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NUCLEAR REACTIONS: $^{194,195,196,198}Pt(\alpha,xn)^{194,196,198}Hg$; $x = 3,4$. $E = 34\text{-}50$ MeV; $^{172}Yb(^{20}Ne,4n)^{188}Hg$, $E = 104$ MeV; $^{164}Dy(^{28}Si,4n)^{188}Hg$, $E = 128, 135, 144$ MeV;

RADIOACTIVITY: β decay of ^{188}Tl from $^{165}Ho(^{28}Si,5n)$ and $^{159}Tb(^{32}S,3n)$. Measured E_γ, I_γ, $\sigma(E,E_\gamma)$, $I_\gamma(\theta)$, γ-γ coincidence, delayed γ; $^{188,194,196,198}Hg$ deduced levels, J, π, $T_{1/2}$; enriched and natural targets.

HIGH-SPIN EXCITATION MODES IN EVEN Hg NUCLEI[*]

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Abstract

The low-lying high-spin states in mercury isotopes with A = 188, 194, 196, and 198 have been studied by γ-ray spectroscopy following (HI,xn) reactions, and for ^{188}Hg also by the β decay of ^{188}Tl. A variety of modes of excitation are found. Irregularities in the energies of the positive-parity states in ^{188}Hg are interpreted as a shape transition to larger deformation similar to those recently observed in ^{186}Hg and ^{184}Hg. In the heavier Hg isotopes a small spacing between the 8^+ and 10^+ states (less than 100 keV) has been found, and in ^{194}Hg and ^{196}Hg values of $B(E2;10^+ \rightarrow 8^+)$ were determined to be considerably smaller than the $B(E2;2^+ \rightarrow 0^+)$ value. The interpretation of these results as being due to a transition to a two-particle (hole) configuration, predominantly $(\pi h_{11/2}^{-2})$, is discussed. Still another type of excitation is illustrated by the negative-parity band observed up to the 11^- level in ^{194,196,198}Hg. It is most likely a combination of the collective motion of the core and of two-quasiparticle states, predominantly $[\nu i_{13/2}, \nu j]$, with some contribution of $[\pi h_{11/2}, \pi j]$.

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1. Introduction

The mercury nuclei, with Z = 80, have only two protons less than the magic number 82 and lie in the transition region between the strongly deformed prolate rare-earth nuclei and the spherical lead nuclei. The heavier Hg isotopes are considered to be nearly spherical (vibrational) with small oblate deformation.[1] Negative-parity bands have been observed[2,3] in these nuclei starting at spin 5. The E2 transition probabilities[4,5] connecting the lowest members of these bands have strengths of about 30 s.p.u., indicating some collectivity. The negative parity, the fact that the lowest spin in the band is 5, and the occasionally very close spacing of the 5^- and 7^- members, however, suggest a single-particle nature for these states in which an $i_{13/2}$ neutron is coupled to a $p_{1/2}, p_{3/2}, f_{5/2}, \cdots$ neutron. In the very neutron-deficient mercury isotopes with A = 184 and 186, a change from small (probably) oblate deformation to large prolate deformation has been found[6] in the yrast states around spins 2 and 4, respectively.

In the present paper we report on a systematic investigation of the low-lying high-spin states in mercury nuclei with A = 188, 194, 196, and 198 by γ-ray spectroscopy following (HI,xn) reactions. The positive-parity bands have been observed up to spin 14 and the negative-parity bands up to spin 11. Some E1 and E2 transition probabilities have been determined. The results show that the levels in these mercury nuclei can only be understood in a combined model of collective motion and single-particle states.

2. Experimental Techniques

The γ decay of the yrast states of the mercury nuclei with A = 194, 196 and 198 has been studied following (α,xn;x = 3,4) reactions on enriched self-supporting platinum targets of approximately 5 mg/cm^2 thickness. One Pt target had a (heavy) mass composition of 60% ^{198}Pt, 30% ^{196}Pt and 10% ^{195}Pt; the other one had a (light) mass composition of 60% ^{194}Pt, 30% ^{195}Pt, and 10% ^{196}Pt. The α beam was provided by the 88" cyclotron of the Lawrence Berkeley Laboratory. Excitation functions for the (α,3n) and (α,4n) reactions have been studied in the energy range between 34 and 50 MeV. The nucleus ^{188}Hg has been studied with the reactions ^{172}Yb(^{20}Ne,4n) at 104 MeV and ^{164}Dy(^{28}Si,4n) at 128, 135, and 144 MeV, and in the β decay of ^{188}Tl, which has been produced by bombarding ^{165}Ho with ^{28}Si and ^{159}Tb with ^{32}S. These heavy-ion beams were provided by the HILAC at the Lawrence Berkeley Laboratory. The time structure of the beams (pulse width ∿ 10 nsec, distance between beam burst ∿ 150 nsec at the cyclotron and ∿ 5 msec pulse width with a repetition rate of 36 sec^{-1} at the HILAC) were used to accumulate in-beam (IB) and off-beam (OB) spectra in order to determine isomeric transitions and short-lived activities. Approximate A_2 coefficients for the γ transitions were determined by measuring the anisotropy of the γ-ray emission at two angles in the reaction plane. Gamma-gamma coincidences were recorded between a coaxial and a planar Ge(Li) detector using conventional fast-slow coincidence techniques. The relative efficiencies of the Ge(Li) detectors were determined with ^{177m}Lu and ^{152m}Eu sources. The experimental conditions were very similar to previously published work, so details may be found in Refs. 1 and 7.

