High-spin level spectra of the nuclei ^{195}Pb, ^{197}Pb, ^{199}Pb, and ^{201}Pb

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The level structures of the light lead nuclei ^{195}Pb, ^{197}Pb, ^{199}Pb, and ^{201}Pb have been studied by in-beam γ-ray spectroscopy in bombardments of isotopically enriched HgO targets with ^{3}He and ^{4}He ions. The measurements included γ-ray singles, comprehensive $(\gamma\gamma t)$ coincidences, half-life determinations, and γ-ray angular distributions. High-spin level spectra above previously known $13/2^+$ isomers are reported for the four nuclei, and are interpreted in terms of the weak coupling of an $i_{13/2}$ neutron hole to established states of the adjacent even-A core nuclei.

[NUCLEAR REACTIONS ^{200,198}Hg$(\alpha,3n)$, $E=35$–45 MeV, ^{198}Hg$(^3$He$,4n)$, $E=38$ MeV, ^{198}Hg$(^3$He, $6n)$, ^{199}Hg$(^3$He$,7n)$, $E=74$ MeV; measured E_γ, $I_\gamma(\theta)$, γ-γ coin, γ-t relationships; ^{195,197,199,201}Pb deduced high-spin levels, J, π, $T_{1/2}$.]

I. INTRODUCTION

A few years ago we investigated the level spectra of the five odd-A Pb nuclei in the mass range $A=195$–203 by $(^4$He$,3n\gamma)$ and $(^3$He$,xn\gamma)$ reactions. The principal results were summarized in a brief report[1] which emphasized the systematic spectral features of the light Pb nuclei, both odd A and even A. A subsequent paper[2] gave a more complete account of the findings for the five neutron hole nucleus ^{203}Pb. In the present paper, the results for the nuclei ^{201}Pb, ^{199}Pb, ^{197}Pb, and ^{195}Pb are presented in detail for the first time.

Recently, Richel *et al.*[3] have reported on the high spin levels of light odd-A Pb nuclei populated in various (heavy ion, $xn\gamma$) reactions. To the extent that the studies overlapped, our results and theirs are generally consistent, but there are a few significant points of disagreement, as will be discussed later. The only other information available about the level structure of light odd-A Pb nuclei comes from radioactivity studies[4,5] and is limited to low-spin excitations.

II. EXPERIMENTAL PROCEDURE

The targets for these studies were prepared from isotopically enriched ^{198}Hg (96.4%), ^{199}Hg (83.5%), and ^{200}Hg (95.7%), and they consisted of ~10 mg/cm^2 of HgO embedded in thin polystyrene films. These targets were bombarded with beams of ^{3}He and ^{4}He ions from the Michigan State University cyclotron. Levels of ^{199}Pb and ^{201}Pb were investigated by the reactions ^{198}Hg$(\alpha,3n)$ and ^{200}Hg$(\alpha,3n)$ and those of ^{197}Pb and ^{195}Pb by the reactions ^{198}Hg$(^3$He$,4n)$ and ^{199}Hg$(^3$He$,7n)$. Since the experimental techniques were similar to those described in earlier papers,[2,6] only a summary of the procedures and some samples of the data obtained are given here.

Singles γ-ray measurements were performed with a large Ge(Li) spectrometer at 125° to the beam direction. In each of the nuclei studied, a low-lying $\frac{13}{2}^+$ isomeric state and its mode of deexcitation was known from earlier work.[5] Isotopic assignments of the strongest γ rays were based on excitation function measurements and on the requirement of approximate intensity balance, at all bombarding energies, between the transitions populating and depopulating the $\frac{13}{2}^+$ isomers. Comprehensive $\gamma\gamma t$ coincidence measurements were performed using two large Ge(Li) detectors; the data accumulation and sorting procedures have been described previously.[6] The coincidence results identified many weaker γ rays in each of the nuclei, and they were, of course, vital in the construction of the level schemes. Angular distributions of the γ rays with respect to the beam direction were measured at five or six angles in the range 90° to 155° and, where possible, values of the A_2 and A_4 coefficients were extracted.

Many isomeric levels were identified and characterized by determining the time distributions of individual γ rays with respect to the beam bursts on target. The shortest half-lives were measured by recording nine delayed spectra spanning the time interval (typically ~50 ns) between the cyclotron beam bursts. Long half-lives were measured in similar fashion by using a beam-sweeping system which extended the interval between beam bursts on target up to 300–600 ns, or by using an external beam pulser,

TABLE I. Transitions in ^{201}Pb from the ^{200}Hg(α, 3n) reaction with 40 MeV incident α particles.

