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^{73}Ge(t,p)^{75}Ge at $E_t = 15.0$ MeV

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In the reaction ^{73}Ge(t,p)^{75}Ge, 30 angular distributions have been measured and compared with distorted-wave predictions to extract L values. Ten $L = 0$ transitions have been identified, leading to $J^\pi = \frac{9}{2}^+$ assignments—most of them new.

I. INTRODUCTION

The nucleus ^{75}Ge is well studied. Table I lists excitation energies and J^π values from the most recent data compilation[1] and from a recent gamma-decay study.[2] Below 3.5 MeV excitation, the compilation lists 69 levels, only 25 of which have had their J^π identified. The gamma-ray work lists, in the same energy region, only 46 levels (of which seven are tentative). In a few cases their J^π assignments contradict those in the literature; for a few states their work allows tighter limits to be placed on possible values of J^π. Earlier work is summarized in these two references. We have investigated ^{75}Ge with the ^{73}Ge(t,p) reaction.

II. PROCEDURE AND RESULTS

The experimental procedure was virtually identical to that for the (t,p) reaction on even Ge isotopes, for which results have already been published.[3–6] The ^{73}Ge target thickness was determined by measuring elastic scattering and comparing the elastic yield with that from a natural Ge target of known thickness.[7] The resulting areal density of 235 μg/cm^2 for the ^{73}Ge target is somewhat larger than the 150 μg/cm^2 nominal value, but the measured value has been used in computing absolute cross sections. We note that at the two most forward angles, the present cross sections (in mb/sr) for the strong $L = 0$ state at 200 keV are 3.18 ± 0.51 and 1.09 ± 0.05, to be compared with 2.94 ± 0.18 and 1.02 ± 0.10 using a natural target.[7]

A spectrum is displayed in Fig. 1. Resolution is 30–35 keV (full width at half maximum). We have extracted angular distributions for 30 levels, or combinations of levels.

Excitation energies were determined from measured peak positions at the six most forward angles, and averaged to get the mean. The uncertainty in a given excitation energy is the larger of 3.0 keV and the standard deviation of the six measurements from the mean. These excitation energies are listed in Table I, and the angular distributions are plotted in Figs. 2–7.

Uncertainties in the cross section shown are relative only (5% or the statistical uncertainty), except for selected states with larger uncertainties, e.g., the strong $L = 0$ at 200 keV for which the group of tracks is so dense that scanning is difficult.

III. ANALYSIS AND CONCLUSIONS

Theoretical angular distributions were calculated with the code DWUCK,[8] using potential parameters listed in Table II. Because ^{73}Ge has a ground-state J^π of $\frac{9}{2}^+$, states in ^{75}Ge can be reached by a multiplicity of L values. However, we do expect, for kinematic reasons, that whenever a lower L value is allowed, its contribution will be appreciable.

Calculations for all L values except $L = 0$ were done for pure configurations, as listed in Table III. For $L = 0$, we used a Yoshida type of configuration admixture,[9] assuming $2p\frac{3}{2}$, $1f\frac{5}{2}$, $2p\frac{1}{2}$, and $1g\frac{9}{2}$ orbitals are all active. These amplitudes are also given in Table III.

For each angular distribution, the L value (or combination of L values) was determined by fitting to the shape of the angular distribution. These L values are given in Tables I and IV. Of course, observation of *any* $L = 0$ contribution in an angular distribution leads to a J^π assignment of $\frac{9}{2}^+$ for the final state. Other L values are less useful in assigning J values. For example, presence of $L = 2$ merely implies $J^\pi = \frac{5}{2}^+ - \frac{13}{2}^+$. Of course, such information can be helpful. For example, if a level

