Structure of Pb^{206} Determined by the (d,t) Reaction*

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The level structure of Pb^{206} has been studied using the neutron pickup reaction $Pb^{207}(d,t)Pb^{206}$ with a deuteron bombarding energy of 21.6 MeV. Triton angular distributions have been measured in the angular range 10°–80° for 14 levels up to 3.3-MeV excitation in Pb^{206}. The experimental results have been analyzed using a distorted-wave Born-approximation calculation to obtain l values and spectroscopic factors. Configuration assignments, consistent with the experimental data and with the distribution of strength predicted by a sum rule, have been made for all of the observed states. These assignments and the spectroscopic factors are compared with recent shell-model calculations.

I. INTRODUCTION

RECENTLY there has been increasing interest in nuclear spectroscopy in the lead region of the periodic table. The new sector-focused cyclotrons and tandem Van de Graaffs now in operation have sufficient bombarding energy and beam resolution to make precise and definitive charged-particle experiments possible. Detailed studies of nuclei in this region are of interest because of the proximity of these nuclei to Pb^{208} which is doubly magic. Hopefully, these nuclei, which have nearly closed-shell configurations, can be described theoretically in terms of a few interacting holes and particles.

A sizable body of experimental data tabulating the energies, angular momenta, and parities of nuclear levels has already been accumulated. Among the reaction studies, the (d,p) and (d,t) experiments on Pb^{208} which excite the single-neutron particle and hole states in Pb^{209} and Pb^{207}, respectively, have recently been completed.[1] These reactions, studied at several deuteron bombarding energies, serve to check and "calibrate" distorted-wave Born-approximation (DWBA) calculations. As a result, one can now extract spectroscopic factors from (d,p) and (d,t) angular distributions with some confidence. The level structure of Pb^{208} has been investigated with high resolution both via the (d,p) reaction[2] and by proton inelastic scattering.[3] Recent studies of isobaric analog resonances have yielded valuable spectroscopic information concerning states in Pb^{208} and in many of its neighboring nuclei.[4]

In Pb^{206}, the energies of approximately 35 excited states are known from the decay of Bi^{206} and from charged-particle experiments. Vallois, Saudinos, and Beer[5] recently published results of inelastic proton scattering on Pb^{206}. This reaction excites many states and Vallois *et al.* are able to make several angular-momenta assignments. Mukherjee and Cohen[6] have studied Pb^{206} using the (d,t) reaction, but they did not assign l values or obtain spectroscopic factors for the observed transitions.

In the following sections, we report the results of a study of the level structure of Pb^{206} using the neutron pickup reaction $Pb^{207}(d,t)Pb^{206}$. The purpose of this experiment is to augment the existing experimental knowledge of Pb^{206} and to test theoretical wave functions by measuring triton angular distributions, assigning l values, and extracting spectroscopic factors.

II. EXPERIMENTAL PROCEDURE

Targets of enriched Pb^{207} were bombarded by a 21.6-MeV deuteron beam from The University of Michigan 83-in. sector-focused cyclotron. The incident beam, which had a spread in energy on the target of less than 6 keV, was spatially defined by a slit in the scattering chamber and illuminated a 1.5 cm×2 mm spot on the target. Tritons were analyzed in momentum, using one of three available analyzer magnets in the high-resolution magnetic-analysis system.[7] The magnet subtended a solid angle of 1.64×10^{-3} sr and 4° of scattering angle. Each exposure was typically for 120–150 μC. The spectrum spanned about 2.4 MeV in excitation for each magnetic-field setting of the spectrograph. Nuclear track plates at the image surface of the analyzer magnet were used to detect the tritons. After development, the plates were scanned by microscope in $\frac{1}{2}$-mm swaths at 1-mm intervals to count the number of triton tracks.

Several targets of different thicknesses were used during the course of the experiment; the choice depended on the resolution requirements. The targets were prepared by vacuum evaporation of Pb^{207} isotopically enriched to 92.4%[8] onto carbon backings of approximately 20 $\mu g/cm^2$.

