG. 9. $Ca^{44}(He^3,d)Sc^{45}$; DWBA calculations and data on the transition to the 0.944-MeV level of Sc^{45}. $E_{He^3}=10.00$ MeV; $E_x=0.944$ MeV. Solid line—JULIE, $l=0$.

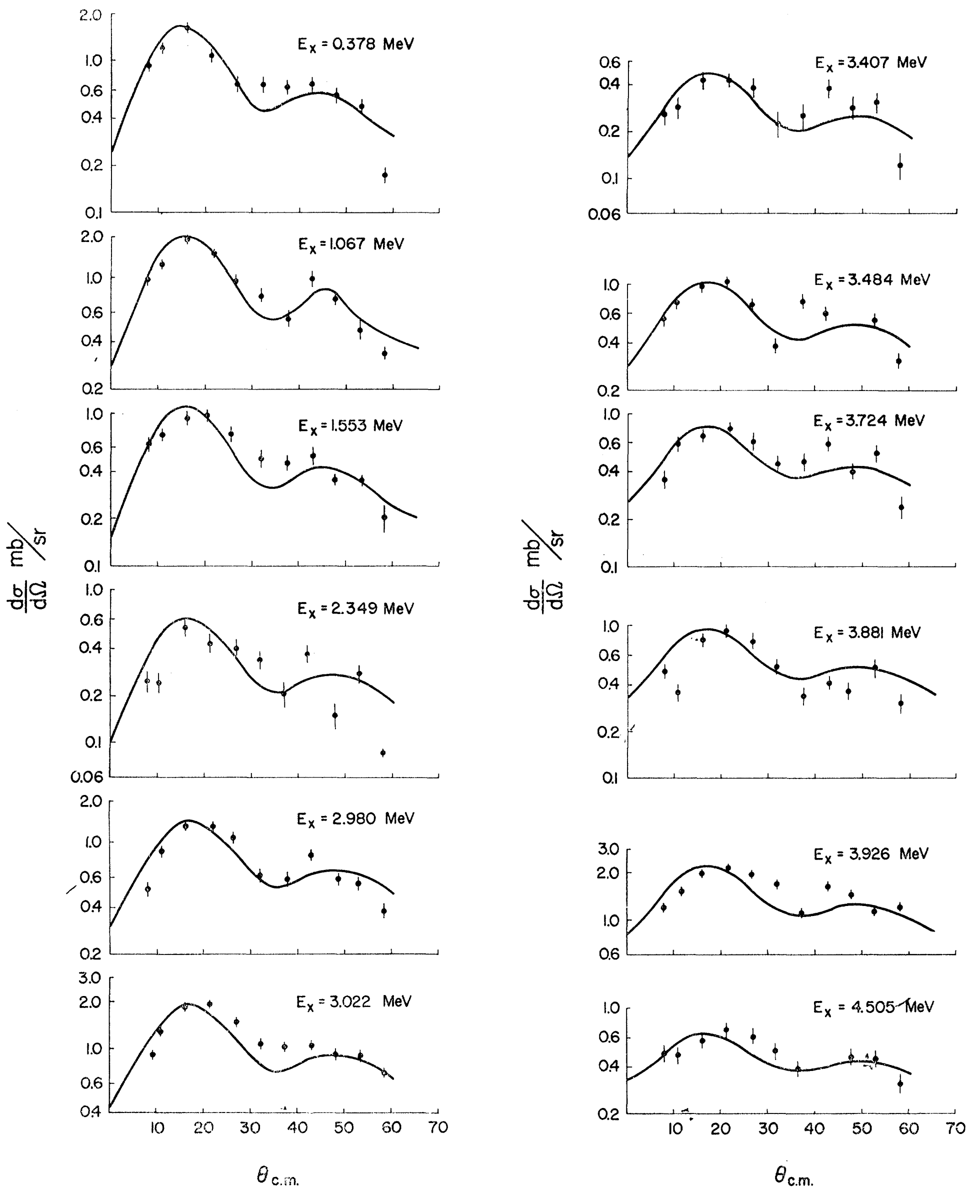

FIG. 10. Ca^{44}(He^3,d)Sc^{45}; DWBA calculations and data on p-wave transitions, $E_{\mathrm{He}^3}=10.00$ MeV. Solid line—JULIE, $l=1$.

and 0.013-MeV state were not resolved, an estimate of the cross section for the 0.013-MeV state was obtained by subtracting out the calculated ground-state cross section, assuming a spectroscopic factor of 0.9. The resulting angular distribution for the 0.013-MeV state is shown in Fig. 7, along with the DWBA calculation for an $l=2$ transition. The fit is satisfactory and confirms the identification of this as the $d_{3/2}$ state. The measured spectroscopic factor of 0.53 is about twice as large as that for the $d_{3/2}$ hole state in Sc^{43}.

