^{82}Se(t,p)^{84}Se reaction at 17 MeV

S. M. Mullins and D. L. Watson
Physics Department, University of York, York YO1-5DD, United Kingdom

H. T. Fortune
Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104
(Received 27 February 1987)

Forty states of ^{84}Se have been observed in the reaction ^{82}Se(t,p), at a triton energy of 17 MeV. For most of them, J^π values have been determined from the measured angular distributions. Excited states with $J^\pi=0^+$, 2^+, and 4^+ exhaust approximately 100% of the strength expected in a $2d\frac{5}{2}$, $3s\frac{1}{2}$, $2d\frac{3}{2}$ space.

I. INTRODUCTION

The possibility of a shape transition within the Se chain of isotopes has been indicated by the results of polarized proton inelastic scattering.[1] Indeed it would appear that a hexadecapole shape may occur around ^{78}Se, probably arising from neutrons in the $1g_{9/2}$ shell. Similar behavior has been observed in other chains of isotopes in which neutrons occupy the $1g_{9/2}$ orbital, namely $^{72-76}$Ge and $^{78-86}$Kr. Two-neutron transfer studies of $^{72-76}$Ge (Ref. 2) and inelastic proton scattering from $^{78-86}$Kr (Ref. 3) suggest a structure change occurs around neutron number $N=40$. This indicates a shape transition between ^{72}Ge and ^{74}Ge and ^{76}Kr and ^{78}Kr, respectively.

In order to investigate the structure of the even Se nuclei, two-neutron transfer studies have been carried out on $^{76-82}$Se. This paper reports on the reaction ^{82}Se(t,p)^{84}Se and discusses the levels found in ^{84}Se. The results from the other Se nuclei have been published elsewhere.[4-6] The previous (t,p) study of ^{84}Se was able to identify 19 levels up to approximately 5.6 MeV excitation.[7] However, apart from the states assigned 0^+, the angular distributions showed little structure. This fact, together with the lack of data in Ref. 7 for angles forward of 12.5° (lab), meant it was only possible to make tentative J^π assignments. The present experiment allowed measurements to be made as far forward as 3.75° (lab). This facility made it possible to extend the angular distributions to more forward angles. Since it is often the forward-angle data that most clearly signifies the L transfer involved, we can be more confident in assigning J^π values to these levels. All the states of Ref. 7 have been identified in the present work, together with 14 others in the same range of excitation. In addition, a further seven levels have been extracted in extending the excitation to nearly 6.4 MeV. In total, angular distributions have been obtained for 40 levels. These have been compared with the predictions of distorted-wave Born approximation (DWBA) calculations in order to ascertain L transfers (and hence assign J^π values) to all the levels.

II. EXPERIMENTAL PROCEDURE

The experiment was undertaken at the University of Pennsylvania using a 17-MeV triton beam provided by the FN tandem accelerator. The protons were momentum analyzed in a multiangle spectrograph, and were recorded in Ilford L4 nuclear emulsions in the focal plane. All particles except protons were stopped by placing thick mylar absorbers directly in front of the emulsions. The emulsions were scanned with the facilities at Bradford, details of which are published elsewhere.[4]

Angular distributions were measured over the range 3.75° to 86.75° (lab) in 7.5° steps. The target was prepared by evaporating Se enriched to 96.8% in ^{82}Se onto a nominally 25 $\mu g/cm^2$ carbon backing. A surface barrier detector was mounted at 40° to the beam in order to monitor the scattering from the target. The measurements taken from this detector allowed us to estimate the target thickness by normalizing the elastic scattering yield to the cross section predicted by the optical model. The target thickness was calculated to be 41.6 $\mu g/cm^2$. This figure was used to determine the absolute cross section, estimated to be accurate to within 10%.

III. RESULTS AND ANALYSIS

In Fig. 1 is shown a typical proton spectrum. This example was measured at a laboratory angle of 18.75°. The energy resolution is approximately 20 keV full-width at half maximum (FWHM). Peaks due to ^{12}C, ^{13}C, and ^{16}O contaminants are shown shaded—these can be differentiated from levels in ^{84}Se by their different kinematics.

Up to approximately 6.4 MeV excitation, forty groups corresponding to levels in ^{84}Se have been identified. All of these were seen at enough angles and were sufficiently strong to allow angular distributions to be obtained. These are shown in Figs. 2–6 together with the results of DWBA calculations. Data points are missing from some of the angular distributions, either because an im-