Several of the states in Pb^{206} can be resolved using a lead target of natural isotopic abundance. Two targets

* Work supported in part by the U. S. Atomic Energy Commission.
[1] G. Muehllehner, A. S. Poltorak, W. C. Parkinson, and R. H. Bassel, Phys. Rev. **159**, 1039 (1967).
[2] J. Bardwick and R. Tickle, Phys. Rev. **161**, 1217 (1967).
[3] J. Saudinos, G. Vallois, O. Beer, M. Gendrot, and P. Lopato, Phys. Letters **22**, 492 (1966).
[4] C. F. Moore, J. G. Kulleck, P. von Brentano, and F. Rickey (to be published); N. Stein, Bull. Am. Phys. Soc. **12**, 537 (1967); G. H. Lenz, J. P. F. Sellschop, and G. M. Temmer, *ibid.* **12**, 538 (1967).
[5] G. Vallois, J. Saudinos, and O. Beer, Phys. Letters **24B**, 512 (1967).
[6] P. Mukherjee and B. L. Cohen, Phys. Rev. **127**, 1284 (1962).
[7] W. C. Parkinson, R. S. Tickle, P. Bruinsma, J. Bardwick, and J. M. Lambert, Nucl. Instr. Methods **18–19**, 93 (1962).
[8] The enriched Pb^{207} was obtained from Oak Ridge National Laboratory.

of natural lead, after being bombarded, were cut and carefully weighed to determine the number of Pb^{207} nuclei per cm^2, and, because all the other necessary factors were known, the absolute differential cross sections for these states could then be determined directly. Absolute cross sections for the remaining levels of Pb^{206} were computed by comparing the intensities of peaks in spectra taken using enriched targets. As an independent check, the cross sections were computed using the areal densities of the enriched targets determined from a measurement of the energy loss of Am^{241} α particles traversing the targets. The absolute cross sections determined by these two methods agreed within 15%.

The most probable sources of error in the determination of the cross sections were inaccuracies in the track counting, in the target thickness, and in the spectrograph solid angle as a function of position along the image surface. It is estimated, after a careful consideration of each of these sources of error, that the absolute cross sections are correct to within 15%.

Fourteen triton angular distributions corresponding to levels in Pb^{206} up to an excitation of 3.3 MeV were measured in the angular range 10°–80°. A triton spectrum recorded at 20° is shown in Fig. 1. Levels in Pb^{206} were identified by comparing spectra taken both with an enriched target and with a target of natural isotopic abundance.

III. RESULTS AND ANALYSIS

As shown in the 20° spectrum in Fig. 1, the $Pb^{207}(d,t)Pb^{206}$ reaction excites 14 states in Pb^{206} up to an excitation of 3.3 MeV. We find two new levels in Pb^{206} which have not been reported previously. These are the weak levels at 2.14 and 2.42 MeV. We believe the level at 1.51 MeV, reported by Mukherjee and Cohen,[6] to be the 0.897-MeV state in Pb^{207} rather than a state in Pb^{206}. The 0.897 MeV state in Pb^{207} would have appeared as an impurity peak in their spectrum.

Triton peaks corresponding to states in Pb^{207} appeared as impurities in the Pb^{206} spectrum as a consequence of the 5% Pb^{208} in the target. Since the Pb^{207} excitation energies have been accurately determined[9] by precise energy measurements of conversion electrons, it was convenient to determine the excitation energies of states in Pb^{206} using the states in Pb^{207} as calibration points. All of the energies for Pb^{206} were determined in this manner and are in reasonably good agreement with the energies quoted in Ref. 6. We believe that the excitation energies are correct to ± 10 keV.

For the (d,t) pickup reaction, assuming an Irving-Gunn wave function for the triton and a Hulthén wave function for the deuteron, the differential cross section can be written[10] as

$$\frac{d\sigma}{d\Omega}=3.3\sum_l S_{lj}\sigma_{lj}(\theta).$$

The reduced cross sections σ_{lj}, which contain the angular dependence, were obtained from the DWBA computer code JULIE.[11] The parameters used in the DWBA calculation were taken from Ref. 1 and are listed in Table I. The reduced cross sections computed using

