^{206}Pb states homologous to the 1.484 MeV, $\frac{11}{2}^-$ state of ^{205}Tl

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This paper is an extension of a previous study of the ^{206}Pb nucleus in the framework of the homology concept. It is concerned with the multiplet of states homologous to the 1.484 MeV, $\frac{11}{2}^-$ level of ^{205}Tl, due to $|\frac{9}{2}^- \otimes \frac{11}{2}^-\rangle$ coupling. The results obtained and the new assignments attributed to ^{206}Pb confirm the importance of the homology concept in the spectroscopy of high excitation energy levels.

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In previous papers (hereafter referred as I and II), we carried out spectroscopic studies on the ^{205}Tl [1] and ^{206}Pb [2] nuclei via the $(\vec{p},\alpha)$ reactions on ^{208}Pb and ^{209}Bi, respectively. For positive parity states in ^{205}Tl, corresponding negative parity states in ^{206}Pb had been identified, which clearly display a relationship of homologous states through a strict correspondence of the differential cross sections and asymmetries for the reactions ^{208}Pb$(\vec{p},\alpha)^{205}$Tl and ^{209}Bi$(\vec{p},\alpha)^{206}$Pb.

In this Brief Report, we present information about the multiplet of states in ^{206}Pb homologous to 1.484 MeV, $\frac{11}{2}^-$ excited level of ^{205}Tl. The information is obtained via a new replay and analysis of the measurement described in II.

In Fig. 1 the relevant part of the α-particle spectrum is shown at a laboratory angle of 10°. Between the high excitation energy levels of ^{206}Pb, the states identified as homologous to the 1.484 MeV, $\frac{11}{2}^-$ state of ^{205}Tl are indicated by underlining the excitation energy of the respective levels.

In Figs. 2(a) and 2(b), the experimental $\sigma(\theta)$ and $A_y(\theta)$ distributions for the transitions to the multiplet of states in ^{206}Pb (solid points) are compared with that for the transition to the corresponding parent level in ^{205}Tl (dashed lines). The latter cross sections of each level i are scaled by a factor $(2J_i+1)/\sum_i(2J_i+1)$. In Table I the energies, spins, and parity values for this multiplet of states in ^{206}Pb are listed. The spin values are assigned on the basis of the $(2J_i+1)$ rule. Because of the coupling of the $\frac{9}{2}^-$ proton with the $\frac{11}{2}^-$ hole, the parity values of these levels are positive.

Among these states, the levels at 4.818, 4.925, 5.011, and 5.078 MeV have not previously been seen. We attribute spin and parity values of 10^+, 5^+, 9^+ and 3^+, respectively. The levels at 4.912, 4.941, and 5.112 MeV are close to the 4.914, 4.939, and 5.111 MeV levels, respectively, which are reported in the adopted level scheme [3], with tentative spin and parity assignments of $J^\pi=(3^-)$, (6^+), and (4^+), respectively, attributed on the basis of (p,p') reactions [4]. However, the angular distributions for these states do not contain enough information to give conclusive J^π assignments. So the above levels may coincide with those we observe and to which we attribute $J^\pi=4^+$, 7^+, and 6^+, respectively.

From the analysis of (t,p) angular distributions Flynn *et al.* [5] report a level at (5134±10) keV with possible spin and parity 8^+. From inelastic proton scattering studies, Finck *et al.* [4] find a level at (5138±7) keV, but do not make a spin and parity assignment. The adopted level scheme reports for this level the energy value 5.134 MeV with an uncertain 8^+ assignment. Due to our FWHM line width of ~ 12 keV, the uncertainty on the quoted energy values is ±3 keV, allowing us to conclude that the 5.149 MeV level, to which we attribute $J^\pi=8^+$, might coincide with the adopted one.

The 1^+ and 2^+ members of the expected multiplet of 10 states are still missing. The cross sections of these transitions are expected to be very small and therefore are difficult to observe.

If the differential cross sections for the transitions to the multiplet of the eight homologous states we observe are summed, the cumulative cross section $\sigma_C(\theta)$ is in agreement with the differential cross section for the population of the 1.484 MeV, $\frac{11}{2}^-$ parent state of ^{205}Tl, as shown in Fig. 3. Acceptable agreement is also obtained for the asymmetry $A_y(\theta)$.