3. Experimental Results

Low-lying levels in the three Hg isotopes with A = 194, 196 and 198 were known previously to the 6^+ and 7^- states,[2] and in ^{188}Hg to the 4^+ state.[8] Our experiments agree with all previous assignments, and add levels up to around spin 12 in both the positive- and the negative-parity bands. Figure 1 shows the IB and OB spectra accumulated during a bombardment of a $^{194(195)}$Pt target with α particles of 47 MeV at an observation angle of 45°. Almost all the stronger OB lines could be assigned as transitions in ^{194}Hg and ^{196}Hg. Figure 2 shows some examples from the angular distribution measurements. In Fig. 3, we present some of our coincidence spectra which led to the decay scheme of ^{198}Hg. Since the decay schemes for the nuclei studied follow quite straightforwardly from the coincidence data, we do not need to discuss the decay of each individual level.

In Fig. 4 are shown the decay schemes for the low-lying high-spin states in the Hg isotopes studied by us. In ^{188}Hg, the order of the 460.3 keV, 503.8 keV and 520.6 keV transitions could not be determined unambiguously from the IB intensities (see Table I). A great help in this case is the γ spectrum from the β decay of ^{188}Tl which populates with decreasing intensity levels in ^{188}Hg up to the 8^+ state, and so determines the sequence of these γ rays uniquely. Figure 5 shows such a spectrum where ^{188}Tl was made in the reaction ^{165}Ho(^{28}Si,5n) at 155 MeV. These data are in good agreement with those quoted in Ref. 9. The coincidence spectrum with the gate on the 591.4 keV transition brings back a line of 591 keV, and the sum of all coincidence spectra yields a 688 keV line. We tentatively assign these two

γ lines as the $(12^+) \to 10^+$ and $(14^+) \to (12^+)$ transitions. An isomeric state makes the $10^+ \to 8^+$, $8^+ \to 6^+$, $6^+ \to 4^+$, $4^+ \to 2^+$, and $2^+ \to 0^+$ transitions appear in the OB spectrum together with two lines of 232.9 and 196.7 keV. All these seven transitions have the same intensity out-of-beam within our experimental accuracy. The 232.9 keV line seems to have a prompt component, whereas the 196.7 keV line, with no prompt part, seems to depopulate the isomeric state itself. M1 and E2 (and higher) multipolarities for these two γ lines are not consistent with our measured γ intensities because the internal conversion process would make them stronger than the following transitions, so we assign them as E1 transitions. The A_2 coefficients indicate that they are of stretched $(I+1 \to I)$ type, so we tentatively assign an 11^- state at 2721.6 keV and a 12^+ state at 2918.3 keV. Unfortunately, we do not have data to determine the half-life of this isomeric state accurately; a preliminary run gave a few tens of nanoseconds, as indicated in Fig. 6. Table I lists the intensities of the transitions in ^{188}Hg in the IB, OB, and β decay of ^{188}Tl spectra, as well as A_2 coefficients, multipolarities and assignments in the decay scheme.

The decay schemes for the nuclei ^{194}Hg through ^{198}Hg follow from the coincidence data. The information on the γ transitions assigned to these nuclei are contained in Tables II, III, and IV. The level order was determined according to decreasing intensity in the IB spectra. Spin assignments were made by the approximate A_2 coefficients, extracted from the measured anisotropy in the γ-ray emission at two angles, 45° and 90° , in the reaction plane. In some cases observation of E1 transitions between states of the positive- and negative-parity bands were very useful in making the spin assignments. The small $10^+ \to 8^+$ spacing leads to isomeric transitions whose lifetimes could be measured by delayed coincidence techniques. Delayed time spectra for the decay of the 10^+ states in ^{194}Hg and ^{196}Hg can be seen in Fig. 7. We obtain $t_{1/2}$ = 10±2 nsec for the 10^+ state in ^{194}Hg and $t_{1/2}$ = 7±1 nsec for the corresponding state in ^{196}Hg. Unfortunately, the high-energy $10^+ \rightarrow 9^-$ transition in ^{198}Hg makes the half-life of this 10^+ state too short to be measured by this technique. In the case of ^{194}Hg the 58.2 keV E2 transition connecting the 10^+ state at 2423.1 keV with the 8^+ state at 2364.9 keV was not observed. However, in the OB spectrum, the 279.7 keV line must be as intense as the 232.7 keV line, and this is only possible, from the theoretical conversion coefficients, with E1 and E2 multipolarity for the two lines, respectively. Their A_2 coefficients indicate that they are stretched transitions, which leads to the proposed decay scheme.