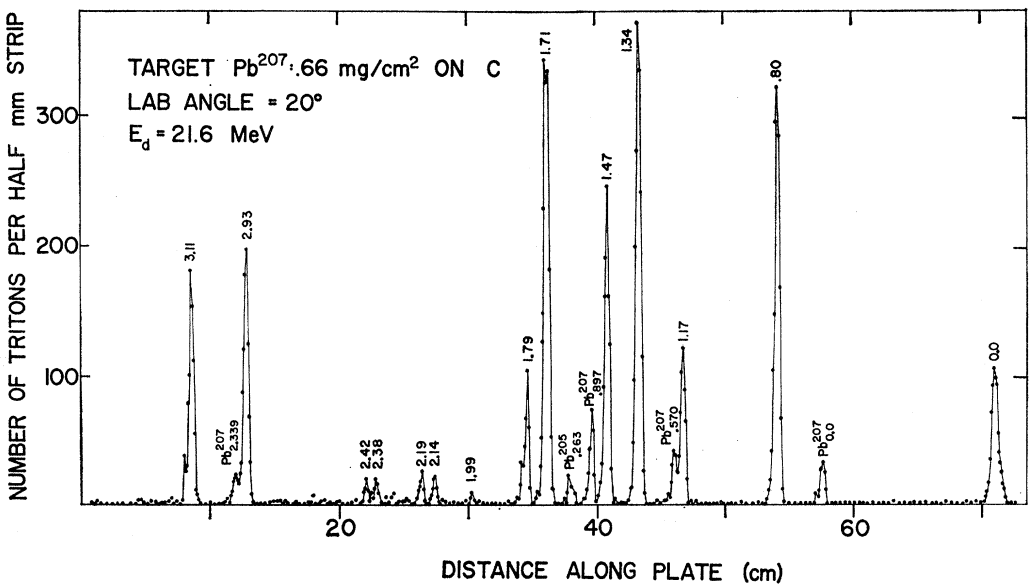

FIG. 1. Triton spectrum at 20° from the $Pb^{207}(d,t)Pb^{206}$ reaction.

[9] F. P. Brady, N. F. Peek, and R. A. Warner, University of California, Davis, Report No. CNL-UCD 23, 1964 (unpublished).
[10] R. H. Bassel, Phys. Rev. 149, 791 (1966).
[11] We are indebted to Dr. G. R. Satchler for performing these calculations.

these parameters have been previously found[1] to reproduce the $Pb^{208}(d,t)Pb^{207}$ angular distributions reasonably well and to result in spectroscopic factors close to the expected values. It is the spectroscopic factors S_{lj} which contain the nuclear-structure information. For a particular transition, the corresponding S_{lj} is a measure of how much the state in Pb^{206} resembles the ground state of Pb^{207} plus a neutron hole. One of the main objectives of the present work is to determine experimentally the spectroscopic factors for each transition and to compare these numbers with the spectroscopic factors computed from theoretical wave functions for the states in Pb^{206}.

Each of the measured triton angular distributions was analyzed to determine, using a least-squares criterion, best fits to the data by the reduced cross sections σ_{lj}. In determining these fits, the possibility that each angular distribution might consist of a mixture of allowable l values was carefully investigated. The angular distributions are shown in Fig. 2. The errors indicated on the measured points are statistical, based only on the number of tracks, and do not reflect any of the uncertainties discussed before, such as variations in track counting. The solid curves are best fits of the reduced cross sections σ_{lj}. Our results from the analysis of the triton angular distributions are presented in Table II.

TABLE I. Parameters used in the DWBA calculations for the $Pb^{207}(d,t)Pb^{206}$ reaction. The form of the optical potential was $U(r)=V_c(r)-V_0(1+e^x)^{-1}-iW_0(1+e^{x'})^{-1}+4iW_d(d/dx')(1+e^{x'})^{-1}$, where $x=(r-r_0A^{1/3})/a$, $x'=(r-r_0'A^{1/3})/a'$, and $V_c(r)$ is the Coulomb potential for a point charge incident on a uniformly charged sphere of radius $R_c=r_cA^{1/3}$. The neutron potential was represented by

$$U_n(r)=-V_0\left[1-\frac{\lambda}{ra}\left(\frac{\hbar}{2m_pc}\right)^2(\sigma\cdot\mathbf{l})\frac{d}{dx}\right](1+e^x)^{-1},$$

where $\lambda=25.0$.

	Deuteron	Neutron	Triton
V_0 (MeV)	100.0		168.0
W_0 (MeV)	0.0		20.0
r_0 (F)	1.14	1.225	1.14
a (F)	0.89	0.70	0.723
r_c (F)	1.3		1.4
r_0' (F)	1.33		1.52
a' (F)	0.75		0.77
W_D (MeV)	13.8		0.0

In the $Pb^{207}(d,t)Pb^{206}$ reaction, the deuteron picks up a neutron from the rather pure $(3p_{1/2})^{-1}Pb^{207}$ ground state. One therefore expects to excite strongly only those states in Pb^{206} with wave functions containing, as a component, a neutron hole coupled to the Pb^{207} ground state, i.e., components such as $(3p_{1/2})^{-1}(2f_{5/2})^{-1}$, $(3p_{1/2})^{-1}(3p_{3/2})^{-1}$, etc.