In Fig. 4 the quantities $[\sigma(J_i)_{\rm Pb}/\sigma_{\rm Tl}]\sum_i(2J_i+1)$ for each multiplet of ^{206}Pb states homologous to the ^{205}Tl parent states we observe in II and in this Brief Re-

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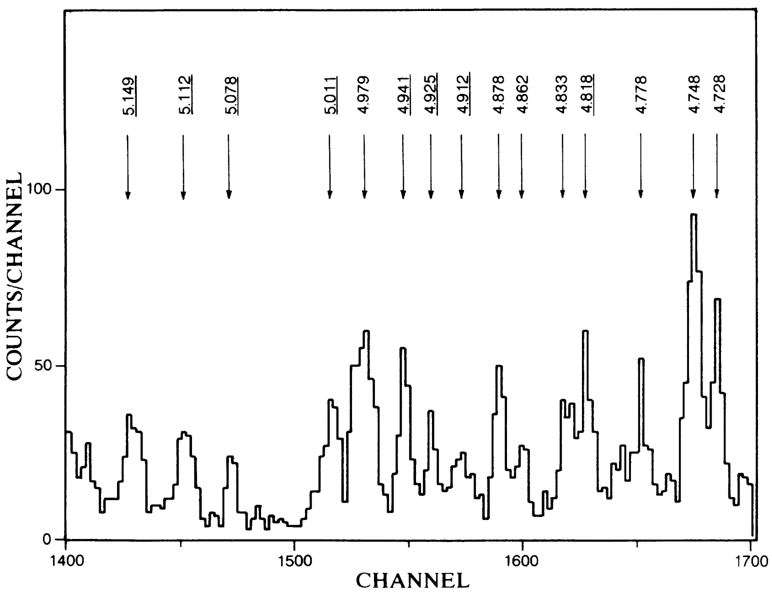

FIG. 1. α particle spectrum from the $^{209}Bi(\vec{p},\alpha)$ ^{206}Pb reaction measured at a laboratory angle of 10°. The excitation energies of the ^{206}Pb levels homologous to the 1.484 MeV, $\frac{11}{2}^-$ level of ^{205}Tl are underlined.

port, are shown as a function of J_i, together with the straight $(2J+1)$ line. A conservative error of 10% is assigned. The satisfactory agreement between the experimental data (solid dots) and the prediction of the weak coupling model (dashed line) also supports the present spin and parity assignment of the ^{206}Pb levels homologous to 1.484 MeV, $\frac{11}{2}^-$ level of ^{205}Tl.

Figure 5 shows an energy level diagram for all proposed multiplets in ^{206}Pb which arise from the coupling of the $h_{9/2}$ proton outside the closed shell with the one-proton-hole–two-neutron-hole states excited in the ^{205}Tl core. This figure clearly shows the spreading of these states over intervals of ± 200 keV, thus providing upper limits for the respective matrix elements.