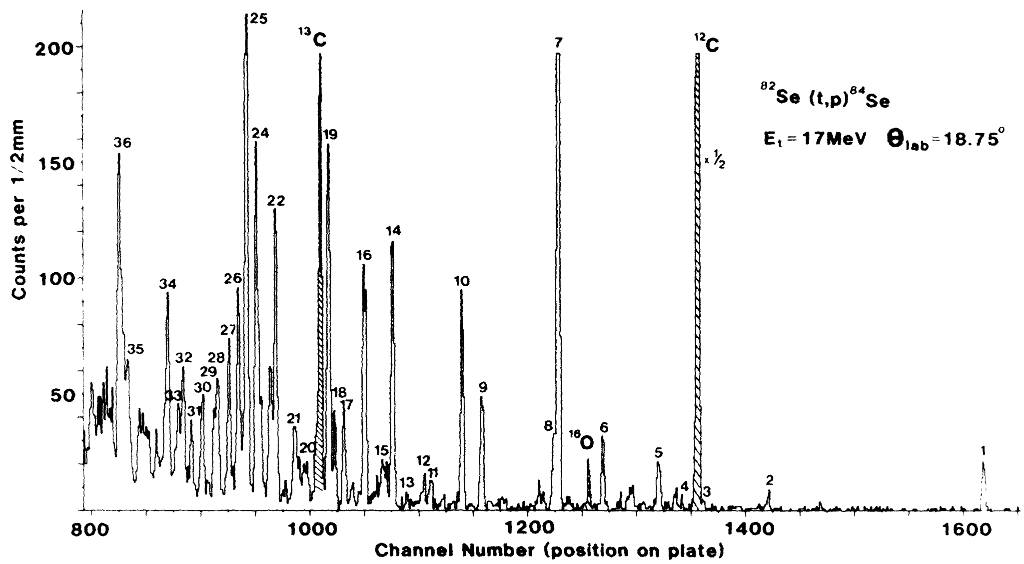

FIG. 1. Spectrum of the reaction ^{82}Se(t,p)^{84}Se, at a bombarding energy of 17.0 MeV and a laboratory angle of 18.75°. Numbered peaks correspond to the levels in Table I.

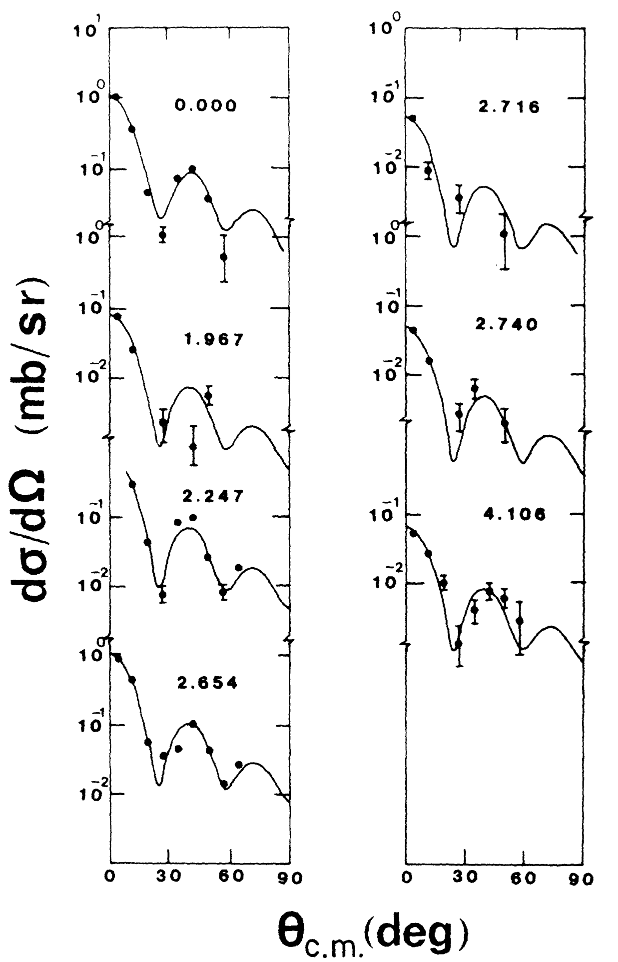

FIG. 2. Angular distributions of 0^+ levels in ^{84}Se, compared with DWBA curves.

purity group was masking the level in question, or the level was too weak to allow reliable extraction of the cross section at that angle.

The excitation energies and maximum cross sections corresponding to levels in ^{84}Se are shown in Table I. The energies given are the means of the values obtained for each angle at which the group was observed. Since the calibration of the spectrograph was known, the measured position of the peak in the focal plane at that particular angle allowed the energy of the level to be determined.

The J^{π} values also listed in Table I are deduced from the comparison of the shape of the data with the DWBA calculations obtained using the code DWUCK4.[8] The optical-model parameters are listed in Table II. The triton parameters came from the work of Knight *et al.*,[7] whilst those for the exit channel (protons) came from the work of Perey.[9] The two-neutron form factors were constructed using microscopic configurations for the transferred neutron pair, following the procedure of Bayman and Kallio.[10] The individual neutron wave functions used in the form factors arose from using a Woods-Saxon potential of fixed geometry, the depth being adjusted such that each neutron was given half the two-neutron binding energy for the final state.

In the absence of any detailed shell-model calculations, pure configurations have been used for the two-neutron transfer amplitudes for all displayed DWBA curves except for the ground state (g.s.). In the simple shell model, ^{84}Se has a closed $N=50$ neutron shell. Hence, the g.s. transition should fill this shell, and all positive-parity excited states should be populated via transfer of two neutrons into the $N=50-82$ shell. For $L=2$, some differences in angular-distribution shape (see Fig. 7) are predicted for different microscopic configurations, but not for other L values.