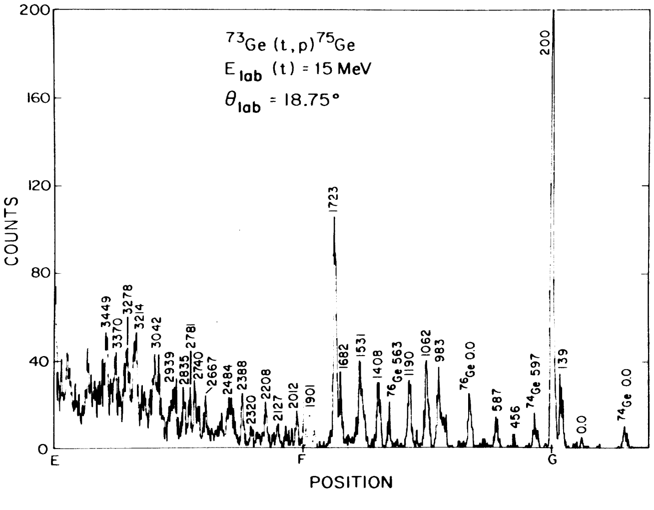

FIG. 1. Spectrum for the reaction ^{73}Ge(t,p)^{75}Ge, at a bombarding energy of 15.0 MeV and a laboratory angle of 18.75°.

TABLE I. Previous and present information for levels of ^{75}Ge.

Previous				Present		
NDS[a]		Ishikawa *et al.*[b]				
E_x (keV)	J^π	E_x (keV)	J^π	E_x (keV)	L	J^π
0.0	$\frac{1}{2}^-$	0.0		0.0	5	
(61.89 9)						
139.68 3	$\frac{7}{2}^+$	139.9		136±4	2+4	
		192.5	$\frac{5}{2}^+$			
200 5	$\frac{9}{2}^+$	200.3		202±4	0	$\frac{9}{2}^+$
252.86 10	$(\frac{1}{2})^-$	253.0	$\frac{3}{2}^-$			
316.72 12	$\frac{5}{2}^-$	316.9	$\frac{5}{2}^-$			
453 5	$\frac{1}{2}^+$					
456.95 12	$\frac{5}{2}^-$	457.0	$\frac{5}{2}^-$			
574.38 11	$\frac{1}{2}^-,\frac{3}{2}^-$	574.8	$\frac{3}{2}^-$			
581 5	$\frac{3}{2}^-$					
584.29 15	$(\frac{3}{2})^+$	584.7	$\frac{5}{2}^+,(\frac{3}{2}^+)$	587±3	2(+6)	$\frac{5}{2}^+-\frac{13}{2}^+$
651 2	$\frac{5}{2}^-,\frac{7}{2}^-$					
675 2	$\frac{1}{2}^+$	673.8	$\frac{1}{2}^-$			
761.10 15		762.4	$\frac{3}{2}^-,(\frac{5}{2}^-)$			
885.19 10	$\frac{1}{2}^-$	885.6	$\frac{1}{2}^-$			
		(901.3)				
		(947.2)				
988 2				983±4	2(+6)	$\frac{5}{2}^+-\frac{13}{2}^+$
		(1063.0)		1062±4	2	$\frac{5}{2}^+-\frac{13}{2}^+$
(1084.7) 21		(1080.6)				
1133 10	$\frac{3}{2}^-$	1128.3				
		1136.9	$\frac{1}{2}^{(-)},\frac{3}{2},\frac{5}{2}^{(-)}$			
				1190±5	0(+2)	$\frac{9}{2}^+$
(1221.8) 3						
1226 10	$\frac{1}{2}^+$					
1240.01 13	$\frac{5}{2}^-$	1240.5	$\frac{1}{2}^{(-)}-\frac{7}{2}^{(-)}$			
1258 2	$(\frac{7}{2}^+,\frac{9}{2}^+)$	1256.9	$\frac{1}{2}-\frac{9}{2}$			
		(1335.2)				
1396 2	$\frac{5}{2}^+$	1394.6				
		(1405.7)		1408±4	0+2	$\frac{9}{2}^+$
1417 5	$\frac{1}{2}^-,\frac{3}{2}^-$	1416.3				
1427.24 15						
		(1494.6)				
1501.28 13	$\frac{1}{2}^-,\frac{3}{2}^-$					
1507 10	$\frac{1}{2}^+$	1514.5	$\frac{1}{2}^-$			
1534 10	$\frac{7}{2}^+,\frac{9}{2}^+$			1531±4	2+4	$\frac{5}{2}^+-\frac{13}{2}^+$
1539 2	$\frac{3}{2}^+,\frac{5}{2}^+$	1538.0	$(\frac{5}{2}^+,\frac{3}{2}^+)$			
1603 2	$\frac{5}{2}^-,\frac{7}{2}^-$					
1699[c] 5				1682±4	0	$\frac{9}{2}^+$
1708 10	$\frac{5}{2}^+$	1718.6	$\frac{5}{2}^+,\frac{3}{2}^+$	1723±5	2	$\frac{5}{2}^+-\frac{13}{2}^+$
1796.40 13	$\frac{1}{2}^-,\frac{3}{2}^-$					
1854 10	$\frac{3}{2}^+$	1869.3	$\frac{3}{2}^+$			
				1901±8	0+2	$\frac{9}{2}^+$
1986 10	$\frac{3}{2}^+$	2004.1	$\frac{3}{2},\frac{5}{2},\frac{7}{2}$	2012±4	4(+2) or (1+3+5)	$\frac{1}{2}^+-\frac{17}{2}^+$
2050 10						
2103.73 20	$(\frac{1}{2}^+)$					
		2110.3	$\geq\frac{3}{2}$			
2136 10				2127±5	2+6	$\frac{5}{2}^+-\frac{13}{2}^+$
2190 10	$\frac{1}{2}^+$	2197.5				

