Levels in Odd-Mass Sb and I Isotopes Studied with the (^{3}He,d) Reaction*

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The (^{3}He,d) reaction has been used to study levels in the residual nuclei ^{125}Sb, ^{127}I, ^{129}I, and ^{131}I up to ≈4 MeV in excitation. The experiments were performed at a bombarding energy of 25 MeV using a broad-range magnetic spectrograph. Angular distributions for the deuterons were compared with distorted-wave Born-approximation predictions to obtain orbital angular-momentum transfers and spectroscopic factors for most of the observed levels. States reached by l equal to 0, 2, 4, and probably 5 were observed in each nucleus. A comparison of the present results with previous decay-scheme studies is also shown.

INTRODUCTION

IN the shell-model description of nuclei, a major shell closure occurs at 50 nucleons. For protons, this corresponds to the tin isotopes. The next major shell (51 to 82 nucleons) comprises the $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$, and $1h_{11/2}$ levels.

A number of antimony and iodine isotopes, which have 51 and 53 protons, respectively, have been studied previously by means of the decay of radioactive nuclei.[1–7] These studies have consistently shown the presence of low-lying states with assigned spins and parities $\frac{7}{2}+$, $\frac{5}{2}+$, $\frac{3}{2}+$, $\frac{1}{2}+$, and in several cases $\frac{11}{2}-$.

In the case of antimony isotopes the simplest assumption is that these states are due to the odd proton occupying one of the single-particle levels beyond the closed proton shell. The problem of core excitation might be expected to be rather small, particularly for those states below about 500 keV, since the first excited state of the tin "core" is over 1 MeV in excitation.

It is intriguing to extend this simple assumption to the iodine isotopes. In this case these levels would be assumed to be due primarily to three protons beyond the appropriate tin isotope core. In particular, some preliminary shell-model calculations on ^{129}I and ^{127}I had indicated that the lowest $\frac{5}{2}+$ state (the 27 keV and ground states, respectively) would be composed predominantly of a $(1g_{7/2})^3{}_{5/2}$ proton configuration.[8] Such a state would not be strongly excited in the proton stripping reaction.

Measurements of the l transfers and strengths for proton stripping to states in these nuclei were desirable for checking these simple model calculations and to determine the importance of the various shell-model orbitals in describing these nuclei.

EXPERIMENTAL DETAILS

The experiment was performed using a 25-MeV ^{3}He beam from the Oak Ridge isochronous cyclotron. The reaction product deuterons were energy-analyzed by a broad-range magnetic spectrograph. The spectrograph and beam preparation system have been described previously.[9] The incident particle beam had an energy spread of approximately 25 keV and was focused on the target by means of two quadrupole triplet lenses. The beam at the target had dimensions of order 1 mm wide by 10 mm high and an angular divergence of approximately ±8 mrad.

The spectrograph entrance slits were adjusted to give an acceptance angle of ±1.5°. The deuteron spectra were recorded on 50-μ-thick Kodak NTB emulsions which were covered by aluminum absorbers to eliminate trition tracks. The deuteron energies recorded by the emulsions corresponded to approximately the first 4 MeV of excitation of the residual nuclei. Exposure zones 3 cm high were used to obtain a solid angle of $\sim 5\times10^{-4}$ sr.

The targets, prepared by the ORNL Isotopes Division, were made from material isotopically enriched to 98–99%, which was vacuum-evaporated on ~25-μg/cm^2 carbon backings. The thicknesses were nominally 600 μg/cm^2 for the ^{124}Sn and 250 μg/cm^2 for the ^{126}Te, ^{128}Te, and ^{130}Te targets. The peak widths obtained in the deuteron spectra were approximately those expected from the energy loss of the ^{3}He particles in the targets, being ~60 keV for the tin target and ~25 keV for the tellurium targets.

Since the target thicknesses were not precisely known, the ^{3}He elastic peak and the distorted-wave Born-approximation (DWBA) prediction for the elastic cross section were used to calculate the (^{3}He,d) cross sections. The elastically scattered ^{3}He particles were detected

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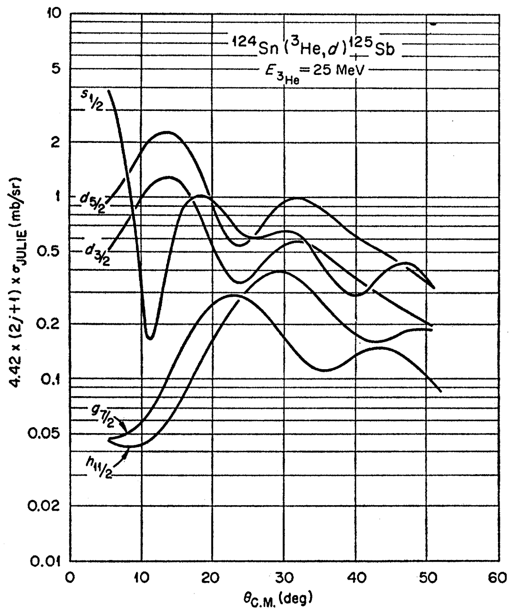

FIG. 1. Calculated angular distributions for the ^{124}Sn(^{3}He,d)^{125}Sb reaction. The cross sections are corrected for finite range and nonlocality and are multiplied by appropriate normalization factors.

by a surface-barrier Si detector mounted at a scattering angle of 30°. A preliminary elastic scattering measurement on ^{124}Sn at a bombarding energy of 31 MeV had shown good agreement between the experimental and predicted cross sections. A further check on the monitor counter was made by exposing several plates to elastic ^{3}He particles in the spectrograph. After appropriate solid angle corrections, the elastic peak areas obtained with the spectrograph and monitor counter agreed to within 5%.