For odd L values, the configurations used in the calcu-

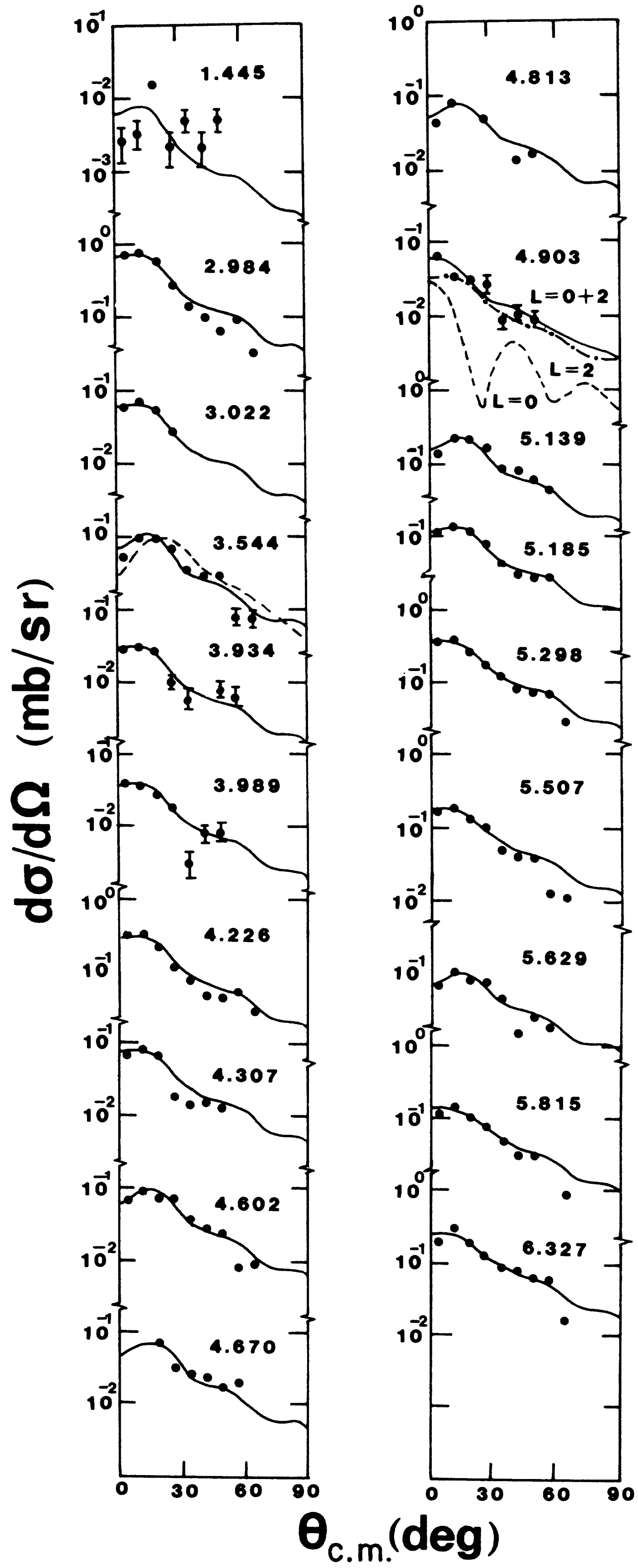

FIG. 3. Same as Fig. 2, but for $L = 2$.

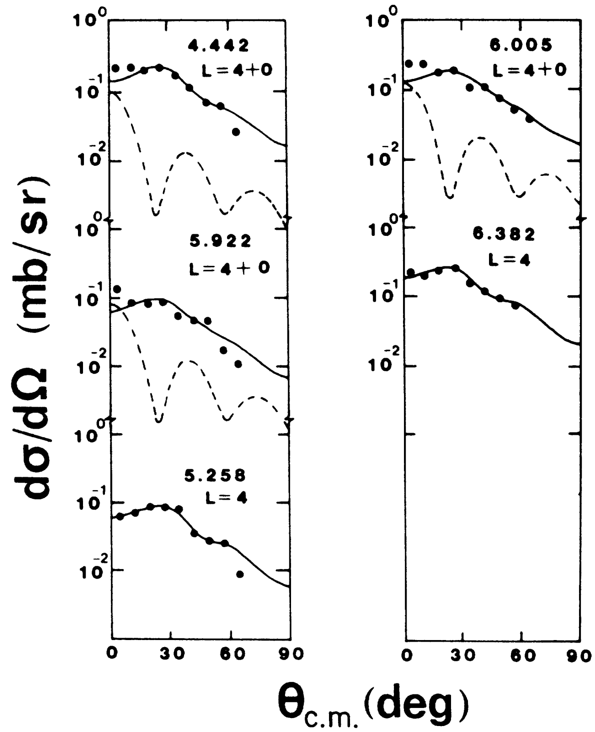

FIG. 4. Same as Fig. 2, but for $L = 4$ and/or $L = 4+(0)$.