Since the protons form a closed shell, the low-lying states in Pb^{206} should be describable in terms of two neutron-hole configurations. In zeroth order, these configurations and their ordering in energy are shown in Fig. 3. Proton single-particle single-hole states formed by breaking the closed $Z=82$ shell should begin at excitation energies greater than 4 MeV, and hence they are not included on the diagram. In the lowest approximation, without interactions, only the $(3p_{1/2})^{-1}(nlj)^{-1}$ states would be excited in the pickup reaction. In Fig. 3, these states are emphasized by the bold horizontal lines. In reality, interactions mix states of the same spin and parity. Therefore, the $(3p_{1/2})^{-1}(nlj)^{-1}$ strength is not concentrated in a single nuclear state, but is fragmented and distributed among several states.

TABLE II. Summary of results for levels of Pb^{206} determined from a study of the reaction $Pb^{207}(d,t)Pb^{206}$ at 2.16 MeV. The excitation energies are believed correct to ± 10 keV. The fourth column gives the spin quantum numbers of the neutron picked up to form the state. Tentative assignments are in closed brackets. The spectroscopic factors S_{lj} are listed in the fifth column.

Excitation energy (MeV)	$d\sigma/d\Omega_{max}$ (mb/sr, lab)	θ_{max} (deg, lab)	l, j	S_{lj}
0	1.19	10°	$3p_{1/2}$	0.57
0.8	2.12	20°	$\{0.75\ 2f_{5/2}$	1.69
			$\{0.25\ 3p_{3/2}$	0.56
1.17	1.26	10°	$3p\ (3p_{1/2})$	0.48
1.34	2.63	20°	$2f_{5/2}$	3.92
1.47	5.10	10°	$3p\ (3p_{3/2})$	2.14
1.71	3.52	10°	$3p\ (3p_{3/2})$	1.53
1.79	0.96	10°	$3p\ (3p_{3/2})$	0.34
1.99	0.038	20°	$2f_{7/2}$	0.10
2.14	0.23	10°	$3p\ (3p_{3/2})$	0.08
2.19	0.42	35°	$1i_{13/2}$	9.3
2.38, 2.42	0.31	35°	$\{0.98\ 1i_{13/2}$	4.65
			$\{0.02\ 3p\ (3p_{3/2})$	0.10
2.93	1.37	20°	$2f_{7/2}$	3.86
3.11	1.19	20°	$2f_{7/2}$	3.70

In zeroth order, the $(3p_{1/2})^{-1}(3p_{1/2})^{-1}$ and $(3p_{1/2})^{-1}$-$(3p_{3/2})^{-1}$ configurations are not widely separated in energy. Consequently, we expect to find $p_{1/2}$ and $p_{3/2}$ strength in about the same region of excitation. Therefore it is not possible, solely on the basis of where in the spectrum an $l=1$ transition occurs, to determine whether the transition corresponds to the pickup of a $3p_{1/2}$ neutron or to the pickup of a $3p_{3/2}$ neutron. Thus, except for the ground state and the state at 0.8 MeV, the $l=1$ transitions in Fig. 2 are labeled simply "p." The spin of the ground state is 0^+. This state can therefore be populated only by pickup of a $3p_{1/2}$ neutron and still conserve angular momentum.

Because the spin of the 0.8-MeV state is 2^+ and because the transition to this state includes an $l=3$ admixture, the $l=1$ component must correspond to $3p_{3/2}$ pickup.

Fits of the reduced cross section σ_{lj} to the $l=1$ angular distributions are reasonably good. The experimental points at 10° for the $l=1$ transitions tend to be higher than predicted by the DWBA calculation. This trend is also seen in the 20.1-MeV data of Ref. 1.