THE DWBA ANALYSIS

The angular distributions for the various deuteron groups were analyzed using the code JULIE.[10] The absolute values for the calculated cross sections are subject to some uncertainty since the ^{3}He optical-model parameters are not well determined in this mass and energy region. An attempt was made to determine these parameters by studying the elastic scattering of 31-MeV ^{3}He particles from a ^{124}Sn target. However, the calculated cross sections were relatively insensitive to the optical-model parameters. The (^{3}He,d) calculations were therefore performed using a potential similar to that used by Gibson *et al.*[11] The parameters are listed in Table I. Elastic scattering cross sections calculated using these parameters gave good agreement with the 31-MeV data. Some attempts were made to improve the agreement with the (^{3}He,d) data by varying the real well depth (V), radius (r_0), diffuseness (a), and the volume imaginary well depth (W) over a small range of values ($\sim\pm10\%$). These variations in the optical potential parameters made very little improvement in the fit to the data and only changed the magnitude of the calculated cross sections. The $l=0$ cross sections were most sensitive to the changes in the parameters and typically varied by $\pm20\%$. The $l=2$ and $l=4$ cross sections generally changed by less than 10%. Calculations were also made for different Q values. Again, only the magnitudes changed and corrections were determined for calculating spectroscopic factors.

The deuteron optical parameters, also listed in Table I, are an average set obtained from the more recent analysis by Perey and Perey of 25.3- and 25.9-MeV elastic scattering on nuclei from iron to gold.[12]

The parameters of the bound-state potential were those used by Hiebert *et al.*,[13] with values of $r_0=1.2$ F,

TABLE I. Optical-model parameters used in the DWBA calculation of (^{3}He,d) cross sections.

	^{3}He	d
V(MeV)	172	101.4
r_0(F)	1.14	1.085
a(F)	0.70	0.857
W(MeV)	16	0
W_D(MeV)	0	15.25
r_0'(F)	1.54	1.293
a'(F)	0.80	0.788
V_{so}(MeV)	0	7.20
r_c(F)	1.4	1.3

TABLE II. Summary of results obtained from the ^{124}Sn(^{3}He,d)-^{125}Sb reaction. The first j value in parentheses is the value used in calculating the centers of gravity and total strengths for the $l=2$ states. The spectroscopic factors are presented in the same order as the j values.

Level No.	Energy (MeV)	l	j	C^2S
1	0	4	$\frac{7}{2}$	0.79
2	0.332	2	$\frac{5}{2}$	1.01
3	0.643	2	$\frac{3}{2}$	0.29
4	0.923	0	$\frac{1}{2}$	0.35
5	1.483	2	$(\frac{5}{2},\frac{3}{2})$	(0.08,0.15)
6	1.560			
7	1.66			
8	1.72	2	$(\frac{3}{2},\frac{5}{2})$	(0.30,0.17)
9	1.80	0	$\frac{1}{2}$	0.03
10	1.88	(5)	$(\frac{11}{2})$	(1.2)
11	1.95	2	$(\frac{3}{2},\frac{5}{2})$	(0.14,0.08)
12	2.48			
13	2.57	0	$\frac{1}{2}$	0.18
14	2.67	0	$\frac{1}{2}$	0.13
15	2.71	0	$\frac{1}{2}$	0.10
16	2.78			
17	2.82			
18	2.89	2	$(\frac{3}{2},\frac{5}{2})$	(0.15,0.09)

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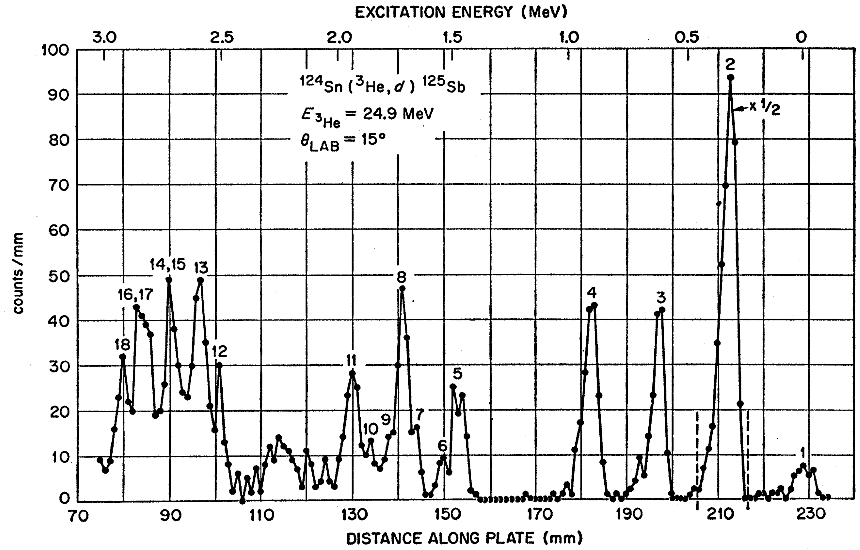

FIG. 2. Deuteron spectrum from the ^{124}Sn(^{3}He,d)^{125}Sb reaction.