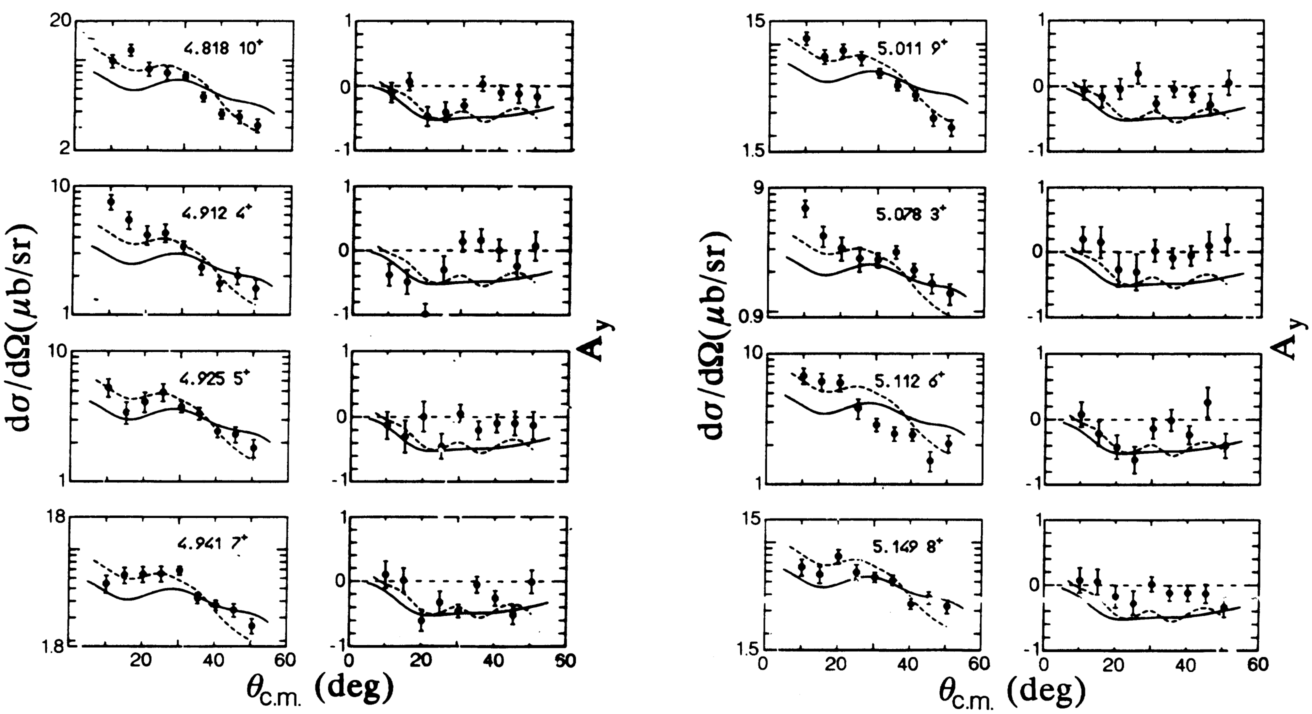

FIG. 2. Experimental cross sections and analyzing powers for the population of the ^{206}Pb levels at 4.818, 4.912, 4.925, 4.941 MeV (solid points), homologous to the 1.484 MeV, $\frac{11}{2}^-$ level of ^{205}Tl, compared with (1) the experimental cross section [scaled according to the $(2J_i+1)$ rule with the J_i value shown] and analyzing power for the population of the 1.484 MeV state (dotted line) and (2) the cross sections and the analyzing powers calculated with DWUCK5 using a double-folded α-particle potential (solid line). (b) Same as (a) but for the levels of ^{206}Pb at 5.011, 5.078, 5.112, 5.149 MeV.

TABLE I. Energy, spin, parity, and integrated cross section for the parent state in ^{205}Tl (columns 1,2,3); energies, spins, parities (columns 4,5), and adopted spin and parity values [3] (column 6) for the corresponding homologous states in ^{206}Pb.

^{205}Tl			^{206}Pb		
E_{exc}	J^{π}	$\sigma_c(\mu b)$	E_{exc}	J^{π}	J^{π}_{ad}
1.484	$\frac{11}{2}^-$	82.355	4.818	10^+	
			4.912	4^+	(3^-)
			4.925	5^+	
			4.941	7^+	(6^+)
			5.011	9^+	
			5.078	3^+	
			5.112	6^+	(4^+)
			5.149	8^+	(8^+)

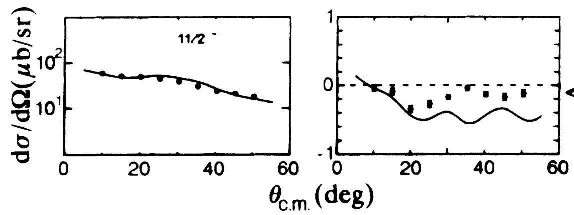

FIG. 3. Cumulative cross sections and analyzing powers for population of the multiplet of states of ^{206}Pb (solid points) homologous to the 1.484 MeV, $\frac{11}{2}^-$ state of ^{205}Tl, compared with the cross section and analyzing power for population of the parent state (solid line). The J^{π} value indicates spin and parity of the parent state.

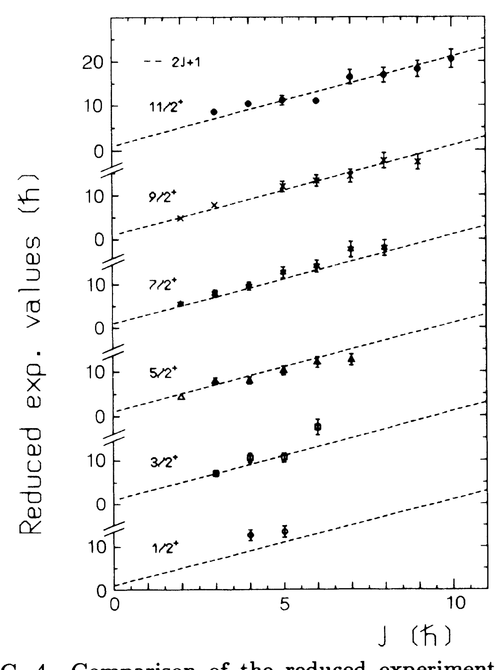

FIG. 4. Comparison of the reduced experimental values $[\sigma(J_i)_{Pb}/\sigma_{Tl}]\sum_i(2J_i+1)$ for the multiplets of ^{206}Pb states (solid points), homologous to the ^{205}Tl parent states, we identified, with the straight line $(2J+1)$ predicted by the weak coupling model (dashed line). The J^{π} value indicates spin and parity of the parent state.