TABLE I. (*Continued*).

Previous				Present		
NDS[a]		Ishikawa *et al.*[b]				
E_x (keV)	J^π	E_x (keV)	J^π	E_x (keV)	L	J^π
		2215.0	$\frac{3}{2}^{(+)},\frac{5}{2}^{(+)},\frac{7}{2}^{(+)}$	2208±7	2	$\frac{5}{2}-\frac{13}{2}^{-}$
2281 3						
2310 10	$\frac{1}{2}^{+}$					
2323 3	$\frac{1}{2}^{-},\frac{3}{2}^{-}$					
2359 4						
2359 10	$\frac{5}{2}^{+}$			2320±6	0+2	$\frac{9}{2}^{+}$
2382 4	$\frac{7}{2}^{+},\frac{9}{2}^{+}$	2382.5	$\frac{5}{2}^{+}$	2388±5	0+2+4	$\frac{9}{2}^{+}$
2462 10				2484±4	2	$\frac{5}{2}^{+}-\frac{13}{2}^{+}$
2510 10	$\frac{3}{2}^{+},\frac{5}{2}^{+}$					
		2526.8	$\frac{3}{2}^{+},(\frac{5}{2}^{+})$			
2534 4	$\frac{5}{2}^{-},\frac{7}{2}^{-}$					
2572 4	$\frac{1}{2}^{-},\frac{3}{2}^{-}$					
2636 10	$\frac{1}{2}^{+}$					
		2660.9	$\frac{1}{2}^{+}$			
2664.07 23		2664.9	$\frac{1}{2}-\frac{7}{2}$	2667±5	3	$\frac{3}{2}^{-}-\frac{15}{2}^{-}$
2681 7	$\frac{1}{2}^{-},\frac{3}{2}^{-}$					
2725 10	$\frac{1}{2}^{+}$					
				2740±6	3	$\frac{3}{2}^{-}-\frac{15}{2}^{-}$
		2759.0	$\frac{1}{2}^{+}$			
				2781±10	0+2(+4)	$\frac{9}{2}^{+}$
2824 10	$\frac{3}{2}^{+},\frac{5}{2}^{+}$					
				2835±8	3	$\frac{3}{2}^{-}-\frac{15}{2}^{-}$
2857 7		2852.5	$\frac{5}{2}^{+}(\frac{3}{2}^{+})$			
2924 10				2939±7	3	$\frac{3}{2}^{-}-\frac{15}{2}^{-}$
2954 4						
3000 15	$\frac{3}{2}^{+},\frac{5}{2}^{+}$					
3016 15	$\frac{3}{2}^{+},\frac{5}{2}^{+}$					
3034 15	$\frac{1}{2}^{+}$	3031.0				
				3042±9	0+(2) or 1+(3)	$(\frac{9}{2}^{+})$
3052 15	$\frac{1}{2}^{+}$	3049.0				
		3065.1				
		3082.1		3092±16	3	$\frac{3}{2}^{-}-\frac{15}{2}^{-}$
3126 15	$\frac{1}{2}^{+}$					
				3136±11	0+(2 or 3)	$\frac{9}{2}^{+}$
3165 5		3162.5	$\frac{1}{2}^{+}$			
3182 7						
3194 7						
				3213±5	2	$\frac{5}{2}^{+}-\frac{13}{2}^{+}$
3247 15						
3272 5		3279.6	$\frac{1}{2}-\frac{5}{2}$			
		3290.3	$\frac{1}{2}-\frac{7}{2}$	3278±7	1+3	$\frac{7}{2}^{-}-\frac{11}{2}^{-}$
3334 15				3370±16	1	$\frac{7}{2}^{-}-\frac{11}{2}^{-}$
3362 15						
3385 5						
3451 5				3449±7	1+3+5	$\frac{7}{2}^{-}-\frac{11}{2}^{-}$

[a] Reference 1.