Calculations of the level structure of the $(f_{7/2})^5$ configuration have also been carried out by McCullen *et al.*[1] The predicted locations and strengths of the $(J^\pi,T)=(\frac{7}{2}^-,\frac{3}{2})$ levels are shown along with the experimental results for $l=3$ transitions in Table VI. The 2.75-MeV level with C^2S of 0.14 agrees well with the prediction of a $(J^\pi,T)=(\frac{7}{2}^-,\frac{3}{2})$ level at 2.62 MeV and C^2S of 0.17. The 2.75-MeV level should thus be assigned a spin and parity of $\frac{7}{2}^-$. The angular distribution of deuterons leading to the 2.75-MeV level is shown in Fig. 8. $T=\frac{5}{2}$ levels lie at slightly higher excitation energy than was reached in this measurement.

As shown in Fig. 9, the angular distribution of deuterons to the level at 0.944 MeV is fitted quite well with a DWBA calculation assuming $l=0$, indicating that this is the $s_{1/2}$ hole state. The measured spectroscopic factor is 0.27, again about twice as large as that for the $s_{1/2}$ hole state in Sc^{43}.

TABLE VII. Calculated values of C^2S for p-wave transitions in $Ca^{44}(He^3,d)Sc^{45}$. For $(J,T)=(J,\frac{3}{2})$ theoretical $\sum C^2S=0.8$.

Excitation (MeV)	C^2S for $J=\frac{3}{2}$	C^2S for $J=\frac{1}{2}$
0.378	0.14	0.32
1.067	0.14	0.32
1.553	0.07	0.16
2.349	0.03	0.07
2.980	0.06	0.14
3.022	0.10	0.23
3.407	0.02	0.05
3.484	0.05	0.12
3.724	0.05	0.12
3.881	0.05	0.12
3.926	0.10	0.23
4.505	0.04	0.09

The 0.378-MeV level is excited by p-wave transitions, indicating a spin of $\frac{3}{2}^-$ or $\frac{1}{2}^-$. Measurements[16] of gamma rays following Coulomb excitation of this state indicate that the spin cannot be $\frac{1}{2}$ but are consistent with a spin of $\frac{3}{2}$ if it is assumed that the decay proceeds to the 0.013-MeV state.[17] Preliminary measurements[18] indicate that this assumption is correct, and it is concluded that the spin is $\frac{3}{2}^-$.

Other strongly excited levels at energies of 1.067, 1.553, 2.349, 2.980, 3.022, 3.407, 3.484, 3.274, 3.881, 3.926, and 4.505 MeV also show angular distributions characteristic of $l=1$. The comparison between measured and calculated angular distributions for these states is shown in Fig. 10. There is no clear grouping of these levels which might indicate a separation between $p_{3/2}$ and $p_{1/2}$ states as found in Sc^{43} although it appears that the major portion of both the $p_{3/2}$ and $p_{1/2}$ strength is accounted for. For example, if it is assumed that the six lower states are components of the $p_{3/2}$ single-particle state and the other six components of the $p_{1/2}$ state, then approximately 75% of the strength is observed for the $T=\frac{3}{2}$ components of both the $p_{3/2}$ and $p_{1/2}$ single particle states. (See Table VII.) An interesting feature of these results is that, excluding the two very weakly excited levels at 0.714 and 1.410 MeV, the first five states excited in this reaction appear at about the same energies and with the same angular momentum transfers as the first five states of Sc^{43} excited in this reaction.

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SUMMARY

Angular distributions characteristic of a single-particle stripping reaction have been observed in the (He^3,d) reaction leading to a number of levels in Sc^{43} and Sc^{45}. Levels with $J^\pi=\frac{7}{2}^-$ arising from the $(f_{7/2})^n$ configuration are identified in both nuclei, with positions and strengths in good agreement with calculations of McCullen *et al.*[1] Essentially all of the $1f_{7/2}$ transition strength is accounted for. The spectroscopic strength of the $2p$ single-particle levels is distributed over a number of final states. In Sc^{43}, most of the available $2p_{3/2}$ strength is observed, but the $2p_{1/2}$ levels are not clearly identified. In Sc^{45} much of the total $2p$ transition strength can be accounted for, but the $2p_{3/2}$ and $2p_{1/2}$ levels appear to overlap considerably in energy. Levels which can be identified as $d_{3/2}$ and $s_{1/2}$ hole states are found in both nuclei. The strength of these hole states is found to be significantly greater in Sc^{45} than in Sc^{43}.

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