In order to analyze the experimental data, we have calculated both the differential cross sections and asymmetries in the distorted wave Born approximation using the computer code DWUCK5 [6]. A triton pick-up mechanism with $\Delta J = \frac{11}{2}^-$ describes the angular distributions of the transitions to the homologous states rather well. The advantage of the concept of homology is that one has to deal with a unique l transfer, namely that one which is given by the transition to the corresponding parent

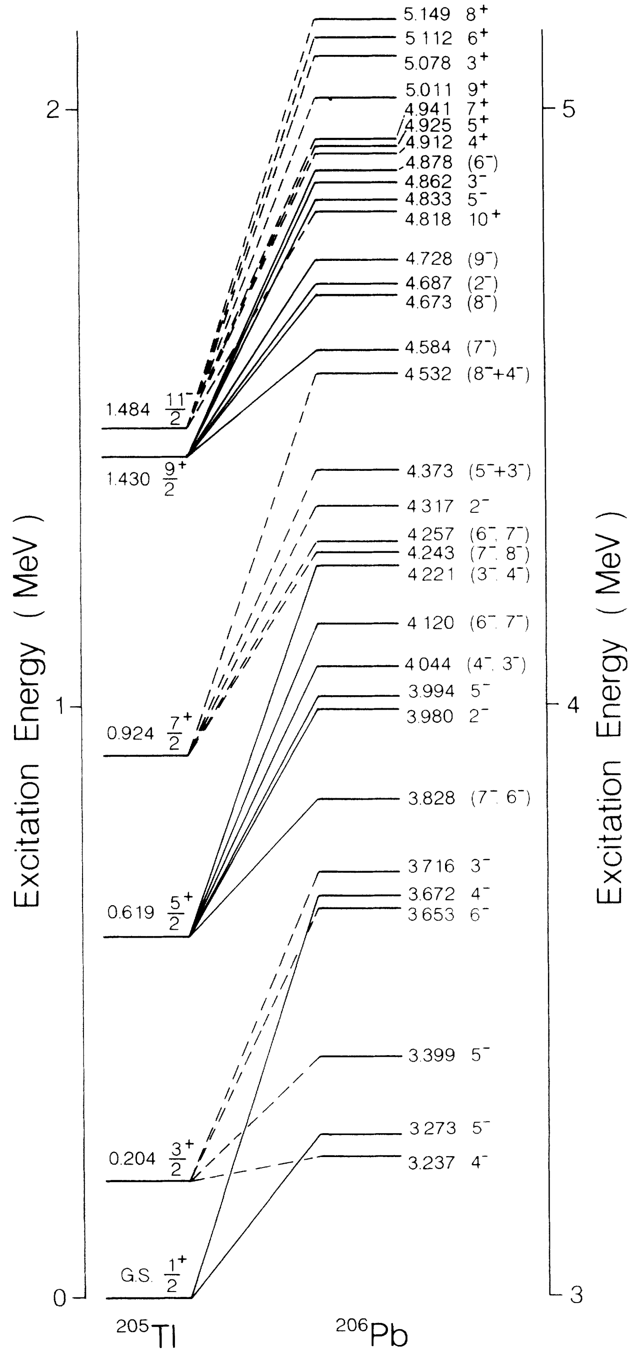

FIG. 5. Proposed scheme of weak-coupling states of the $h_{9/2}$ proton with the one-proton-hole–two-neutron-hole states excited in the ^{205}Tl core.

state. As a consequence of the good results given in II, we used only double-folded optical potentials in the α channel, the details of this method being described in I and in references therein. The potentials in the p channel are of the Woods-Saxon type. The potential parameters are given in Tables III and IV of II. The results of the calculations are shown in Figs. 2(a) and 2(b) (solid lines) and compared with the experimental data (solid points).

The new results presented here further confirm the validity of the concept of homology as a spectroscopic tool to identify spin and parity of highly excited states populated by $(\vec{p},\alpha)$ reactions on odd-mass target nuclei. In fact the homology concept allows us to single out the dominant configuration of a given transition simply by comparison with experimental results for the parent nucleus without applying complex shell-model calculations.

The surprising observation of at least six different multiplets in ^{206}Pb shows the dominance of pure single-particle configurations even in this range of relatively high excitation energy.

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