[b] Reference 2.

[c] This group is only seen in (p,d).

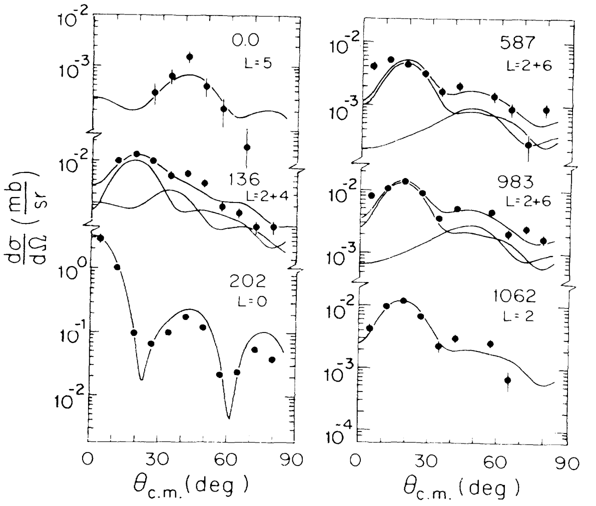

FIG. 2. Angular distributions for the reaction ^{73}Ge(t,p), compared with DWBA curves for the L values indicated.

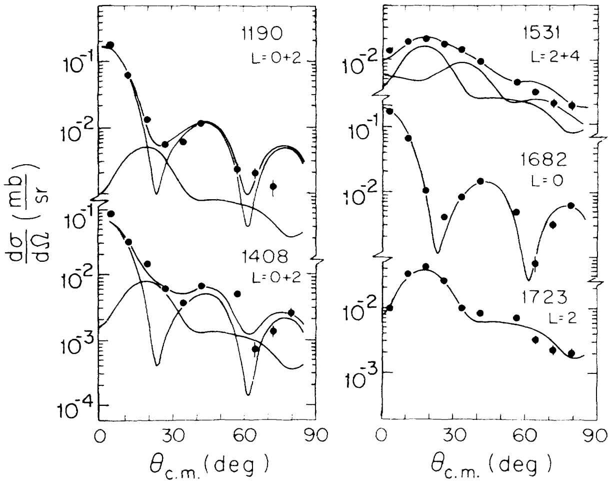

FIG. 3. Same as Fig. 2, but for additional levels.

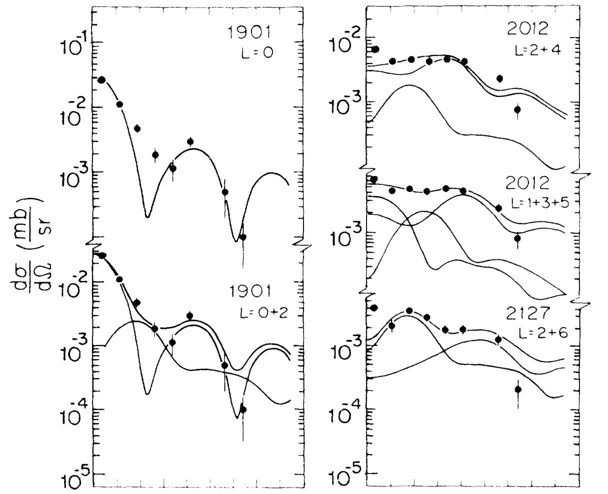

FIG. 4. Same as Fig. 2, but for additional levels.