γ-ray energy [a] (keV)	Relative γ-ray intensity [a] (125°)	Angular distributions A_2/A_0	A_4/A_0	Inferred multipolarity	Placement (keV)
166.2(2)	41(4)				2068 → 1902
222.2(1)	320(30)	0.00 ± 0.03	−0.06 ± 0.04	$E2$ [b]	2718 → 2496
297.9(3)	7(1)	−0.99 ± 0.13	0.13 ± 0.05	$M1/E2$	2794 → 2496
350.3(2)	260(25)	0.09 ± 0.02	−0.07 ± 0.04	($E2$)	1896 → 1546
354.3(2)	435(40)	0.19 ± 0.03	0.01 ± 0.04	$M1/E2$	1896 → 1542
360.4(3)	253(25)	0.25 ± 0.03	−0.08 ± 0.04	$E2$	1902 → 1542
594.1(3)	11(2)				2496 → 1902
600.2(1)	463(46)	−0.10 ± 0.03	−0.03 ± 0.04	$E1$	2496 → 1896
628.8(4)	981(88)			$M4$	629 → 0
667.3(3)	21(2)	−0.38 ± 0.06	−0.16 ± 0.09	$M1/E2$	2735 → 2068
708.1(2)	56(5)				
818.5(2)	47(5)				
912.7(2)	1000	0.21 ± 0.03	−0.05 ± 0.04	$E2$	1542 → 629
916.7(2)	352(32)	−0.28 ± 0.03	0.04 ± 0.04	$M1/E2$	1546 → 629

[a] Uncertainties in the least significant figures are indicated in parentheses.
[b] Multipolarity from intensity balance considerations.

suitable for determining half-lives greater than 0.5 μs.

III. EXPERIMENTAL RESULTS

A. The ^{201}Pb level scheme

The known 61-s $\frac{13}{2}^+$ isomer in ^{201}Pb deexcites to the $\frac{5}{2}^-$ ground state by a 629-keV $M4$ transition. The present study showed that two strong parallel cascades of 913-, 354- and 917-, 350-keV γ rays account for the bulk of the observed population of the 629-keV $\frac{13}{2}^+$ state in the ^{200}Hg(α, 3n) reaction at $E_\alpha = 40$ MeV. The properties of these and other ^{201}Pb γ rays identified in the coincidence measurements are summarized in Table I. Representative $\gamma\gamma$ coincidence spectra are shown in Fig. 1 and the ^{201}Pb level scheme constructed on the basis of all the experimental data is presented in Fig. 2.

In the timing measurements between cyclotron beam bursts, the 350-, 354-, 913-, and 917-keV transitions alone showed a 3.2 ± 0.6 ns decay component and this half-life is therefore associated with the 1896-keV level, which has a probable spin-parity of $\frac{19}{2}^+$. The 360 keV $E2$ transition feeding the 1542 keV $\frac{17}{2}^+$ level establishes the $\frac{21}{2}^+$ level at 1902 keV. Strong 600-keV and weak 594-keV transitions populate the $\frac{19}{2}^+$ and $\frac{21}{2}^+$ levels from the 2496 keV parent level; the 600 keV γ-ray angular distribution indicates $\Delta I = 1$ dipole character and the 2496 keV level is assigned $J^\pi = \frac{21}{2}^-$ in keeping with the negative parity level systematics[1] across the Pb nuclei. The strong isotropic 222-keV transition feeds the 2496 keV level from the 55-ns isomer at 2718 keV. From the delayed in-