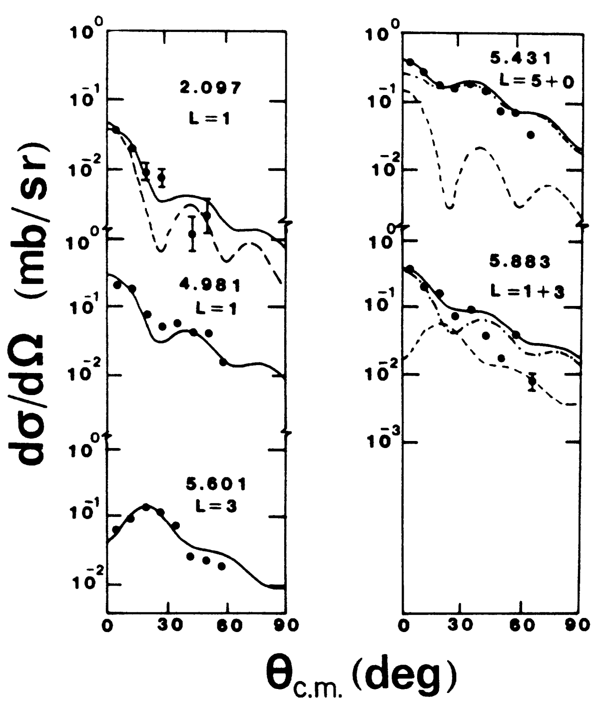

FIG. 5. Same as Fig. 2, but for odd L.

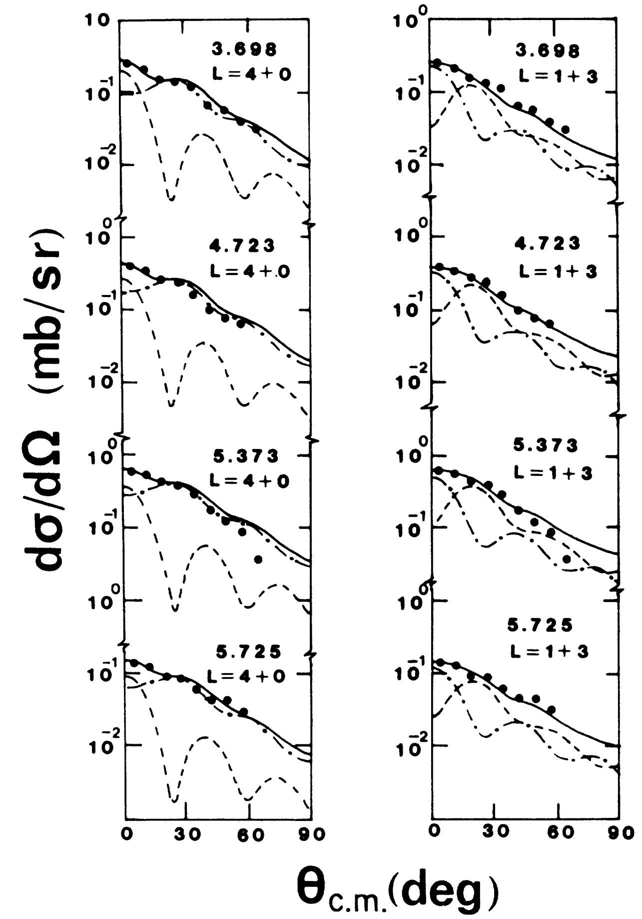

FIG. 6. Angular distributions for four additional states, fitted with mixtures of $L=4+0$ (left) and $L=3+1$ (right).

lations were: for $L=1$ $(2p_{1/2},3s_{1/2})$; for $L=3$ $(2p_{1/2},2d_{5/2})$; for $L=5$ $(2p_{1/2},1g_{9/2})$. The transition amplitudes to the ground state were calculated in the quasiparticle limit[11] assuming the $1g_{9/2}$, $1f_{5/2}$, $2p_{3/2}$, and $2p_{1/2}$ orbitals were available. Full details are given in Ref. 6. Configurations for other even L values are discussed later. Some levels appeared to be unresolved doublets, and are fitted by incoherent mixtures of two L values. These will be discussed further below. The magnitudes of the theoretical and experimental cross sections have been compared in order to obtain enhancement factors, ϵ defined by

$$\sigma_{\exp}(\theta)=230\epsilon\sigma_L(\theta)_{\mathrm{DWBA}} .$$

The factor 230 is discussed in previous papers.[4] The enhancement factors give a measure of the relative transition strength which is independent of Q-value effects.

Table I summarizes the mean excitation energy, the maximum differential cross section, the deduced L transfer, the J^π assignment, and the enhancement factor for each level extracted.

Also shown in Table I are excitation energies and J^π assignments for the previously known levels of ^{84}Se. There is a one-to-one correspondence between all the levels reported in the previous (t,p) work and those found by the present investigation. In addition, there are 21 new levels which have not been reported previously.

IV. DISCUSSION

A. $L=0$

With ^{84}Se having a closed neutron shell ($N=50$), at low excitation one would expect its level structure to be dominated by proton configurations. In this regime, the (t,p) process should thus exhibit small cross sections for all positive-parity states [excluding the ground state, which is reached by filling the two neutron holes that exist in ^{82}Se (g.s.)]. Significant strength should exist at somewhat higher excitation energy, where the neutrons are transferred into the next major shell.