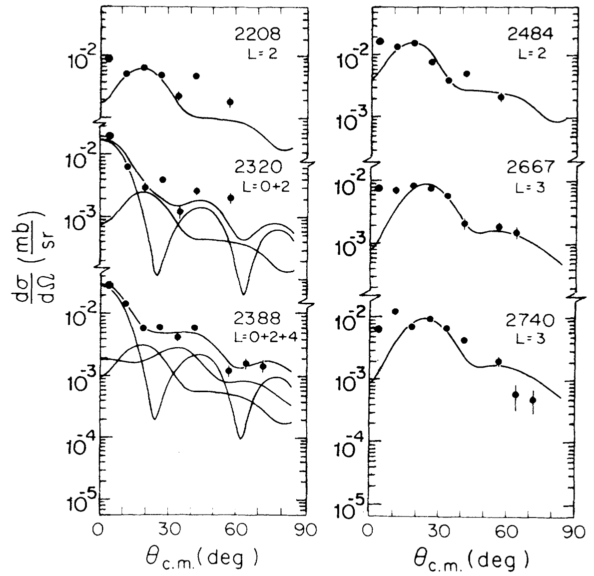

FIG. 5. Same as Fig. 2, but for additional levels.

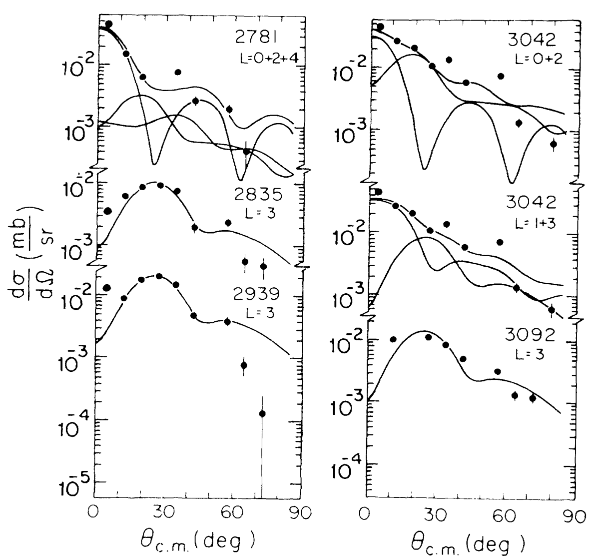

FIG. 6. Same as Fig. 2, but for additional levels.

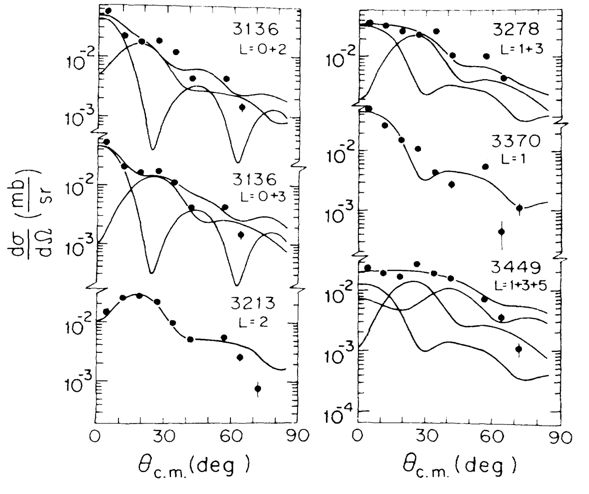

FIG. 7. Same as Fig. 2, but for additional levels.

TABLE II. Optical-model parameters. (Strengths in MeV, lengths in fm.)

	V	r_0	a	W	$W'=4W_D$	r_0'	a'	r_{0c}
^{73}Ge+t	168	1.20	0.65	13.5	0	1.60	0.87	1.3
^{75}Ge+p	50.5	1.25	0.65	0	60.0	1.25	0.47	1.3
^{73}Ge+n	adjusted	1.27	0.67					

of ^{75}Ge is populated with $l=2$ in one-nucleon transfer, it has $J^\pi = \frac{3}{2}^+$ or $\frac{5}{2}^+$. An observation of $L=2$ in (t,p) eliminates the $\frac{3}{2}^+$ possibility.