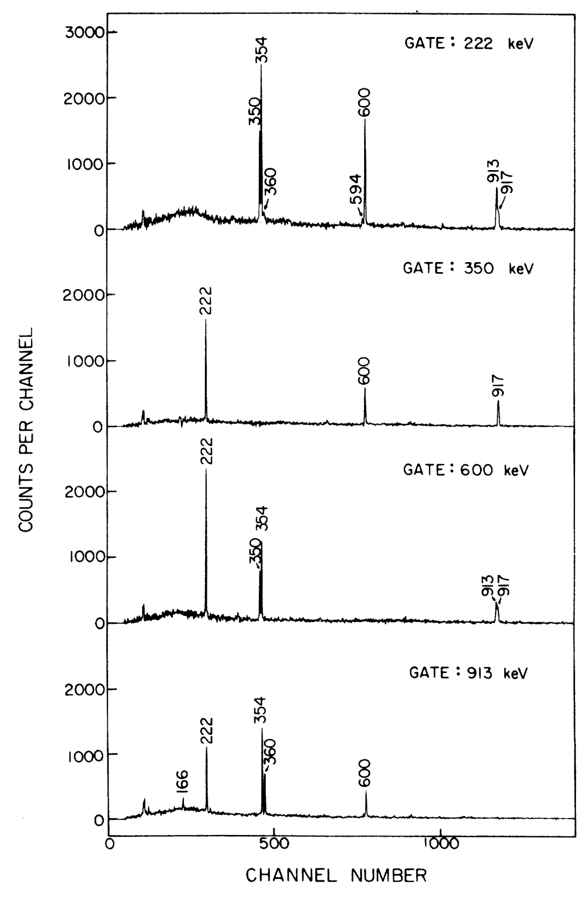

FIG. 1. Key γ-γ coincidence spectra for the ^{201}Pb nucleus.

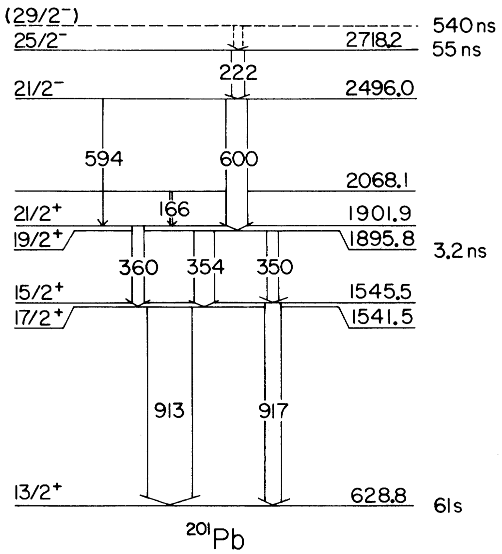

FIG. 2. The level scheme of ^{201}Pb above the $\frac{13}{2}^+$ isomer.

tensity balance, a total conversion coefficient of 0.34 ± 0.03 was obtained for the 222-keV transition, establishing its character as $E2$ and indicating $J^\pi = \frac{25}{2}^-$ for the 55-ns isomeric state. The timing measurements with a μs pulsed beam showed that a higher-lying 540 ± 40 ns isomer deexcites through the 2718-keV level; however, the connecting transition(s) could not be detected and must be lower in energy than 70 keV.

The coincidence results also established the weakly populated levels at 2068, 2735, and 2794 keV, which are not fed in the 55- or 540-ns isomeric decays.

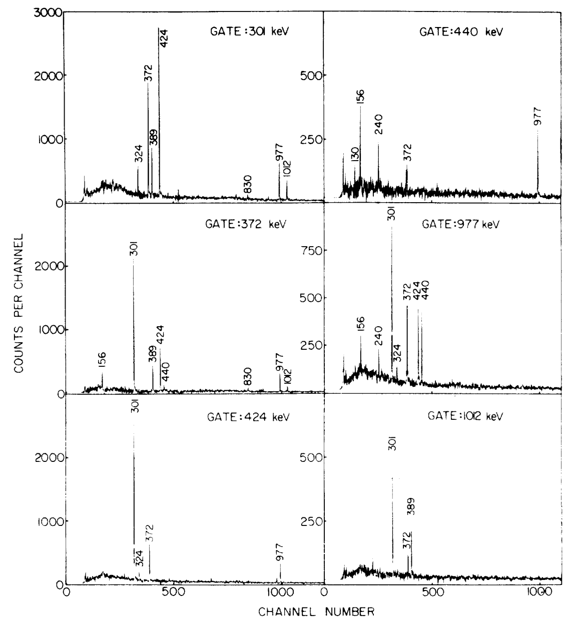

FIG. 3. Key γ-γ coincidence spectra for the ^{199}Pb nucleus.

B. The ^{199}Pb level scheme

The 12.2-min $\frac{13}{2}^+$ isomer at 425 keV in ^{199}Pb was known from earlier work.[5] In the ^{198}Hg(α, 3$n\gamma$) excitation function measurements, strong γ rays of 977 and 1012 keV were identified as transitions populating the $\frac{13}{2}^+$ isomer from $\frac{17}{2}^+$ and $\frac{15}{2}^+$ levels at 1402 and 1437 keV, respectively. The $\gamma\gamma$ coincidence measurements (e.g., Fig. 3) identified many other transitions in ^{199}Pb; their properties are summarized in Table II.

TABLE II. Transitions in ^{199}Pb from the ^{198}Hg(α, 3n) reaction with 40 MeV incident α particles.