In general, states populated by $L=0$ stripping are the easiest to identify by virtue of their distinctive oscillatory structure. The levels in ^{84}Se assigned $J^\pi=0^+$ on the basis of the fit to the DWBA prediction are shown in Fig. 2. These are the ground state, 1.967, 2.244, 2.654, 2.716, 2.740, and 4.106 MeV levels. The ground state has the largest measured cross section, and its shape is well fitted by the DWBA prediction.

The angular distribution for the weak group at 1.967 MeV contains only five data points, ^{12}C masking the level at 18.75° (lab). However, the forward angle data is well reproduced by an $L=0$ DWBA curve suggesting $J^\pi=0^+$. At this position in the focal plane would fall a $J^\pi=0^+$ corresponding to the 3.449-MeV level in ^{82}Se, so this group may well come from a ^{80}Se contaminant in the target. Approximately 6% of ^{80}Se would account for the observed strength of the level, whereas the group corresponding to the ground state of ^{82}Se suggests less than 3% of ^{80}Se contaminant. (The supplier claims ^{80}Se impurity is 1.98%.) Therefore some of the strength is probably due to a $J^\pi=0^+$ state in ^{84}Se at 1.967 MeV.

Both the 2.244- and 2.654-MeV levels have been previously reported as $J^\pi=0^+$, though the latter was only a tentative assignment. The present work clearly confirms that both these levels have $J^\pi=0^+$.

The next two states are at 2.716 and 2.740 MeV, both of which are weak and have not been reported before. Both appear to be $L=0$. As no other Se isotope or other likely target contaminant would give groups at these positions, each appears to be due to a $J^\pi=0^+$ state in ^{84}Se. The final level assigned $J^\pi=0^+$ is at 4.106 MeV, no state having been reported at this energy before. The fit to an $L=0$ DWBA curve is good enough to allow a confident assignment of $J^\pi=0^+$.

There is possible evidence for $L=0$ transfer in some other levels, but another L value is also present in each case. These will be discussed below.

B. $L=2$

The angular distributions which appear to arise from $L=2$ stripping, nine of which are new, are shown in Fig. 3. The 1.445-MeV level is the first-excited state of ^{84}Se and has been previously reported from (t,p) and

TABLE I. Summary of the experimental data for ^{84}Se.

Previous			Present					
E_x (MeV)	J^π	σ_{max} (mb/sr)	Level No.	E_x (MeV)	L	J^π	σ_{max} (mb/sr)	ϵ
0	0^+	0.50	1	0.00 ±0.005	0	0^+	1.074±0.054	1.39
1.451±0.005	(2^+)	0.060	2	1.445±0.015	(2)	(2^+)	0.016±0.003	0.006
			3	1.967±0.003	(0)	(0^+)	0.076±0.007	0.043
			4	2.097±0.011	(1)	(1^-)	0.036±0.005	0.04
2.247±0.005	0^+	0.50	5	2.244±0.007	0	0^+	0.621±0.031	0.353
2.655±0.005	(0^+)	0.50	6	2.654±0.004	0	0^+	0.904±0.045	0.532
				2.716±0.010	(0)	(0^+)	0.053±0.006	0.031
				2.740±0.011	(0)	(0^+)	0.046±0.005	0.027
2.984±0.005	(2^+)	1.5	7	2.984±0.006	2	2^+	0.787±0.038	0.254
			8	3.022±0.005	(2)	(2^+)	0.071±0.006	0.023
3.541±0.010	$(2^+,3^-)$	0.30	9	3.544±0.006	2	2^+	0.094±0.006	0.030
3.693±0.010	(4^+)	0.51	10	3.698±0.006	[a]		0.259±0.013	
			11	3.934±0.008	2	2^+	0.030±0.004	0.009
			12	3.989±0.007	2	2^+	0.040±0.005	0.012
			13	4.106±0.017	0	0^+	0.053±0.006	0.031
4.231±0.010	(2^+)	0.44	14	4.226±0.004	2	2^+	0.332±0.017	0.100
			15	4.307±0.007	(2)	(2^+)	0.081±0.006	0.024
4.447±0.010	(4^+)	0.71	16	4.442±0.004	4(+ 0)	$4^+ +(0^+)$	0.233±0.012	$0.10(4^+),0.048(0^+)$
4.606±0.010			17	4.602±0.006	2	2^+	0.091±0.007	0.027
			18	4.670±0.009	(2)	(2^+)	0.071±0.006	0.021
4.729±0.010	(4^+)	0.71	19	4.723±0.006	[a]		0.393±0.020	
				4.813±0.005	(2)	(2^+)	0.043±0.005	0.013
			20	4.903±0.007	(2 + 0)	$(2^+ +0^+)$	0.066±0.006	$0.015(0^+),0.010(2^+)$
			21	4.981±0.009	1	1^-	0.208±0.011	0.39
5.145±0.010	(2^+)	0.43	22	5.139±0.006	2	2^+	0.224±0.009	0.064
5.191±0.010	$(2^+,3^-)$	0.25	23	5.185±0.006	2	2^+	0.138±0.008	0.040
				5.258±0.006	4	4^+	0.085±0.007	0.043
5.297±0.010	(2^+)	0.63	24	5.295±0.009	2	2^+	0.382±0.019	0.109
5.377±0.010	(2^+)	0.77	25	5.373±0.009	[a]		0.603±0.030	
5.443±0.010	(1^-)	0.74	26	5.437±0.009	5 + (0)	$5^- +(0^+)$	0.326±0.016	$0.59(5^-),0.071(0^+)$
5.511±0.015	(2^+)	0.25	27	5.507±0.009	2	2^+	0.190±0.010	0.054
5.605±0.015			28	5.601±0.009	3	3^-	0.119±0.006	0.12
5.633±0.015	(2^+)	0.16	29	5.627±0.009	2	2^+	0.109±0.006	0.031
			30	5.725±0.014	[a]		0.139±0.009	
			31	5.815±0.012	2	2^+	0.151±0.008	0.042
			32	5.883±0.012	(3 + 1)	$(3^- +1^-)$	0.337±0.017	$0.37(1^-),0.05(3^-)$
			33	5.922±0.009	4(+ 0)	$4^+ +(0^+)$	0.129±0.009	$0.038(4^+),0.055(0^+)$
			34	6.005±0.012	4(+ 0)	$4^+ +(0^+)$	0.246±0.012	$0.095(4^+),0.094(0^+)$
			35	6.329±0.021	2	2^+	0.295±0.021	0.080
			36	6.382±0.018	4	4^+	0.246±0.012	0.116