Once the L-value contributions were determined, enhancement factors ϵ_L could be extracted, using the formula

$$\sigma_{\text{exp}}(\theta) = 230\frac{(2J_f+1)}{(2J_i+1)}\sum_L \frac{\epsilon_L \sigma_L(\theta)}{(2L+1)} ,$$

if the final-state J_f were known. Unfortunately, for many states J_f is not known, so we quote in Table IV the values of

$$\epsilon_L' = (2J_f+1)\epsilon_L / 10(2L+1) .$$

The presence of so many $L=0$'s may be surprising. However, most of them have little strength compared to the very strong $L=0$ at 202 keV. In Table V we contrast the $L=0$'s observed in (t,p) on ^{72,73,74}Ge. For ^{73}Ge we use the cross section that has been identified as the $L=0$ contribution at the most forward angle. The distribution of $L=0$ strength is very similar for targets of ^{72}Ge and ^{73}Ge, except that the 1485-keV strength in ^{74}Ge appears to be fragmented among the three or four levels in ^{75}Ge.

We now discuss our results for some of the individual states and compare with earlier information. Of our nine $L=0$ (and hence $J^\pi = \frac{9}{2}^+$) assignments, one was previously known—the state at 200 keV. The 1190, 1408, 1682, 1901, 2320, 2781, 3042, and 3136 keV states were either (1) previously unknown, (2) known but with no J^π information, or (3) near another level whose J^π information is incompatible with a $\frac{9}{2}^+$ assignment. The state we observe at 2388±5 keV is undoubtedly the level listed in the compilations at 2382±4 keV, with $J^\pi = \frac{7}{2}^+, \frac{9}{2}^+$. We note, however, that Ishikawa gives $J^\pi = \frac{5}{2}^+$ for a state at 2382.5 keV—an assignment incompatible with our result.

We observe (excluding those with an $L=0$ contribution mentioned above) ten angular distributions characteristic of $L=2$. These are at $E_x = 136$, 587, 983, 1062, 1531, 1723, 2127, 2208, 2484, and 3213 keV. Of those, six are relatively pure, implying $J^\pi = \frac{5}{2}^+ - \frac{13}{2}^+$. The presence of higher L values does not further restrict the J^π possibilities for the other states. The 136-keV state is known to have $J^\pi = \frac{7}{2}^+$ (at $E_x = 140$ keV). The 587-keV level may contain contributions from several unresolved levels, but all but one of them has been assigned negative parity. The positive-parity state at 584 keV has $J^\pi = (\frac{3}{2})^+$ in the compilation, but $J^\pi = \frac{5}{2}^+, (\frac{3}{2}^+)$ in Ishikawa *et al.* Our $L=2$ assignment rules out the $\frac{3}{2}^+$ possibility.

The 983-keV state is probably to be identified with a level at 988±2 keV (with no J^π information) in Nuclear Data Sheets (NDS). No mention is made of this state in Ref. 2. The 1062-keV level has no counterpart in NDS, but may be the tentative 1063.0-keV state of Ref. 2. Our 1531-keV state, which is observed to have comparable contributions from $L=2$ and 4, could contain at least four previously known states, three of which have positive parity. The absence of any $L=0$ would appear to eliminate $\frac{9}{2}^+$ for the 1534-keV level, leaving $\frac{7}{2}^+$ as the only possibility.

The 1723-keV angular distribution is pure $L=2$. This state probably corresponds to the $\frac{5}{2}^+$ state at 1708±10 keV (NDS) or 1718.6 keV (Ref. 2). Our 2127-keV level could contain contributions from two or three states—2104, $\frac{1}{2}^+$; 2136±10 (no J^π) in NDS; and 2110.3, $J \geq \frac{3}{2}$ in Ref. 2. Our results require $J^\pi = \frac{5}{2}^+ - \frac{13}{2}^+$ for at least one of the latter, as the $L=2$ component cannot be due to the $\frac{1}{2}^+$ state.

Our 2208-keV state is not the $\frac{1}{2}^+$ level at 2190±10 keV in NDS (because $\frac{1}{2}^+$ cannot be reached via $L=2$), but could be the state at 2215.0 keV in Ref. 2, with $J^\pi = \frac{3}{2}^{(+)}, \frac{5}{2}^{(+)}, \frac{7}{2}^{(+)}$. Our results, combined with the limits of Ref. 2, give $J^\pi = \frac{5}{2}^+$ or $\frac{7}{2}^+$.