$a=0.65$ F, $r_c=1.25$ F, and $\lambda_{so}=25$. The well depth was chosen to reproduce the experimental separation energy of the proton.

In order to calculate spectroscopic factors, the predicted cross sections were multiplied by 4.42, which is the normalization factor calculated by Bassel,[14] and the statistical factor $(2j+1)$. The calculated cross sections include corrections for finite range in the (^{3}He,d) interaction and for nonlocality in the optical potentials.[15] The predicted angular distributions for the ^{124}Sn(^{3}He,d)-^{125}Sb reaction are shown in Fig. 1.

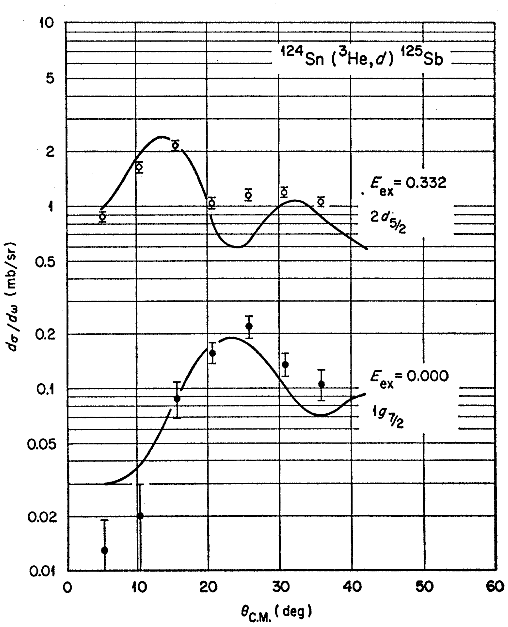

FIG. 3. Comparison of calculated and experimental angular distributions for the ground and 0.332-MeV states in ^{125}Sb.

RESULTS AND DISCUSSION

^{124}Sn(^{3}He,d)^{125}Sb Reaction

Results from the study of this reaction have been reported previously.[16] This target was included in this work to provide a calibration test for the DWBA predicted cross sections. Such a use is based on the aforementioned assumption that the orbits in the 51–82 proton shell are essentially empty in the ^{124}Sn target nucleus.

A deuteron spectrum is shown in Fig. 2. Data were taken up to 4 MeV of excitation, but no strongly excited levels were observed above about 3 MeV. The

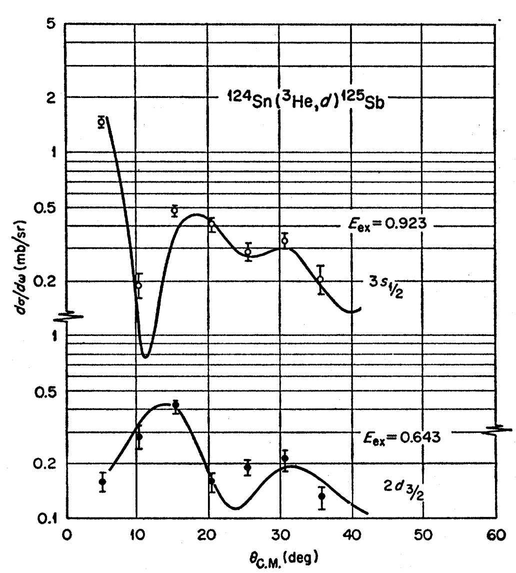

FIG. 4. Comparison of calculated and experimental angular distributions for the 0.643- and 0.923-MeV states in ^{125}Sb.

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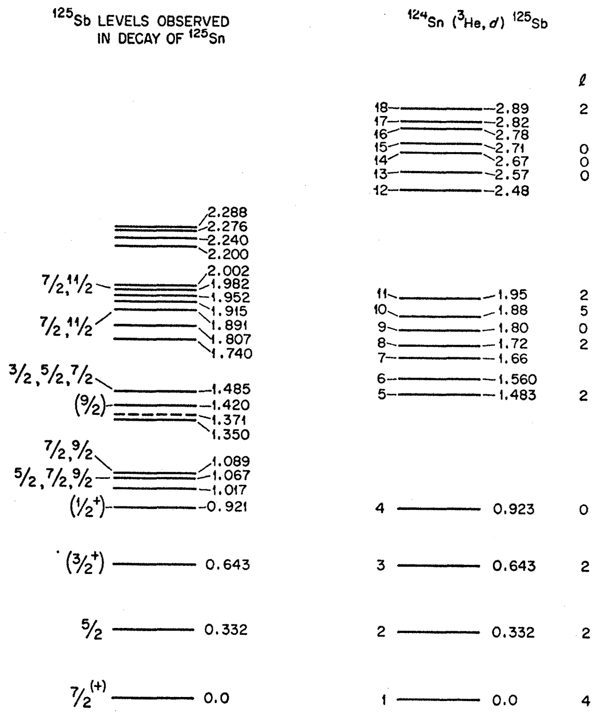

FIG. 5. Comparison of ^{125}Sb levels observed in decay-scheme studies (Ref. 1) with those seen in the present work. The excitation energies obtained at the various angles were consistent to within ±5 keV for the levels below 1.6 MeV. At higher excitations, where spectrum stripping was required, the uncertainty in the energies is estimated at ±20 keV. Note: More recent studies on ^{125}Sn decay (Ref. 2) suggest additional states at 1.700, 2.113, and 2.253 MeV and show that the level at 1.017 MeV should be eliminated.

angular distributions for transitions to the ground and first three excited states of ^{125}Sb are shown in Figs. 3 and 4. They are compared with the DWBA predictions for transitions to $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, and $3s_{1/2}$ states, respectively. The angular distributions clearly distinguish the various orbital, but not the total, angular-momentum transfers. Unless spin assignments are available from other studies, the spectroscopic factors for $l=2$ states have been calculated for both $j=\frac{3}{2}$ and $\frac{5}{2}$.