[a]See Fig. 6 and text for discussion of L value assignments and enhancement factors for these states.

gamma-ray measurements. It is only very weakly excited, and one therefore suspects that this level is due primarily to proton configurations. As it is the first excited state, it is assumed to have $J^\pi = 2^+$.

The next two $L = 2$ levels are closely spaced, one at 2.984 MeV, the other at 3.022 MeV. Only the 2.984-MeV state had been previously reported, and it had a tentative assignment of $J^\pi = 2^+$; the present data confirm this assignment. The 3.022-MeV group was extractable at only the first four angles, but these data points all fall on the predicted $L = 2$ DWBA curve. Hence this level is tentatively assigned $J^\pi = 2^+$.

The 3.544-MeV level is probably identical to the former 3.541-MeV state. The lack of data in Ref. 7 for angles smaller than 12.5° (lab) and the rather structureless nature of the angular distribution had made it impossible to distinguish between $L = 3$ and $L = 2$ stripping for this state. Here the prediction of the DWBA calculations for both cases are shown for comparison. The solid curve is the $L = 2$ result, the dashed curve $L = 3$. The $L = 3$ curve peaks further out than the data, whilst the $L = 2$ curve gives a good fit. On this evidence it is clear that the $L = 2$ curve is preferred, hence this level is assigned $J^\pi = 2^+$.

The 3.934- and 3.989-MeV states are both new. On the evidence of the fits to the DWBA curves, these states are assigned $J^\pi = 2^+$.

The 4.226-MeV level corresponds to the previous

TABLE II. Optical-model and bound-state parameters used in the analysis of the ^{82}Se(t,p)^{84}Se reaction. Potentials are given in MeV and lengths in fm.

	Tritons[a]	Protons[b]	Bound state
V_0	171.0	46.9	c
r_0	1.16	1.25	1.26
a_0	0.78	0.65	0.60
W	22.5		
W_D		12.95	
r_w	1.52	1.25	
a_w	0.74	0.47	
V_{so}		7.5	$\lambda=25$
r_{so}		1.25	
a_{so}		0.47	
r_c	1.25	1.25	1.25

[a]Reference 7.
[b]Reference 9.
[c]See text.

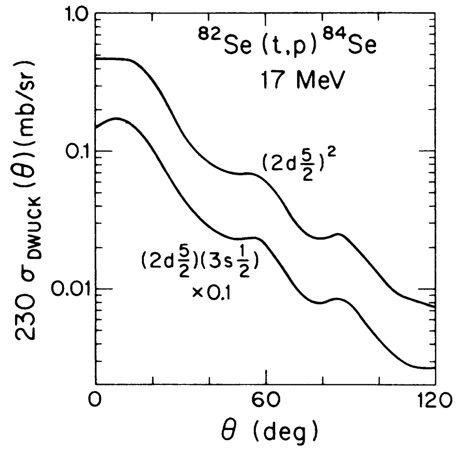

FIG. 7. DWBA curves for $L=2$ calculated with two different pure configurations.

4.231-MeV state to which a tentative $J^\pi=2^+$ assignment has been given. The quality of the fit of the present data to the DWBA prediction allows this assignment to be confirmed.

The 4.307-MeV state was not previously reported, and it is assigned $J=2^+$.

The 4.602-MeV level is identified with the former 4.606-MeV state for which no L value could be determined in Ref. 7. It is clear that $L=2$ transfer characterizes this state, and hence it is assigned $J^\pi=2^+$.

The 4.670-MeV state had not been reported before. There seems little doubt that this state is populated by $L=2$ stripping. Therefore it is assigned $J^\pi=2^+$.

Similarly the 4.813-MeV state is new. It was masked by a peak from ^{12}C at 18.75° (lab). The other missing data points arise from the state being two weakly excited to allow reliable extraction of the cross section. The five data points obtained suggest $L=2$ angular momentum transfer and hence the level is tentatively assigned $J^\pi=2^+$.