The $2f_{5/2}$ and $2f_{7/2}$ hole states in Pb^{207} are well separated in energy, and therefore the $l=3$ $f_{5/2}$ and $f_{7/2}$ transitions should occur in different parts of the spec-

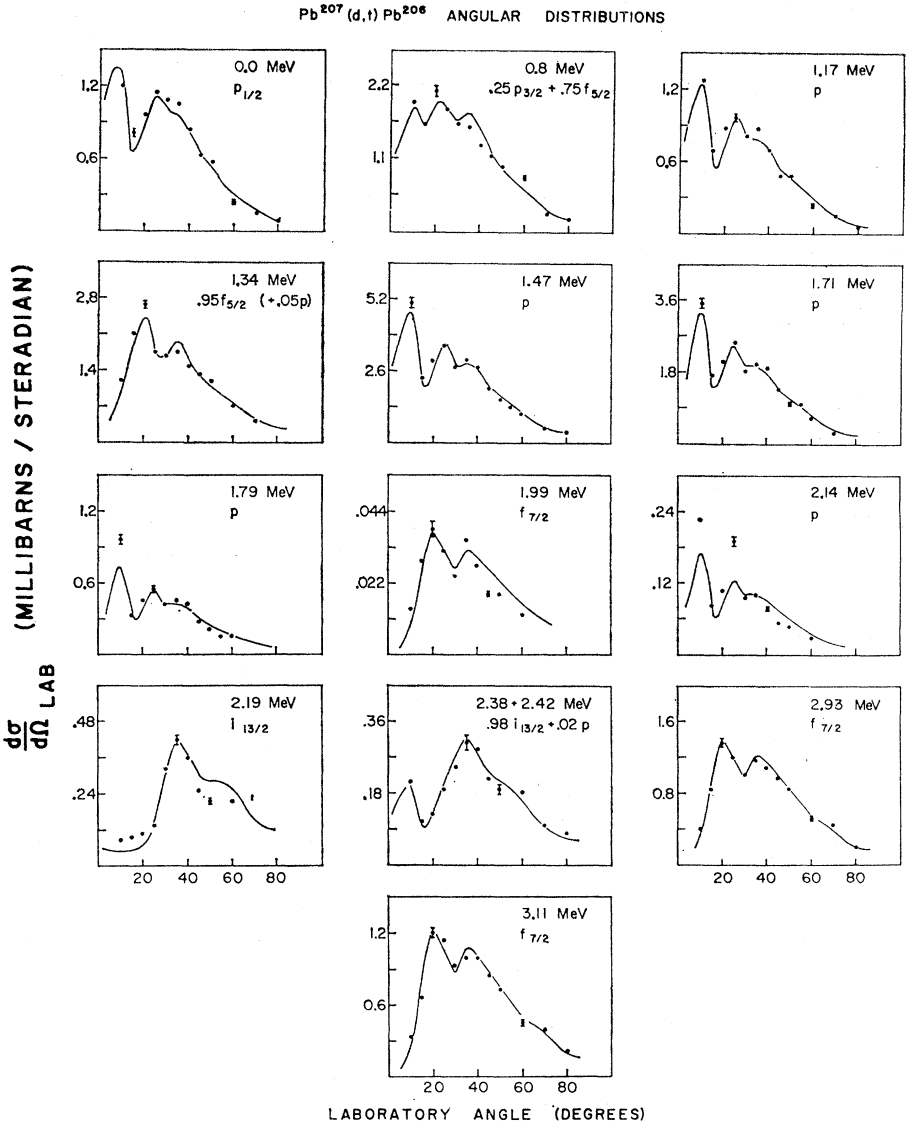

FIG. 2. Angular distributions of the triton groups from $Pb^{207}(d,t)Pb^{206}$ at a deuteron energy of 21.6 MeV. The solid curves are the normalized reduced cross sections σ_{lj} obtained from the DWBA analysis. The 5% $l=1$ admixture in the 1.34-MeV state is due to a Pb^{206} impurity in the target.

TABLE III. Comparison of the experimentally determined total strengths $\sum S$ with predictions of the sum rule. The first column identifies the shell-model orbital of the picked-up neutron. The sums of the spectroscopic factors for each orbital as given by a sum rule are listed in column 2. Column 3 lists the experimentally determined sums of spectroscopic factors for each l value. The last column gives the experimental sums based on the assumed configuration assignments discussed in the text.