The energies and l assignments for the ^{125}Sb levels are given in Table II. The $l=5$ assignment for the 1.88-MeV level must be considered tentative, since this state is weakly excited at most angles, but the data indicate that the angular distribution for this state peaks at a larger angle than does the $l=4$ distribution.

It is apparent from Table II that only the $g_{7/2}$ and $d_{5/2}$ strengths are concentrated in single levels. The value of $C^2S=0.79$ for the only observed $l=4$ transition (to the ground state) could indicate that other states having $1g_{7/2}$ single-particle components are present at higher excitation. Examples of splitting of the $1g_{7/2}$ strength have been observed in ^{117,119}Sb by Ishimatsu *et al.*[17] Such states could easily be missed since the cross sections for $l=4$ stripping are very small compared to the $l=0$ and $l=2$ cross sections. It is also possible, since the calculations for the higher-l transitions are most sensitive to the parameters of the bound state and optical potentials, that the calculated cross sections are in error.

The two states at 0.64 and 0.92, the lowest $\frac{3}{2}+$ and $\frac{1}{2}+$ states, account for only about one-third of the $2d_{3/2}$ and $3s_{1/2}$ strengths, respectively. Thus these two levels must contain a significant amount of core excitation (in the sense that ^{124}Sn is considered a core). This may not be too surprising in view of the excitation energies of these states compared with the energy of the first excited state of ^{124}Sn (1.13 MeV). Evidence for a strong proton-core interaction in low-lying levels of ^{121}Sb and ^{123}Sb has been reported by Barnes *et al.*[18]

The results of recent decay-scheme studies of ^{125}Sn states are compared with the present results in Fig. 5. While there are a number of levels which are observed in both experiments, there are a significant number of levels seen in the decay studies that are not observed with the stripping reaction. The results of the two experiments are consistent for the levels where both

TABLE III. Summary of results obtained from the ^{126}Te(^{3}He,d)-^{127}I reaction. The first j value in parentheses is the value used in calculating the centers of gravity and total strengths for the $l=2$ states. The spectroscopic factors are presented in the same order as the j values.

Level No.	Energy (MeV)	l	j	C^2S
1	0	2	$\frac{5}{2}$	0.59
2	0.058±0.005	4	$\frac{7}{2}$	0.72
3	0.205	(2)	$\frac{3}{2}$	0.06
4	0.375	0	$\frac{1}{2}$	0.20
5	0.420	2	$\frac{5}{2}$	0.12
6	0.995	2	$(\frac{3}{2},\frac{5}{2})$	(0.22,0.12)
7	1.095	2	$(\frac{5}{2},\frac{3}{2})$	(0.32,0.56)
8	1.12	0	$\frac{1}{2}$	0.07
9	1.236	(5)	$(\frac{11}{2})$	0.65
10	1.27			
11	1.399	2	$(\frac{3}{2},\frac{5}{2})$	(0.18,0.10)
12	1.445	0	$\frac{1}{2}$	0.22
13	1.555±0.010	2	$(\frac{3}{2},\frac{5}{2})$	(0.14,0.08)
14	1.66			
15	1.79			
16	1.83	0	$\frac{1}{2}$	0.05
17	1.86	2	$(\frac{3}{2},\frac{5}{2})$	(0.09,0.06)
18	1.89	2	$(\frac{3}{2},\frac{5}{2})$	(0.11,0.07)
19	1.92	0	$\frac{1}{2}$	0.05
20	2.065	0	$\frac{1}{2}$	0.09
21	2.16	2	$(\frac{3}{2},\frac{5}{2})$	(0.11,0.07)
22	2.50±0.020	0	$\frac{1}{2}$	0.02
23	2.85	0	$\frac{1}{2}$	0.03
24	2.93	0	$\frac{1}{2}$	0.04
25	3.12	0	$\frac{1}{2}$	0.02