γ-ray energy[a] (keV)	Relative γ-ray intensity[a] In beam (125°)	Delayed	Angular distributions A_2/A_0	A_4/A_0	Inferred multipolarity	Placement (keV)
129.6(3)	18(3)	19(3)	−0.10 ± 0.04	−0.10 ± 0.06	$M1$[b]	1972 → 1842
155.6(2)	64(7)	99(10)	−0.11 ± 0.04	−0.03 ± 0.06	$E1$[b]	2127 → 1972
240.2(3)	38(5)					2082 → 1842
301.4(1)	625(40)	1183(76)	−0.10 ± 0.02	−0.09 ± 0.04	$E1$	2127 → 1826
324.2(2)	77(7)	66(6)	0.40 ± 0.03			2451 → 2127
372.4(1)	463(37)	1166(93)	0.06 ± 0.02		($E2$)	2500 → 2127
388.5(2)	162(14)	283(25)	0.11 ± 0.02		($E2$)	1826 → 1437
423.5(3)	382(50)	698(80)	−0.40 ± 0.03	−0.11 ± 0.05	$M1/E2$	1826 → 1402
424.9(3)	303(40)				$M4$	425 → 0
439.6(2)	250(18)	130(10)	0.18 ± 0.03	−0.06 ± 0.04	$E2$	1842 → 1402
569.3(3)	20(4)	14(3)	0.03 ± 0.11			1972 → 1402
830.0(2)	92(9)		−0.11 ± 0.04	−0.07 ± 0.06		3330 → 2500
903.4(2)	96(10)		0.29 ± 0.04	−0.16 ± 0.06	$E2$	2745 → 1842
977.4(1)	1000	1000	0.15 ± 0.03	−0.11 ± 0.04	$E2$	1402 → 425
1012.4(3)	264(25)	341(32)	−0.25 ± 0.02	−0.00 ± 0.04	$M1/E2$	1437 → 425

[a] Uncertainties in the least significant figures are indicated in parentheses.
[b] Multipolarity from intensity balance considerations.

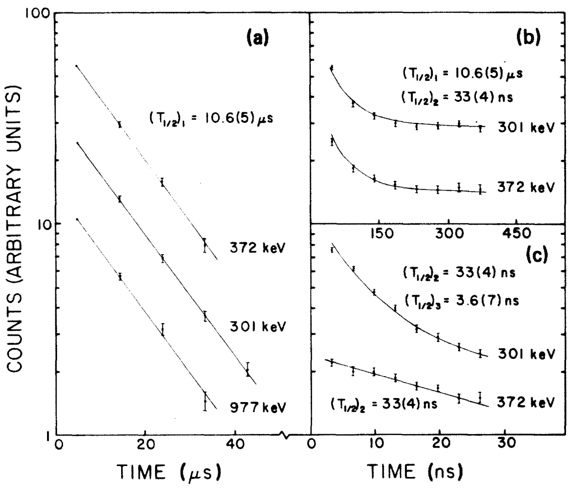

FIG. 4. Decay curves for some ^{199}Pb γ rays obtained in (a) slow beam pulsing, (b) beam sweeping, and (c) between beam bursts timing experiments.

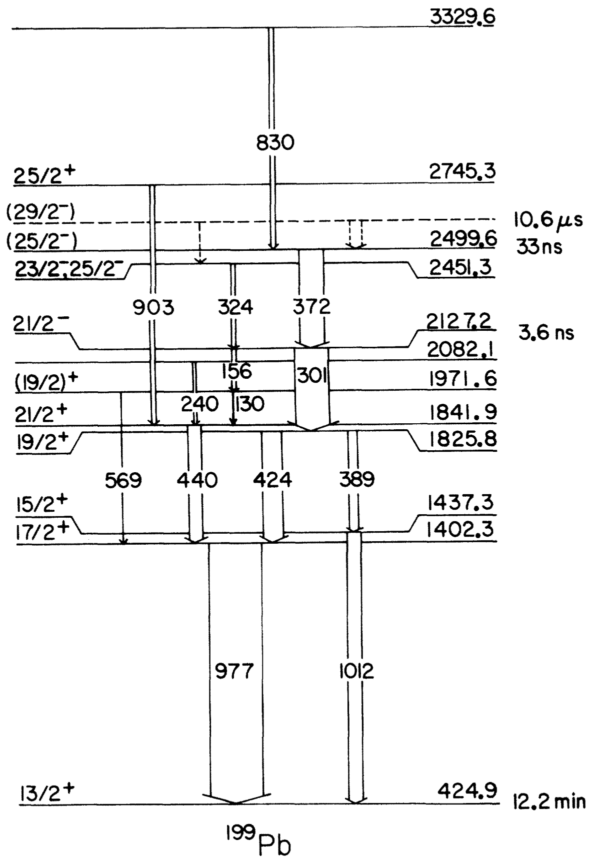

FIG. 5. The level scheme of ^{199}Pb above the $\frac{13}{2}^+$ isomer.