The 4.903-MeV state is also a new assignment which appears to be predominantly due to $L=2$ stripping. The dot-dashed curve shows the DWBA prediction for pure $L=2$ transfer. For comparison the solid line shows the result of an $L=0+2$ mixture. (The dashed curve is pure $L=0$.) The sum fits the data far better, especially at forward angles. Therefore this group is probably due to an unresolved doublet, and the components are assigned $J^\pi=2^+ + (0^+)$. The evidence for the $L=0$ member is, however, not compelling.

The 5.139-, 5.185-, 5.295-, 5.507-, and 5.627-MeV states all correspond to levels formerly seen in ^{84}Se. All had been previously given a tentative $J^\pi=2^+$ assignment. The present data confirm the assignments for all these states.

The final two levels assigned $J^\pi=2^+$ are at 5.815 and 6.329 MeV. As both are beyond the highest excitation reached in the previous (t,p) work, these two 2^+ assignments are new.

C. $L=4$

Five levels in ^{84}Se show definitive evidence of $L=4$ angular momentum transfer. These are the states at 4.442, 5.258, 5.922, 6.005, and 6.382 MeV, whose angular distributions are shown in Fig. 4. The 4.442, 5.922, and 6.005 MeV levels all exhibit a small forward-angle rise which might indicate a mixed $L=4+0$ transfer, indicating possibly three unresolved doublets. In each case the solid line is the pure $L=4$ DWBA prediction, whilst the dashed curve shows the result of an $L=0$ calculation. The quality of the fits only mildly suggests the presence of a weak $L=0$ component in these dominantly $L=4$ angular distributions. Or, it may be that we are observing two different types of $L=4$ angular distributions—one with a small forward-angle rise, and one without.

The angular distributions for the 5.258 and 6.382 MeV levels are both well reproduced by the corresponding pure $L=4$ DWBA calculation. Hence they each have $J^\pi=4^+$.

D. Odd L transfer

The five levels which indicate an odd L angular momentum transfer are shown in Fig. 5. These are the 2.097, 4.981, 5.437, 5.601, and 5.883 MeV states in ^{84}Se.

Both levels assigned $J^\pi=1^-$ have not been reported in any previous publication. The 2.097-MeV state is rather weakly excited, but the forward-angle data allow a comparison between the $L=1$ and $L=0$ DWBA predictions. The $L=1$ (solid curve) is the better fit, so this state is tentatively assigned $J^\pi=1^-$. The 4.981-MeV level is more strongly excited and is fairly well fitted by the $L=1$ DWBA curve. On this evidence, this level has $J^\pi=1^-$.

The 5.601-MeV state is identical to the former 5.605-MeV level. It had previously not been possible to ascertain the L transfer to this level, but the present work clearly shows that this state is populated by $L=3$ stripping. Consequently it can be confidently assigned $J^{\pi}=3^-$.

The 5.883-MeV level is shown fitted to an incoherent $L=1+3$ mixture. The data agrees with the theoretical prediction at the first four angles, but falls off more sharply further out. For this reason the assignment $J^{\pi}=3^-+1^-$ to the components is only tentative.

The final level which appears to be characterized by an odd L transfer is at 5.437 MeV. This angular distribution seems to be dominated by $L=5$, but with a hint of a small $L=0$ component. The solid line is the pure $L=5$ DWBA prediction and the dashed line shows the result of adding a small $L=0$ component to it. As for some of the $L=4$ states, this $L=0$ component is not compelling.

E. Other levels

The four remaining levels which have yet to be discussed are at 3.698, 4.723, 5.373, and 5.725 MeV. These four states exhibit almost identical angular distributions, strongly suggesting that they are characterized by the same L transfer. The shapes are, however, not typical of any single L value, which leads one to surmise that a mixed L transfer may be responsible. This would mean that all four states are unresolved doublets with almost exactly the same admixture of L values. This possibility is unlikely, though this line of analysis was tried.

Initially an $L=4+0$ transfer was considered because a pure $L=4$ DWBA curve fitted the data fairly well beyond about 30° (c.m.). However, in each case the forward-angle data are much stronger than the $L=4$ curve, so an $L=0$ component was introduced. As can be seen from the left-hand column of Fig. 6, the fits obtained are satisfactory, but not perfect.

An $L=3+1$ mixture was tried, and was also found to fit these angular distributions reasonably well. The right-hand column of Fig. 6 shows these fits. But as remarked earlier it seems unlikely that each proposed doublet would have the same ratio of the two components (see Table III). The strength of these states suggests that they cannot be of unnatural parity. We must conclude that we are unable to assign L values to these four states. Table III lists the enhancement factors for the curves in Fig. 6.

V. ENHANCEMENT FACTORS AND SUM-RULE STRENGTH FOR POSITIVE-PARITY STATES

The maximum cross sections for states reached via $L=0$, 2, and 4 transfer are plotted vs E_x in Fig. 8. As mentioned earlier, it is likely that the ground state is reached primarily by filling the remaining two holes in the $N=50$ shell, and all the other 0^+, 2^+, 4^+ states by transfer into the $N=50-82$ shell.