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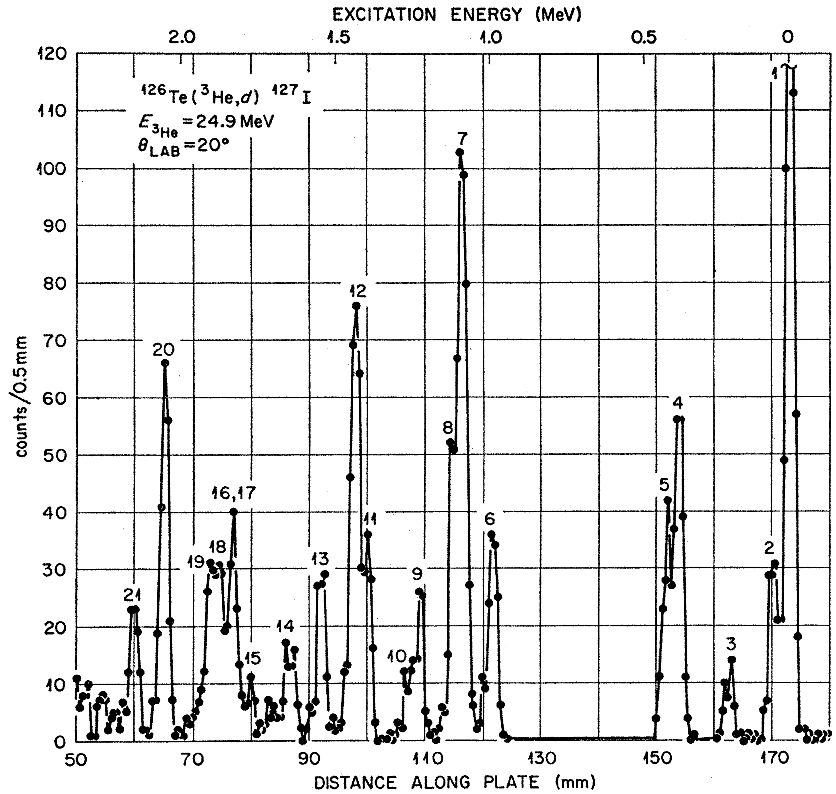

FIG. 6. Deuteron spectrum from the ^{126}Te(^{3}He,d)^{127}I reaction.

total and orbital angular-momentum assignments are available.

Levels in ^{127}I, ^{129}I, and ^{131}I

Spectra obtained with the ^{126}Te, ^{128}Te, and ^{130}Te targets are shown in Figs. 6, 7, and 8, respectively. At excitation energies above about 2 MeV, only the strongest peaks could be analyzed due to numerous unresolved and weakly excited states at higher excitation energies.

Orbital angular-momentum assignments and spectroscopic factors were determined for all levels having

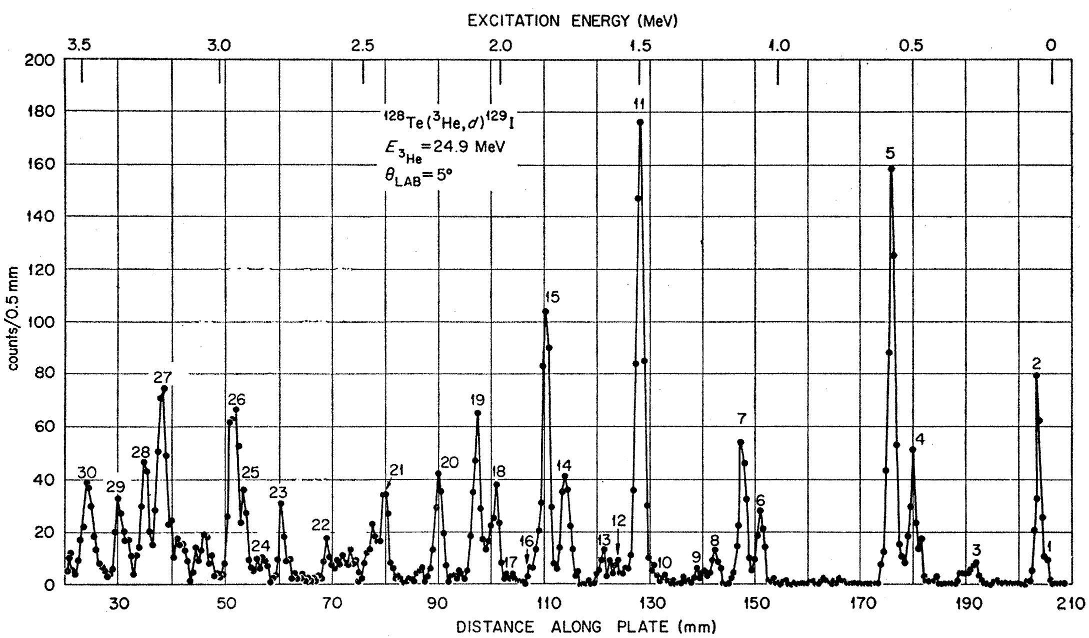

FIG. 7. Deuteron spectrum from the ^{128}Te(^{3}He,d)^{129}I reaction.

TABLE IV. Summary of results obtained from the ^{128}Te(^{3}He,d)-^{129}I reaction. The first j value in parentheses is the value used in calculating the centers of gravity and total strengths for the $l=2$ states. The spectroscopic factors are presented in the same order as the j values.