Reference 1 lists two states—2462±10 keV (no J^π) and 2510±10 keV, $J^\pi = \frac{3}{2}^+$, $\frac{5}{2}^+$—that could correspond to our 2484 keV level. Reference 2 lists a single state at 2526.8 keV, with $J^\pi = \frac{3}{2}^+, (\frac{5}{2}^+)$. Our $L=2$ angular distribution requires $J^\pi = \frac{5}{2}^+ - \frac{13}{2}^+$. Our 3213-keV level, with $J^\pi = \frac{5}{2}^+ - \frac{13}{2}^+$ is not near enough to any state in NDS or Ref. 2 to make a correspondence.

Other than the states already discussed, the only clear-cut $L=4$ angular distribution that we observe is for a

TABLE III. Configurations used for DWBA calculations.

L	Configuration
0	$\sqrt{(9\times15)/(22\times22)}[\sqrt{2}(2p\frac{3}{2})^2 + 1.0(2p\frac{1}{2})^2 + \sqrt{3}(1f\frac{5}{2})^2 - \sqrt{5}(1g\frac{9}{2})^2]$
2,4,6	$(1g\frac{9}{2})^2$
1	$(1g\frac{7}{2})(1f\frac{5}{2})$
3,5	$(1g\frac{9}{2})(1f\frac{5}{2})$

TABLE IV. Cross sections and enhancement factors for ^{73}Ge(t,p).

E_x (keV)	$d\sigma/d\Omega\,|_{\max}$ (μb/sr)	L	$\epsilon_L'^{\,a}$
0.0	1.4±0.3	5	0.025
136±4	12.3±0.8	2	0.43
		4	0.23
202±4	3186±500	0	0.56
587±3	5.9±0.6	2	0.18
		6	0.06
983±4	15.2±0.9	2	0.49
		6	0.21
1062±4	12.1±0.9	2	0.41
1190±5	162±4	0	0.026
		2	0.17
1408±4	82±4	0	0.011
		2	0.27
1531±4	20.7±1.0	2	0.47
		4	0.54
1682±4	171±8	0	0.026
1723±5	41±2	2	1.21
1901±8	28±1.5	0	0.005
		0	0.004
		2	0.09
2012±4	7.0±0.6	(2)	(0.07)
		4	0.22
		(1)	(0.024)
		(3)	(0.15)
		(5)	(0.10)
2127±5	4.1±0.8	2	0.08
		6	0.10
2208±7	9.3±0.8	2	0.24
2320±6	20.7±1.1	0	0.003
		2	0.064
2388±5	32.5±1.4	0	0.005
		2	0.12
		4	0.15
2484±4	17.6±1.1	2	0.54
2667±5	9.1±0.7	3	0.66
2740±6	13.0±0.9	3	0.63
2781±10	45±3	0	0.006
		2	0.09
		4	0.12
2835±8	10.5±0.7	3	0.73
2939±7	22.7±1.1	3	1.54
3042±9	50±3	0	0.006
		2	0.62
		1	0.22
		3	0.61
3092±16	11.9±0.8	3	0.87
3136±11	52±2	0	0.006
		2	0.50
		0	0.008
		3	0.91
3213±5	28.8±1.2	2	1.06
3278±7	40.2±1.5	1	0.20
		3	1.56
3370±16	54±2	1	0.26
3449±7	28.7±1.3	1	0.08
		3	0.90
		5	0.28

[a] $\sigma_{\text{exp}}=230\dfrac{(2J_f+1)}{(2J_i+1)}\sum_L \dfrac{\epsilon_L\sigma_{\text{DWBA},L}}{(2L+1)}$ and $\epsilon_L'=\dfrac{(2J_f+1)\epsilon_L}{10(2L+1)}$.

TABLE V. Maximum $L = 0$ differntial cross sections (in μb/sr) observed in ^{72,73,74}Ge(t,p).

$72 \rightarrow 74^a$		$73 \rightarrow 75$		$74 \rightarrow 76^a$	
E_x (keV)	$\sigma_{\max}$	E_x (keV)	$\sigma^b_{\max}$	E_x (keV)	$\sigma_{\max}$
0	3790	202	3186	0	4580
		1190	162		
1485	769	1408	82		
		1682	171		
1913	2.8	1901	28	1911	229
2164	16				
2229	79	2320	20		
2610	2.2	2388	33		
2758	20	2781	45	2901	97
		(3042)	(35)		
		3136	38		
3356	75			(3314)	(11)
				(3472)	(114)
Total	4754		3800		4906

[a]Reference 7.

state at 2012 keV. This may be the state listed as 1986±10 keV, with $J^\pi = \frac{3}{2}^+$, in the compilation and/or 2004.1 keV, with $J = \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$ in Ref. 2. The hint of a possible weak $L = 2$ component is not compelling enough to overturn the existing $\frac{3}{2}^+$ assignment, if it is the same state.