The 389- and 424-keV transitions populate the $\frac{15}{2}^+$ and $\frac{17}{2}^+$ levels from a $\frac{19}{2}^+$ level at 1826 keV, and the 440 keV $E2$ transition deexcites a $\frac{21}{2}^+$ level at 1842 keV. The intense 372-, 301-keV γ-ray cascade feeds the 1826-keV $\frac{19}{2}^+$ level from the 33-ns isomeric state through the intermediate $\frac{21}{2}^-$ level at 2127 keV. This $\frac{21}{2}^-$ level was also found to be isomeric with $t_{1/2} = 3.6 \pm 0.7$ ns. Samples of the timing data recorded in the ^{198}Hg(α, $3n$) reaction at $E_\alpha = 40$ MeV are illustrated in Fig. 4. The analysis of all the data gave the half-lives $t_{1/2} = 3.6 \pm 0.7$ ns for the 2127-keV level, $t_{1/2} = 33 \pm 4$ ns for the 2500-keV level, and $t_{1/2} = 10.6 \pm 0.5$ μs for a higher lying isomer which decays through the 2500-keV level. The angular distribution of the 372 keV isomeric transition was found to be almost isotropic, and the spin-parity values proposed for the 33-ns isomer and for the higher-lying 10.6-μs isomer are entirely based on level systematics.

Less strongly populated levels at 1972, 2082, 2451, 2745, and 3330 keV are also established rather clearly by the results of the prompt and delayed γ-γ coincidence measurements, but firm spin-parity assignments were generally not possible. The level scheme shown in Fig. 5 is much more detailed than the scheme presented by Richel *et al.*,[3] which accommodates only seven transitions and includes no lifetime information.

Since it has been suggested[3] that an 829-keV γ ray might be the $\frac{29}{2}^+ \to \frac{29}{2}^-$ transition in ^{199}Pb, it is worth noting that our delayed coincidence data established that the 830-keV transition populates the 33-ns isomer and not the 10.6-μs isomer. The 830-keV γ ray itself showed a strong delayed component, indicating yet another isomer at 3330 keV or higher in ^{199}Pb with a half-life of 55 ± 8 ns.

C. The ^{197}Pb level scheme

The nuclei ^{197}Pb and ^{195}Pb were not accessible with the available α-particle energies and their level structures were studied using (^{3}He,xn) reactions instead. The 42-min $\frac{13}{2}^+$ isomer in ^{197}Pb decays mainly by electron capture to levels in ^{197}Tl followed by the emission of a strong 222-keV γ ray.[5] In ^{3}He ion bombardments of ^{198}Hg, the population of the ^{197}Pb $\frac{13}{2}^+$ isomer was monitored by determining the 222-keV transition intensity, and strong 1005- and 1082-keV γ rays feeding the ^{197}Pb isomeric state were identified from approximate intensity balance requirements. Detailed $\gamma\gamma$ coincidence measurements, performed using the ^{198}Hg(^{3}He, $4n$)^{197}Pb reaction at a bombarding energy of 38.0 MeV, led to the identification of other in-beam γ rays coincident with the 1005- and 1082-keV lines. The properties of the nine transitions assigned to ^{197}Pb are summarized in Table III.

The coincidence results showed that parallel cascades of 532-, 1005- and 455-, 1082-keV transitions populate the $\frac{13}{2}^+$ isomer from a level at 1856

TABLE III. Transitions in ^{197}Pb from the ^{198}Hg(^{3}He, 4n) reaction with 38 MeV incident ^{3}He ions.

γ-ray energy[a] (keV)	Relative γ-ray intensity[a] In beam (125°)	Delayed	Angular distributions A_2/A_0	A_4/A_0	Inferred multipolarity	Placement (keV)
57.3(5)	121(30)	500(100)			$E1$[b]	1914→1856
387.0(6)	c	c				2301→1914
454.6(3)	128(10)	336(31)	0.23 ± 0.19	−0.06 ± 0.22	$E2$	1856→1402
531.5(2)	260(18)	587(42)	−0.01 ± 0.04	−0.04 ± 0.05	$(M1/E2)$	1856→1325
556.8(4)	215(20)	74(20)	0.41 ± 0.08	−0.09 ± 0.11	$E2$	1881→1325
589.3(4)	42(10)	90(25)				1914→1325
738.4(2)	114(10)		0.38 ± 0.04	−0.11 ± 0.06	$E2$	2063→1325
1005.2(2)	1000	1000	0.34 ± 0.05	0.03 ± 0.07	$E2$	1325→ 319
1082.3(2)	284(28)	306(31)	−0.05 ± 0.07	0.09 ± 0.10	$(M1/E2)$	1402→ 319