Level No.	Energy (MeV)	l	j	C^2S
1	0	4	$\frac{7}{2}$	0.66
2	0.028±0.005	2	$\frac{5}{2}$	0.59
3	0.280	2	($\frac{3}{2}$)	0.07
4	0.487	2	($\frac{5}{2}$)	0.21
5	0.561	0	$\frac{1}{2}$	0.21
6	1.052	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.25,0.14)
7	1.111	2	($\frac{5}{2}$,$\frac{3}{2}$)	(0.25,0.47)
8	1.210	0	$\frac{1}{2}$	0.02
9	1.262	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.05,0.03)
10	1.400	(5)	($\frac{11}{2}$)	0.63
11	1.483	0	$\frac{1}{2}$	0.21
12	1.566±0.010	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.08,0.04)
13	1.621	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.10,0.05)
14	1.741	0	$\frac{1}{2}$	0.04
15	1.823	0	$\frac{1}{2}$	0.10
16	1.861	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.10,0.06)
17	1.963			
18	2.012	0	$\frac{1}{2}$	0.04
19	2.073	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.19,0.10)
20	2.208	0	$\frac{1}{2}$	0.04
21	2.40	0	$\frac{1}{2}$	0.03
22	2.59±0.020	0	$\frac{1}{2}$	0.02
23	2.79	0	$\frac{1}{2}$	0.02
24	2.85	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.05,0.02)
25	2.91	0	$\frac{1}{2}$	0.02
26	2.95	0	$\frac{1}{2}$	0.05
27	3.20	0	$\frac{1}{2}$	0.06
28	3.25	0	$\frac{1}{2}$	0.04
29	3.35	0	$\frac{1}{2}$	0.02
30	3.45	0	$\frac{1}{2}$	0.03

TABLE V. Summary of results obtained from the ^{130}Te(^{3}He,d)^{131}I reaction. The first j value in parentheses is the value used in calculating the centers of gravity and total strengths for the $l=2$ states. The spectroscopic factors are presented in the same order as the j values.

Level No.	Energy (MeV)	l	j	C^2S
1	0	4	$\frac{7}{2}$	0.64
2	0.149±0.005	2	$\frac{5}{2}$	0.53
3	0.491	2	($\frac{3}{2}$)	0.07
4	0.601	2	($\frac{5}{2}$)	0.47
5	0.874	0	$\frac{1}{2}$	0.21
6	1.094			
7	1.145	2	($\frac{5}{2}$,$\frac{3}{2}$)	(0.14,0.26)
8	1.296	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.25,0.13)
9	1.345	0	$\frac{1}{2}$	0.03
10	1.425	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.03,0.02)
11	1.499	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.10,0.05)
12	1.638±0.010	(5)	($\frac{11}{2}$)	0.70
13	1.672			
14	1.718	0	$\frac{1}{2}$	0.31
15	1.797	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.05,0.03)
16	2.040			
17	2.175	0	$\frac{1}{2}$	0.05
18	2.308	0	$\frac{1}{2}$	0.09
19	2.346	0	$\frac{1}{2}$	0.03
20	2.408	2	($\frac{3}{2}$,$\frac{5}{2}$)	(0.15,0.09)
21	2.444			
22	2.699±0.020			
23	2.744	0	$\frac{1}{2}$	0.07
24	2.807	0	$\frac{1}{2}$	0.02
25	2.870			
26	2.940	0	$\frac{1}{2}$	0.07
27	3.040	0	$\frac{1}{2}$	0.07
28	3.17			
29	3.70	0	$\frac{1}{2}$	0.06

well-defined angular distributions. These values are summarized in Tables III, IV, and V. The levels without spectroscopic information did not have angular distributions which would allow specific l assignments and are presumably multiplets composed of states having different l values.

The $l=5$ assignments are again only tentative due to the low cross sections for these peaks at most angles. The assignment for the 0.205-MeV level in ^{127}I is also tentative because of poor statistics.

In all three isotopes the strongest $l=2$ transition is to the lowest $\frac{5}{2}+$ state. The strength is nearly the same in each case and amounts to approximately half of the expected total strength for stripping in a $d_{5/2}$ proton. The description of this state as largely due to the $(1g_{7/2})^3{}_{5/2}$ configuration is thereby ruled out.

In general the strengths are distributed in such a way that the construction of the states appears very complex with all of the nearby shell-model orbitals actively participating. For example, the 0.205-MeV level in ^{127}I has been assigned spin and parity $\frac{3}{2}+$ on the basis of

TABLE VI. Single-particle strengths and centers of gravity deduced from the present work.

Residual nucleus	^{125}Sb		^{127}I		^{129}I		^{131}I	
Level	$\sum C^2S$	C.G.[a] (MeV)	$\sum C^2S$	C.G. (MeV)	$\sum C^2S$	C.G. (MeV)	$\sum C^2S$	C.G. (MeV)
$1g_{7/2}$	0.8	≥0	0.7	≥0	0.7	≥0	0.6	≥0
$2d_{5/2}$	1.1	0.42	1.0	0.33	1.1	0.39	1.1	0.45
$2d_{3/2}$	0.9	1.60	0.9	1.39	0.9	1.54	0.7	1.50
$3s_{1/2}$	0.8	1.85	0.8	1.41	1.0	1.84	1.0	1.94
$(1h_{11/2})$	(1.2)	≥1.9	(0.6)	≥1.2	(0.6)	≥1.4	(0.7)	≥1.6

[a] C.G. = center of gravity.