Shell-model state	$\sum S$ Sum rule	$\sum S$ expt	$\sum S$[a]
$3p_{1/2}$	1		(1.1)
		5.8	
$3p_{3/2}$	4		(4.7)
$2f_{5/2}$	6		(5.6)
		13.3	
$2f_{7/2}$	8		(7.7)
$1i_{13/2}$	14	13.9	

[a] Based on assumed configuration assignments.

trum. This is observed experimentally with four strong $l=3$ transitions. The $l=1$ admixture in the lowest of these four transitions, to the 0.8 MeV state, rules out $f_{7/2}$ pickup. The best fit to the angular distribution for the 1.34-MeV state included a 5% $l=1$ admixture. Since the spin of this state is believed[12] to be 3^+, we attribute the $l=1$ component to the ground-state doublet of Pb^{205} which has approximately the same Q value. Almost certainly the 1.34-MeV state is also $f_{5/2}$ while the upper two states at 2.93 and 3.11 MeV are probably $f_{7/2}$. Because the weak state at 1.99-MeV is a 4^+ state,[5] it must be formed by $f_{7/2}$ pickup. Sum-rule considerations also support these assignments.

The angular distributions for the two weak states at

[12] A. M. Hellwege and K. H. Hellwege, *Energy Levels of Nuclei A=5 to A=257 in Landolt Bornstein* (Springer-Verlag, Berlin, 1961).

2.38 and 2.42 MeV were not well separated. Consequently, these two states were analyzed together. The DWBA predictions best fit the experimental data with a mixture of $0.98\sigma_{l=6}+0.02\sigma_{l=1}$. The $l=6$ component probably belongs to the 2.38-MeV state. The level at 2.19 MeV is also $l=6$, corresponding to pickup of an $i_{13/2}$ neutron.

It is of interest to compare the total strength $\sum S_{lj}$ for transitions corresponding to pickup of neutrons from each of the shell-model orbitals with the strength predicted theoretically by a sum rule.[13] For the total strength, the sum rule predicts $\sum S_{lj}=N$, where N is the number of neutrons occupying the (l,j) orbital in the target ground state. For example, if we sum the spectroscopic factors for each transition to a level in Pb^{206} corresponding to the pickup of an $f_{5/2}$ neutron, then according to the sum rule the result should be $2j+1=6$ as the $f_{5/2}$ orbital is filled in the Pb^{207} ground state. A comparison of experimental with theoretical total strength is shown in Table III. The total observed strength for each l value agrees well with the sum-rule predictions of $\sum S=5$, 14, and 14 for p, f, and i pickup. A further division of the $l=3$ strength into $f_{5/2}$ or $f_{7/2}$ as previously discussed also results in satisfactory agreement with the sum-rule predictions for these two cases. The discrepancies between observed and theoretical strength are less than 16%, indicating that we have probably located all of the significant strength and that our assignments of l values and configurations are, on the whole, correct.

For the $l=1$ transitions, it is possible to infer with reasonable certainty whether the transitions proceed via $p_{1/2}$ or $p_{3/2}$ neutron pickup. This possibility follows from a consideration of where the transition occurs in the spectrum and what the transition contributes to the total strength. As previously noted, to conserve angular momentum, the $l=1$ transitions to the 0^+ ground state and to the 2^+ 0.8-MeV state correspond to $p_{1/2}$ and $p_{3/2}$ pickup. Transitions to the 1.47- and 1.71-MeV states have $S_{lj}=2.14$ and $S_{lj}=1.53$, respectively. According to the sum rule, the $p_{1/2}$ total strength is unity. The strength for either of these transitions, when added to the $p_{1/2}$ strength of 0.57 for the ground state, would seriously violate the sum-rule limit. Hence, on this basis we assign the 1.47- and 1.71-MeV states as $3p_{3/2}$. For the 1.47-MeV state, this is consistent with its tentative spin assignment[12] of 2^+.

The 1.17-MeV state is sufficiently low in excitation energy to be considered as having been formed by $p_{1/2}$ pickup. This state has tentatively been assigned[12] 0^+, and its strength when added to that of the ground state brings the sum to approximately unity as predicted by the sum rule. It is therefore likely this transition proceeds via $3p_{1/2}$ pickup.

The remaining $l=1$ states at 1.79, 2.14, and 2.42 MeV have strengths $S_{lj}=0.34$, 0.08, and 0.10, respectively. Because these states are at a relatively high excitation energy they are probably $p_{3/2}$. The tentative configuration assignments as discussed above, result in $\sum S=1.1$ for $p_{1/2}$ pickup, and $\sum S=4.7$ for $p_{3/2}$ pickup. This is in reasonable agreement with the theoretical values of 1 and 4.

Table IV compares the experimental centers-of-gravity based on the configuration assignments above, with the corresponding neutron-hole energies in Pb^{207}.