[a]Uncertainties in the least significant figures are indicated in parentheses.
[b]Multipolarity from intensity balance considerations.
[c]Not resolved from the 387.6-keV transition in ^{197}Tl.

keV (Fig. 6). This level and the intermediate levels at 1402 and 1325 keV are assigned spin-parity values of $\frac{19}{2}^+$, $\frac{15}{2}^+$, and $\frac{17}{2}^+$; the similarities to the lower parts of the ^{199}Pb and ^{201}Pb level spectra are obvious. Furthermore, a 557-keV $E2$ transition is found to deexcite a $\frac{21}{2}^+$ level at 1881 keV. A pulsed beam timing experiment showed that the five γ rays mentioned above have strong delayed components with $t_{1/2} = 1.5 \pm 0.2$ μs. Transitions of 57 and 589 keV, which also decay with this half-life and showed no prompt decay component, are identified as isomeric transitions deexciting the 1.5-μs state. The observed delayed γ-ray intensities and the requirement of intensity balance at the 1914-keV level place an upper limit of 1.0 on the total conversion coefficient of the 57-keV transition, showing that it is predominantly $E1$. The isomeric state is therefore assigned $I^\pi = \frac{21}{2}^-$, implying an $M2$ character for the 589-keV isomeric transition.

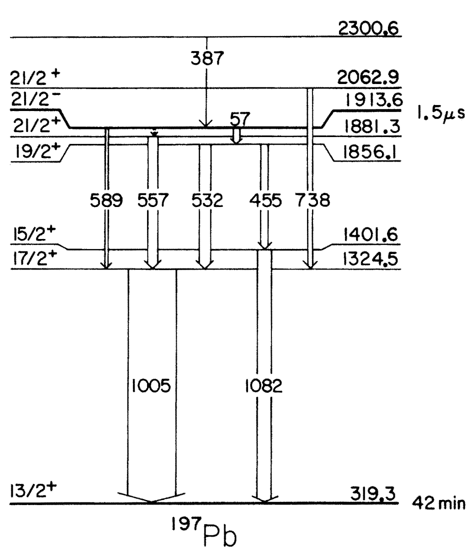

FIG. 6. The level scheme of ^{197}Pb above the $\frac{13}{2}^+$ isomer.

Resorting of the coincidence events with time conditions selecting transitions preceding the $\frac{21}{2}^-$ isomeric state identified the 387-keV γ ray as a transition feeding the 1.5-μs isomer, but the higher-lying transitions reported by Richel *et al.*[3] were not observed in these (^{3}He, 4n) measurements. The occurrence of an unobserved 32-keV $\frac{21}{2}^- \to \frac{21}{2}^+$ transition is also indicated by the data. The half-life of the $\frac{21}{2}^-$ isomer determined in this work is a factor of 2 larger than the value reported earlier.[3]

D. The ^{195}Pb level scheme

The electron capture (EC) decays of the 11-min ^{194}Pb ground state and of a 16-min high-spin ^{195}Pb isomer to levels in ^{194}Tl and ^{195}Tl have been well studied,[5] and the strong γ rays characterizing each decay are known. The ^{195}Pb isomer is almost certainly the $i_{13/2}$ neutron hole state. The $\frac{13}{2}^+ \to \frac{5}{2}^-$ $M4$ transition has not been observed in this case and so the excitation energy of the $\frac{13}{2}^+$ state is unknown, but from systematics it is likely to be about 200 keV. Two groups[7-9] have already studied ^{194}Pb by in-beam γ-ray spectroscopy and have identified the ^{194}Pb yrast levels up to 10$^+$. One group[9] reported that the lowest-lying transitions in ^{194}Pb, with energies of 965 and 575 keV, decay with a 10-μs half-life, and they tentatively assigned this half-life to a 1541 keV 5$^-$ state in ^{194}Pb. On the other hand, Pautrat *et al.*,[8] observing no such 10-μs decay component, interpreted the 1541 keV as the lowest 4$^+$ state in the nucleus.