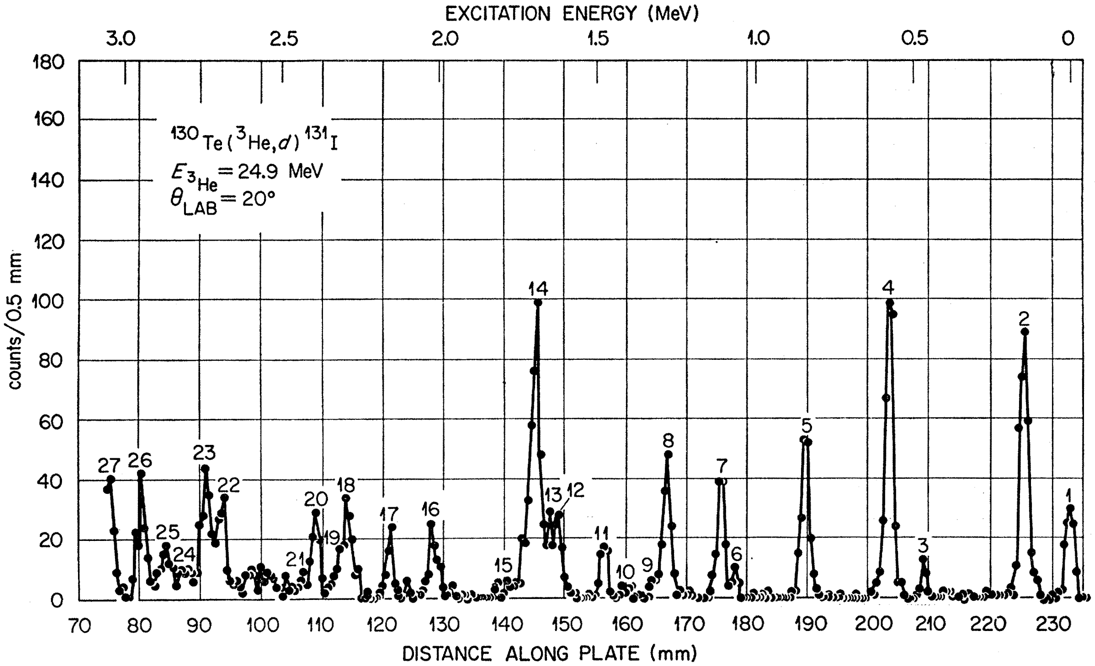

FIG. 8. Deuteron spectrum from the ^{130}Te(^{3}He,d)^{129}I reaction.

angular-correlation and conversion-coefficient studies. The very small spectroscopic factor observed in this work shows that this state is primarily composed of higher seniority proton configurations such as $(g_{7/2})^3{}_{3/2}$. Similar states are observed in ^{129}I and ^{131}I at 0.280 and 0.491 MeV, respectively.

There have also been recent decay-scheme studies of the iodine isotopes and comparison is made in Figs. 9, 10, and 11. As was observed in ^{125}Sb, there are a number of levels which are observed in only one of the experiments. The angular-momentum assignments for levels populated in both experiments are consistent for all levels except the 1.052- and 1.400-MeV states in ^{129}I.

SUMMARY

The total single-particle strengths and centers of gravity for the nuclei studied here are presented in Table VI. As mentioned previously, the absolute magnitude of the strengths are subject to some error due to uncertainties in optical-model parameters. In choosing j values for the $l=2$ states in order to obtain total strengths and centers of gravity, an attempt was made to keep the total strengths nearly equal for the $d_{3/2}$ and $d_{5/2}$ states. It is believed that this is a reasonable requirement since preliminary results of (d,^{3}He) studies on these tellurium isotopes show that the amount of filling of the $d_{3/2}$ and $d_{5/2}$ levels in their ground states is less than 10%.[19] This requirement could not be met in ^{131}I and may indicate that some of the levels without l assignments contain the missing $d_{3/2}$ strength.

Most of the single-particle strengths for the $3s_{1/2}$, $2d_{3/2}$, and $2d_{5/2}$ levels are very close to the expected value of $\sim$1.0. However, the $1g_{7/2}$ strengths are somewhat lower than the values of $\sim$1.0 expected in ^{125}Sb and $\sim$0.8 expected in the iodine isotopes. This may indicate the presence of additional $l=4$ states at higher excitation, which are not observed due to their small

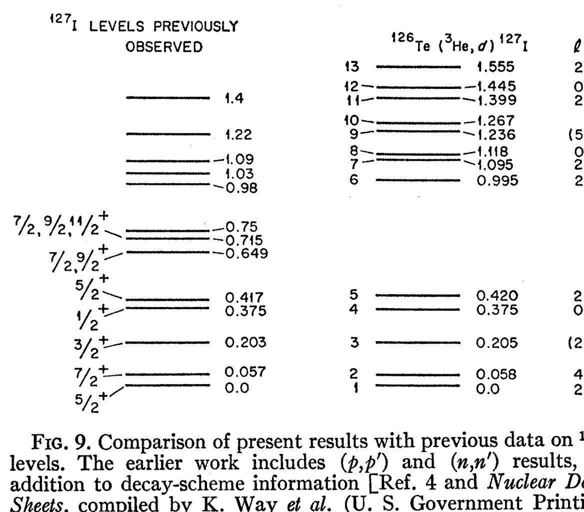

FIG. 9. Comparison of present results with previous data on ^{127}I levels. The earlier work includes (p,p') and (n,n') results, in addition to decay-scheme information [Ref. 4 and *Nuclear Data Sheets*, compiled by K. Way *et al.* (U. S. Government Printing Office, National Academy of Sciences—National Research Council, Washington, D. C.), NRC 61-1-72, 76]. The uncertainties in the excitation energies obtained in the present work are estimated at ±5 keV.

[19] R. L. Auble, J. B. Ball, and C. B. Fulmer (unpublished).