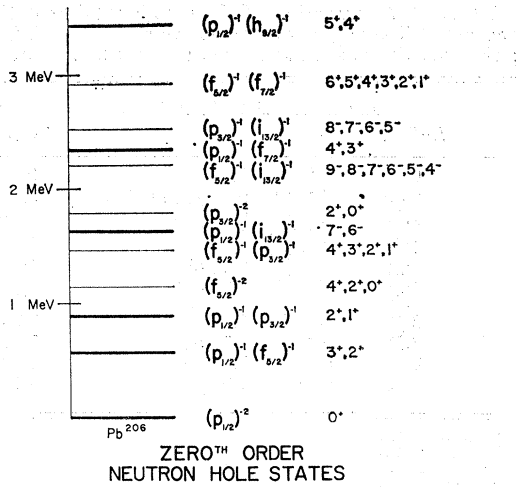

FIG. 3. Zeroth-order neutron hole states in Pb^{206}. The heavy lines denote those states having as a component of their wave function a $3p_{1/2}$ hole coupled to one of the other available neutron holes.

IV. DISCUSSION

The level structure of Pb^{206} has been calculated by True and Ford[14] (TF) and more recently an improved calculation has been made by True.[15] Both of these calculations were based on two neutron-hole configurations and included a weak coupling between the neutron orbitals and excitations of the core. The TF calculation gives for the square of the coefficient of the $(3p_{1/2})^{-2}$ component in the ground-state wave function a value

TABLE IV. Comparison of the experimentally determined center-of-gravity energies for low-lying configurations in Pb^{206} with the energies of the neutron hole states in Pb^{207}.

Configuration	Expt center of gravity (MeV)[a]	Neutron-hole energies[b] (MeV) in Pb^{207}
$(3p_{1/2})^{-2}$	0.0	0.0
$(3p_{1/2})^{-1}(2f_{5/2})^{-1}$	0.64	0.57
$(3p_{1/2})^{-1}(3p_{3/2})^{-1}$	0.99	0.90
$(3p_{1/2})^{-1}(1i_{13/2})^{-1}$	1.72	1.63
$(3p_{1/2})^{-1}(2f_{7/2})^{-1}$	2.47	2.34

[a] For levels based on the same configuration, the center of gravity is defined as $\sum_i E_x^i S_{lj}/\sum S_{lj}$ where E_x^i is the excitation energy. The resulting values have been normalized to zero.
[b] See Ref. 9.

[13] M. H. Macfarlane and J. B. French, Rev. Mod. Phys. 32, 620 (1960).

[14] W. W. True and K. W. Ford, Phys. Rev. 109, 1675 (1958).

[15] W. W. True, Phys. Rev. (to be published). We are grateful to Professor True for furnishing these results prior to publication.

TABLE V. A comparison of the experimental excitation energies and configurations with those calculated by True[a] and by True and Ford.[b] The very weak states have been omitted. Only the $(3p_{1/2})^{-1}(nlj)$ components (represented as lj) which play a role in the pickup reaction and the squares of their coefficients are tabulated.

Experimental configurations			Configurations from True			Configurations from True and Ford		
E_X(MeV)	I^π		E_X(MeV)	I^π		E_X(MeV)	I^π	
0	0^+	$0.57\ p_{1/2}$	0	0^+	$0.68\ p_{1/2}$	0	0^+	$0.73\ p_{1/2}$
0.80	2^+ [c,d]	$0.68\ f_{5/2}+0.22\ p_{3/2}$	0.637	2^+	$0.52\ f_{5/2}+0.27\ p_{3/2}$	0.725	2^+	$0.57\ f_{5/2}+0.30\ p_{3/2}$
1.17	(0^+) [d]	$0.48\ p_{1/2}$	1.314	0^+	$0.25\ p_{1/2}$	1.363	0^+	$0.18\ p_{1/2}$
1.34	3^+ [d,e]	$1.12\ f_{5/2}$	1.433	3^+	$0.99\ f_{5/2}$	1.404	3^+	$1.00\ f_{5/2}$
1.47	(2^+) [d,e]	$0.86\ p_{3/2}$	1.435	2^+	$0.59\ p_{3/2}+0.38\ f_{5/2}$	1.391	2^+	$0.60\ p_{3/2}+0.37\ f_{5/2}$
1.71	(1^+) [d,e]	$1.02\ p_{3/2}$	1.782	1^+	$0.99\ p_{3/2}$	1.745	1^+	$0.99\ p_{3/2}$
1.79		$p_{3/2}$						
2.19	7^- [d]	$1.24\ i_{13/2}$	2.208	7^-	$0.91\ i_{13/2}$	2.166	7^-	$0.91\ i_{13/2}$
2.38	(6^-) [d,e]	$0.72\ i_{13/2}$	2.393	6^-	$0.97\ i_{13/2}$	2.355	6^-	$0.97\ i_{13/2}$
2.93	(4^+) [d]	$0.86\ f_{7/2}$	3.008	4^+	$0.81\ f_{7/2}$	3.010	4^+	$0.90\ f_{7/2}$
3.11	(3^+) [d]	$1.06\ f_{7/2}$	3.105	3^+	$0.98\ f_{7/2}$	3.081	3^+	$1.00\ f_{7/2}$