For these three L values, the enhancement factors listed in Table I were obtained by dividing the measured cross sections by the summed theoretical cross sections for populating the lower part of this shell. Ignoring Q-value effects, for $2n$ transfer from a "vacuum" into a $2n$ space containing orbitals $(nlj)_i$, the total cross section is independent of mixing among the final states. For example, the total $L=0$ strength is that calculated for transfer of $1.0(nlj)_1^2+1.0(nlj)_2^2+1.0(nlj)_3^2+\dots$. It is this form factor that we have used. Specifically, for $L=0$ we used $(2d_{5/2})^2$ and $(3s_{1/2})^2$; for $L=4$, $(2d_{5/2})^2$ and $(2d_{5/2})(2d_{3/2})$; and for $L=2$, $(2d_{5/2})^2$, $(2d_{5/2})(3s_{1/2})$, and $(2d_{3/2})(3s_{1/2})$. (Of course, we do not ignore Q-value effects. We calculate a theoretical cross section separately for each final state.) These are the configurations that lie lowest in energy. In each case, the next configuration expected is predicted to be weak in (t,p). Hence, these represent a sort of sum-rule strength for $L=0$, 2, and 4 transfer into the lower part of the sdg shell.

Using only definite $L=0$ assignments, the observed enhancement factors add up to 0.96. The addition of

TABLE III. Possible L transfers to the other levels in ^{84}Se.

E_x[a] (MeV)	L	J^{π}	ϵ
	4	(4^+)	0.081
3.698	4+0	(4^++0^+)	0.080(4^+),0.127(0^+)
	1+3	(1^-+3^-)	0.23(1^-),0.13(3^-)
	4	4^+	0.127
4.723	4+0	(4^++0^+)	0.126(4^+),0.189(0^+)
	1+3	(1^-+3^-)	0.35(1^-),0.23(3^-)
	4	(4^+)	0.192
5.373	4+0	(4^++0^+)	0.190(4^+),0.284(0^+)
	1+3	(1^-+3^-)	0.54(1^-),0.37(3^-)
	4	4^+	0.043
5.725	4+0	(4^++0^+)	0.040(4^+),0.069(0^+)
	1+3	(1^-+3^-)	0.13(1^-),0.08(3^-)

[a]These correspond to the angular distributions shown in Fig. 6.

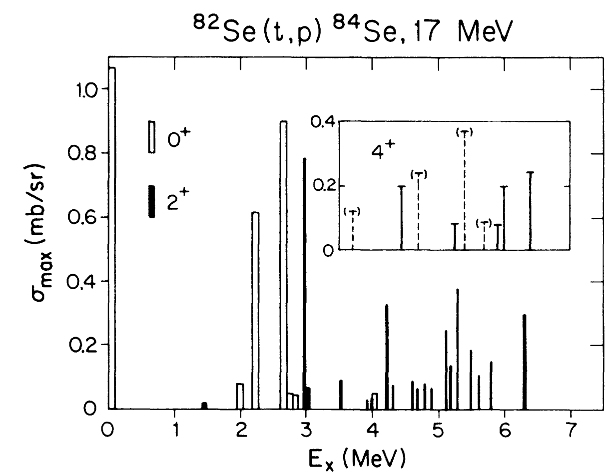

FIG. 8. Plot of σ_{max} vs E_x for $L=0$, 2, and 4.

seven weak and tentative $L=0$ assignments makes the total 1.30. Thus, it appears that we are observing most of the low-lying strength expected for $L=0$.

For $L=2$, the definite 2^+ states provide a sum of enhancement factors of 0.85. Six additional, tentative 2^+ states increase the sum to 0.95. So, again most of the expected strength has been observed.

The situation for $L=4$ is somewhat less clear, because of the ambiguity in about half of the 4^+ assignments. The enhancement factors for the five definite 4^+ states sum to 0.39. If all additional tentative 4^+ levels are added in, the sum is 0.82, so we are observing between 40 and 80 percent of the expected $L=4$ strength. As the $L=4$ strength is dominated by the $(2d\frac{5}{2})(2d\frac{3}{2})$ configuration, whose centroid probably lies above our excitation energy cutoff, we would expect to see less of the $L=4$ sum rule than for $L=0$ and 2.

VI. SUMMARY

We have used the ^{82}Se(t,p) reaction to populate levels in ^{84}Se. Angular distributions have been measured for 40 states or groups of states. Comparisons with DWBA calculations have allowed L values (and hence J^π assignments) and strengths (as defined by the enhancement factors ϵ) to be determined for 36 of the levels. The final states with $J^\pi=0^+$, 2^+, and 4^+ exhaust approximately 100% of the strength expected in $2d\frac{5}{2}$, $3s\frac{1}{2}$, $2d\frac{3}{2}$ space.

ACKNOWLEDGMENTS

We acknowledge financial support from the Science and Engineering Research Council (U.K.) and the U.S. National Science Foundation. We are grateful to Mrs. B. Hargreaves, Mrs. V. Ratcliffe, and Mrs. J. Lees for their careful scanning of the emulsions.

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