In our investigation, enriched ^{198}Hg and ^{199}Hg targets were individually bombarded with 74-MeV

^{3}He ions and the relative yields of ^{194}Pb and ^{195}Pb^m were determined from the observed intensities of the known ^{194}Pb and ^{195}Pb^m radioactivity γ rays. The ratio of ^{195}Pb^m to ^{194}Pb activities with the ^{199}Hg target was found to be greater by a factor of 3 than the same ratio with the ^{198}Hg target. Similarly, the intensity of a prominent 970 keV in-beam γ ray, relative to the intensities of the 965 and 574 keV ^{194}Pb in-beam lines, was observed to be approximately three times greater with the ^{199}Hg target than with the ^{198}Hg target; these findings indicated that the 970 keV transition should be assigned to ^{195}Pb. In subsequent $\gamma\gamma$ coincidence measurements, 581 and 586 keV γ rays were found to be in prompt coincidence with the 970 keV γ ray, but not in coincidence with each other. Timing measurements with a 10-μs on, 40-μs off pulsed beam showed that the 581-, 586-, and 970-keV γ rays decay with a common half-life, $t_{1/2}=$ 10.0 ± 0.7 μs, while the 575- and 965-keV γ rays of ^{194}Pb were observed to decay quickly with no μs decay component.

The energies and intensities of the three transitions assigned to ^{195}Pb are given in Table IV and the proposed level scheme is shown in Fig. 7. The 586-keV transition, which showed no prompt decay component, is interpreted as an $M2$ isomeric transition competing with an unobserved 5-keV $E1$ transition feeding the 1551-keV level. Although no transition multipolarities have been determined, both the level systematics and the observed isomeric transition probabilities favor this interpretation of the γ-ray data. The $B(M2)$ for the 586 keV transition is almost identical to the value obtained for the $\frac{21}{2}^- \to \frac{17}{2}^+$ 589-keV $M2$ transition in ^{197}Pb, and the $B(E1)$ for the 5-keV transition is similar to the values obtained for the $5^- \to 4^+$ and $\frac{21}{2}^- \to \frac{19}{2}^+$ transitions in the heavier even-A and odd-A Pb nuclei. Richel *et al.*[3] adopted the partial ^{195}Pb level scheme shown in Fig. 7 and placed several transitions above the $\frac{21}{2}^-$ isomeric state; not surprisingly, these higher lying transitions were not identified in the present (^{3}He, $7n\gamma$) study.

TABLE IV. Transitions in ^{195}Pb from the ^{199}Hg(^{3}He, $7n$) reaction with 74 MeV incident ^{3}He ions.

γ-ray energy[a] (keV)	Relative γ-ray intensity[a] In beam (125°)	Delayed	Placement[b] (keV)
581.2(3)	54(6)	30(3)	1551 → 970
586.4(2)	45(5)	60(6)	1556 → 970
969.5(1)	100	100	970 → 0

[a]Uncertainties in the least significant figures are indicated in parentheses.

[b]Level energies are expressed relative to zero energy for the $\frac{13}{2}^+$ isomeric state of ^{195}Pb.

IV. DISCUSSION

We have previously[1] drawn attention to the close and detailed correspondence between the level spectra of the even-A and odd-A Pb nuclei over the entire mass range studied. The observed levels of each odd-A nucleus can be attributed to the coupling of an additional $i_{13/2}$ neutron hole with known states of the adjacent even-A core nucleus. Specifically, the closely spaced $\frac{17}{2}^+$, $\frac{15}{2}^+$ and $\frac{19}{2}^+$, $\frac{21}{2}^+$ doublets in ^{201}Pb, ^{199}Pb, and ^{197}Pb are interpreted as the highest spin members of hole-core multiplets associated with the 2_1^+ and 4_1^+ core states; in ^{195}Pb only a single member of each multiplet is observed. A similar hole-core coupling interpretation of the $\frac{21}{2}^-$, $\frac{25}{2}^-$, and $\frac{29}{2}^-$ levels is also strongly indicated by the energy systematics of these levels and the 5^-, 7^-, and 9^- levels in the even-A neighbors. Moreover, a comparison of the $B(E1)$ and $B(E2)$ values extracted from the many measured half-lives (Table V) shows generally close agreement between the transition probabilities for corresponding transitions in adjacent odd-A and even-A nuclei, and points towards a weak coupling description of the odd-A level spectra.