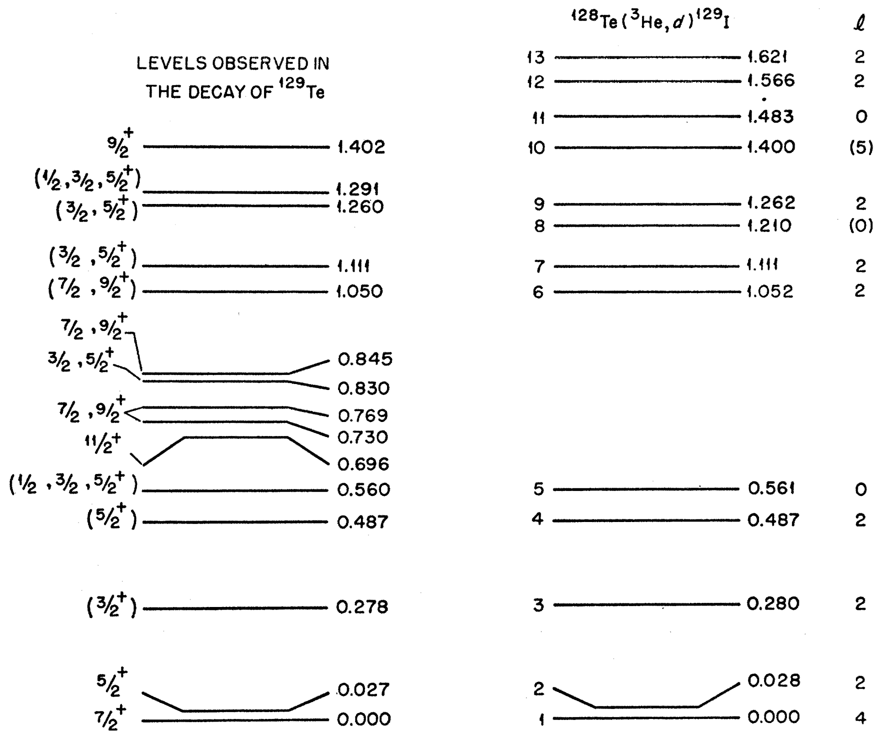

FIG. 10. Comparison of ^{129}Te levels observed in decay-scheme studies (Ref. 5) with those seen in the present work. The uncertainty in the excitation energies is estimated at ±5 keV for states below 1.5 MeV, and ±10 keV for those above 1.5 MeV.

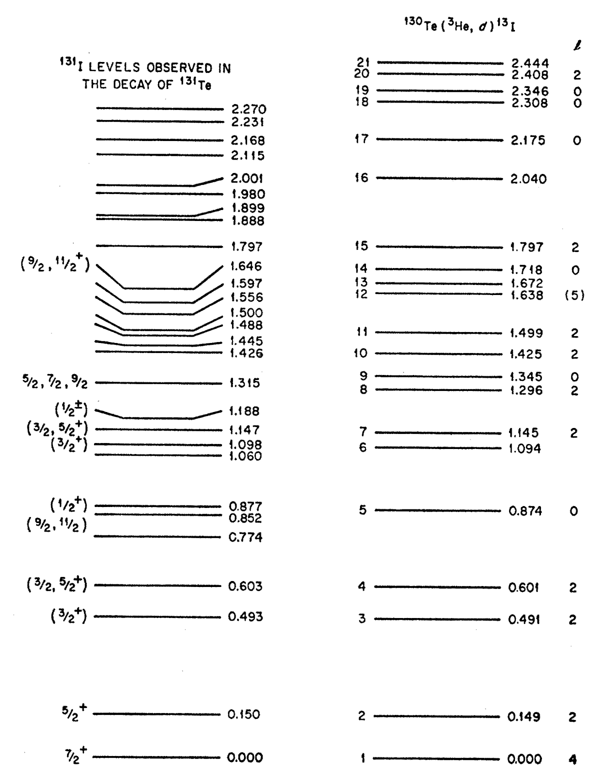

FIG. 11. Comparison of ^{130}Te levels observed in decay-scheme studies (Refs. 6, 7) with those seen in the present work. The uncertainty in the excitation energies is estimated at ±5 keV for states below 1.5 MeV, and ±10 keV for those above 1.5 MeV.

cross sections. The $2d_{5/2}$-$2d_{3/2}$ splitting suggested in this work for the proton states is of the order of 1 MeV. This splitting is about half of the reported splitting for neutrons filling these same states in the zirconium isotopes.[20]

The present results are somewhat discouraging from the standpoint of being able to treat the states in these nuclei with a reasonably simple shell-model interpretation. While the majority of the proton strength apparently goes to filling the $g_{7/2}$ level, even for the very low-lying states it seems apparent that all of the nearby proton levels are actively participating. Thus the $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$, and possibly even the $1h_{11/2}$ proton levels must be considered in constructing the wave functions for these states. In addition, there seems to be evidence that excited neutron states of the tin isotope core also participate in dividing the single-particle proton strength and, therefore, are well mixed into the lowest states. The necessity, then, of including a complete description of the neutron states with the large number of proton levels makes detailed shell-model calculations for these wave functions extremely difficult.

ACKNOWLEDGMENTS

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[20] B. L. Cohen and O. V. Chubinsky, Phys. Rev. **131**, 2184 (1963).