We observe no $L = 6$ angular distributions, except as contributions to states already mentioned. The remainder of our data require odd L transfer.

The ground state is extremely weak, but the fit to an $L = 5$ DWBA curve is consistent with the known $\frac{1}{2}^-$ assignment. We observe no other odd L strength below 2.5 MeV. (Even though $L = 1+3+5$ gives a better fit to the 2012-keV data, we prefer $L = 4$ as mentioned above.)

We observe relatively pure $L = 3$ angular distributions for states at 2667, 2740, 2835, 2939, and 3092 keV. In the vicinity of the first of these, the compilation lists two levels, at 2664 keV (no J^π information) and 2681±7 keV, $J^\pi = \frac{1}{2}^-, \frac{3}{2}^-$. In Ref. 2 is listed a state at 2660.9 keV, but with $J^\pi = \frac{1}{2}^+$, another at 2669.9 keV, with $J = \frac{1}{2} - \frac{7}{2}$. Of course, $L = 3$ requires $J^\pi = \frac{3}{2}^- - \frac{15}{2}^-$.

Neither NDS nor Ref. 2 lists a state that could be identified with either our 2740±6 or 2835±8 keV states. Our $L = 3$ level at 2939±7 keV could correspond to one (or both) of the levels at 2924±10 and 2954±4 keV in NDS. No levels are listed near this energy in Ref. 2. The 3902±16 keV state could correspond to the 3082.1-keV level (no J^π information) of Ref. 2.

In addition to the $L = 3$'s discussed above, there is some evidence for $L = 3$ contributions to other angular distributions. The 3042-keV angular distribution is reasonably well fitted with a mixture of $0+2$ or $1+3$. We prefer the former and have already discussed the level above. The 3136-keV angular distribution is dominated by $L = 0$, but appears to contain an $L = 3$ component. No state in the literature is an obvious candidate for this negative-parity level.

States at 3278 and 3449 keV are fitted with a sum of $L = 1+3$ and $1+3+5$, respectively. The 3370-keV level has a relative pure $L = 1$ angular distribution. The presence of $L = 1$ requires $J^\pi = \frac{7}{2}^- - \frac{11}{2}^-$. The 3278-keV state may correspond to the $J = \frac{1}{2} - \frac{7}{2}$ state at 3290.3 keV in Ref. 2. If so, it has $J^\pi = \frac{7}{2}^-$. The other two states have no obvious counterparts.

In summary, we have used the ^{73}Ge(t,p) reaction to populate levels of ^{75}Ge. We have measured angular distributions for 30 levels or groups of levels. Comparison with DWBA curves has allowed extraction of L values and strengths (as defined by the enhancement values, ϵ'_L) for all of them. Ten states were observed to be populated with $L = 0$ and hence have $J^\pi = \frac{9}{2}^+$. Our results allow additional restrictions to be placed on the J^π values for several other levels.

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[1] L. P. Ekström, Nucl. Data Sheets **32**, 211 (1981).
[2] Y. Ishikawa, N. Kato, S. Suematsu, and T. Kuroyanagi, Nucl. Phys. **A403**, 396 (1983).
[3] S. Mordechai, H. T. Forutne, R. Middleton, and G. Stephans, Phys. Rev. C **19**, 1733 (1979).
[4] S. LaFrance, S. Mordechai, H. T. Fortune, and R. Middleton, Nucl. Phys. **A307**, 52 (1978).
[5] S. Mordechai, H. T. Fortune, R. Middleton, and G. Stephans, Phys. Rev. C **18**, 2498 (1978).
[6] J. F. Mateja *et al.*, Phys. Rev. C **17**, 2047 (1978).
[7] S. Mordechai, H. T. Fortune, M. Carchidi, and R. Gilman, Phys. Rev. C **29**, 1699 (1984).
[8] P. D. Kunz, private communication.
[9] S. Yoshida, Nucl. Phys. **33**, 685 (1962).