Recently, King Yen *et al.*[10] have carried out weak coupling calculations in a restricted neutron model space consisting of the orbitals $p_{1/2}$, $f_{5/2}$, $p_{3/2}$, and $i_{13/2}$, with single particle energies taken from the ^{207}Pb spectrum. Starting with the experimental energies of the core states and using effective interactions between the core and $i_{13/2}$ hole of the Schiffer-True[11] type (parametrized by a least squares fit to the known states of five even-A Pb nuclei), these workers calculated the

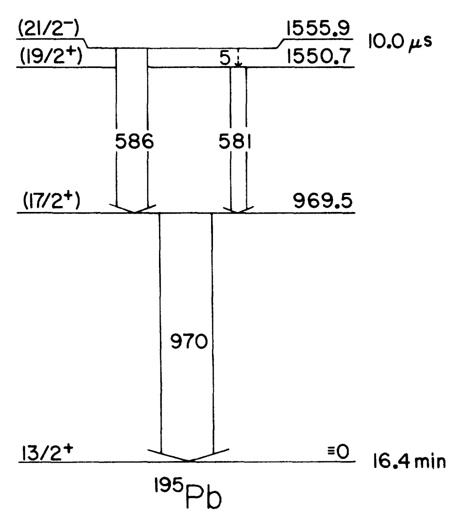

FIG. 7. The level scheme of ^{195}Pb above the $\frac{13}{2}^+$ isomer. Level energies are expressed relative to zero energy for the $\frac{13}{2}^+$ isomeric state.

TABLE V. A summary of transition probabilities for odd-A Pb nuclei determined in the present work and for even-A Pb nuclei from the literature (Refs. 5,7). The ratio B_{exp}/B_{sp} gives the measured transition probabilities in single particle units.

Transition	Multipolarity	A	B_{exp}/B_{sp}
$\frac{19}{2}^{+} \to \frac{15}{2}^{+}$	$E2$	199	>0.11 [a]
	$E2$	200	1.11
or	$E2$	201	0.18
$4^{+} \to 2^{+}$	$E2$	202	0.29
$\frac{21}{2}^{-} \to \frac{17}{2}^{+}$	$M2$	195	7.8×10^{-4}
	$M2$	197	8.8×10^{-4}
$\frac{21}{2}^{-} \to \frac{19}{2}^{+}$	$E1$	195	8.3×10^{-7}
	$E1$	196	5.6×10^{-6}
or	$E1$	197	4.1×10^{-7}
$5^{-} \to 4^{+}$	$E1$	198	5.4×10^{-7}
	$E1$	199	1.9×10^{-6}
	$E1$	200	1.9×10^{-6}
$\frac{25}{2}^{-} \to \frac{21}{2}^{-}$	$E2$	196	>0.23
	$E2$	198	>0.5
or	$E2$	199	0.03
$7^{-} \to 5^{-}$	$E2$	200	0.17
	$E2$	201	0.21
	$E2$	202	0.75
$\frac{29}{2}^{-} \to \frac{25}{2}^{-}$	$E2$	196	1.21
	$E2$	198	>0.037 [b]
or	$E2$	199	>0.013 [b]
$9^{-} \to 7^{-}$	$E2$	200	0.27
	$E2$	201	>0.25 [b]

[a] From experimental upper limit $t_{1/2} < 2$ ns for parent level.

[b] Assuming transition energy less than 80 keV.

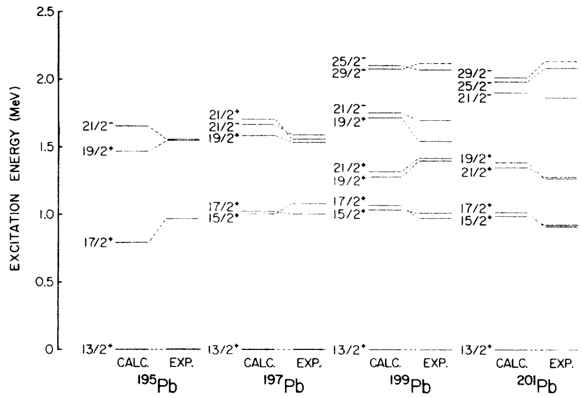

FIG. 8. A comparison of level energies obtained in weak coupling calculations (Ref. 10) with the results of the present experiments.

energies and wave functions of the various high-spin states in the odd-A nuclei under discussion here. From the comparison of the calculated and experimental energies shown in Fig. 8, it is clear that the weak coupling treatment reproduces the main features of the observed spectra reasonably well. The calculations also identify the main core states involved in the core-hole coupling, and indicate that the dominant active components in the $\frac{21}{2}^{-}$, $\frac{25}{2}^{-}$, and $\frac{29}{2}^{-}$ states are $i_{13/2}^{-2}p_{3/2}^{-1}$, $i_{13/2}^{-2}f_{5/2}^{-1} + i_{13/2}^{-2}p_{3/2}^{-1}$, and $i_{13/2}^{-2}f_{5/2}^{-1}$, respectively.

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