[a] Reference 15.
[b] Reference 14.
[c] Reference 5.
[d] Reference 13.
[e] *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 61-4-112.

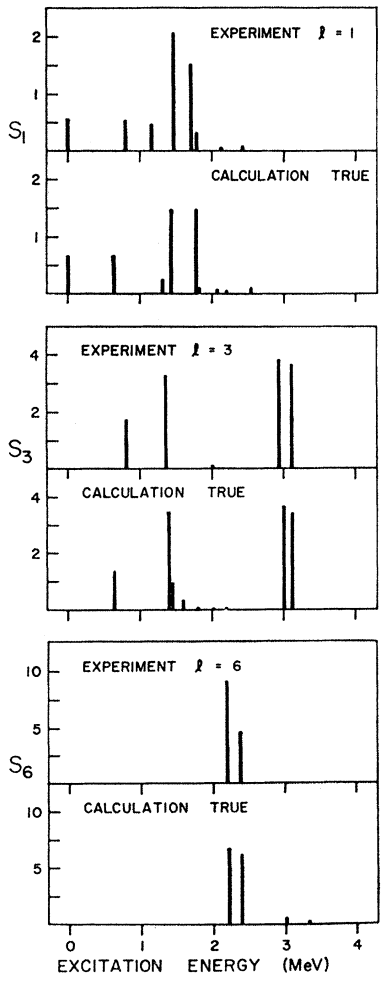

FIG. 4. Comparison of experimentally determined strengths in Pb^{206} with those calculated by True on the basis of two neutron-hole configurations.

of $\alpha^2=0.73$. The experimental results of Mukherjee and Cohen[6] indicated a considerably lower value of $\alpha^2=0.54$, which is close to our value of $\alpha^2=0.57$. Because of this and some other discrepancies, True has improved the TF calculation by including more neutron-hole orbitals, in this case all of the orbitals between the magic numbers 82 and 126. We compare, in Table V, the excitation energies and configurations for the stronger transitions as computed by TF and by True with the same quantities deduced from the experimental data. In our notation $(3p_{1/2})^{-1}(2f_{5/2})^{-1}$ is represented as $f_{5/2}$. The numerical factors are squares of coefficients, i.e., entries are of the form $\alpha^2 p_{3/2}+\beta^2 f_{5/2}$. In the experimental column, the α^2 are computed from the relationship $S_{lj}=\frac{1}{2}(2J_f+1)\alpha^2$, except for $p_{1/2}$ pickup, for which $S_{lj}=\alpha^2$.

This comparison is portrayed graphically in Fig. 4, which displays the spectroscopic factors obtained both from experiment and True's calculations.

The agreement between calculation and experiment for most of the strong levels is close, both in excitation and magnitude. The theoretical value of $\alpha^2=0.68$ for the ground state is still somewhat higher than the experimental value of 0.57. Both calculations predict a 2^+ state at about 1.43 MeV, which is a mixture of $l=1$ and $l=3$ and is not seen experimentally. Because there is not too great a disparity in the spectroscopic factors for this mixture, it is unlikely it would have been missed.

We have presented the results of an experimental investigation of the states in Pb^{206} excited in the reaction $Pb^{207}(d,t)Pb^{206}$. The analysis of the data to obtain l values and spectroscopic factors for the 14 levels observed was aided by the existence of reliable DWBA parameters for this energy range and portion of the periodic table. Tentative configuration assignments, consistent with the experimental data and with the distribution of strength predicted by a sum rule, have been made for all of the states observed.