4. Discussion

The spectra of the even-even mercury nuclei studied by us are shown in Fig. 4. A remarkable similarity of the level energies of the high-spin states for different neutron numbers is apparent in the heavier Hg isotopes, and this trend continues[3,10] in ^{200}Hg and in ^{192}Hg and ^{190}Hg. Also the spectra of the decoupled bands built on the $i_{13/2}$ neutron state in the odd-A nuclei follow the core states in detail.[1,10] The low-lying even-parity states in the even-even Hg nuclei have been discussed in Ref. 2 on the rigid asymmetric-rotor model of Davydov and Fillipov.[11] This yields a good fit for the energies of the 2^+, $2^{+'}$ and 4^+ states and also for the ratio

$B(E2;2^{+'} \rightarrow 0^+)/B(E2;2^{+'} \rightarrow 2^+)$ for an asymmetry parameter of $\gamma \approx 22^\circ$ (the maximum possible asymmetry is $\gamma = 30^\circ$).[‡] But this model fails to reproduce the low energies of the higher spin, even-parity states. Especially the $10^+ \rightarrow 8^+$ energy spacing becomes very small and falls below 100 keV. In ^{198}Hg the $12^+ \rightarrow 10^+$ energy spacing is also quite small, but it becomes larger in the lighter Hg isotopes. Such small energy spacings are reminiscent of the high-spin spectra one obtains from the coupling of two particles or holes in a high-j shell. That is, in these nuclei near the proton closed shell, two such particles or holes can carry angular momentum more cheaply, in terms of energy, than can the collective motion of the weakly deformed core, and so the nature of the band changes from a collective motion towards a stretched j^2 configuration at higher spin. The high-j orbits available in the Hg nuclei are the $i_{13/2}$ neutron and the $h_{11/2}$ proton shells which can be coupled to a maximum spin of 12^+ and 10^+, respectively, and we think such configurations may contribute heavily to the wavefunctions of the higher spin positive-parity states. In ^{198}Hg we conclude from the small $12^+ \rightarrow 10^+$ and $10^+ \rightarrow 8^+$ transition energies that both of the configurations $(\nu i^{-2}_{13/2})$ and $(\pi h^{-2}_{11/2})$ contribute, whereas in the lighter Hg isotopes, where only the $10^+ \rightarrow 8^+$ spacing is small, the configuration $(\pi h^{-2}_{11/2})$ may dominate in the 10^+ and 8^+ states. In Fig. 8 we have plotted the B(E2) values for various transitions in Pb, Hg, and Pt isotopes. Whereas the value of the $B(E2;2^+ \rightarrow 0^+)$ in the Hg nuclei stays approximately at 2900 e^2fm^4, that of the $B(E2;10^+ \rightarrow 8^+)$ drops from 1300 e^2fm^4

[‡] This is not in contradiction to the oblate deformation which has been concluded from the observation of decoupled bands in the odd-A mercuries,[1] since the decoupled bands persist, as a recent study shows,[12] up to quite large γ distortions.

in ^{196}Hg to 680 e^2fm^4 in ^{194}Hg and possibly[‡] to 210 e^2fm^4 in ^{190}Hg. This decrease with decreasing neutron number probably also means that the 10^+ and 8^+ states are becoming purer ($\pi h^{-2}_{11/2}$) configurations. In any case it is clear that the 10^+ states are not of the same collective nature as the lowest positive-parity states. This change in the nature of the positive-parity band in the heavier Hg isotopes is not related to the irregularities found[6] in the yrast states of ^{184}Hg and ^{186}Hg which have been interpreted as an angular-momentum-induced transition to strong deformation. In these latter cases the B(E2) values show a marked increase, rather than a decrease. For example, the $B(E2;6^+ \rightarrow 4^+)$ values for ^{184,186}Hg are also plotted in Fig. 8. They are between one and two orders of magnitude larger than the $B(E2;10^+ \rightarrow 8^+)$ values in the heavier Hg isotopes. It is interesting to note that in the heavier mercury nuclei, no isomeric ($\nu i^{-2}_{13/2}$) 12^+ level has been found, although they have recently been observed in the neighboring Pb isotopes.[14] This may be due to the different position of the Fermi surface with respect to the Nilsson orbits in the spherical Pb and the slightly oblate Hg nuclei.

The spectrum of ^{188}Hg, which at first glance looks like a vibrational spectrum, has to be considered in comparison with the adjacent heavier and lighter Hg isotopes. In ^{186}Hg and ^{184}Hg, a shape transition in the yrast band from small (probably oblate) deformation towards larger prolate deformation has been found[6] around spin 4^+ and the spectrum of ^{188}Hg suggests a similar behavior around spin 6^+. A comparison of the $8^+ \rightarrow 6^+$ and $10^+ \rightarrow 8^+$ transition

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[‡] In ^{190}Hg an isomeric state at 2604 keV with a half-life of 24.5 nsec has been tentatively assigned as a 10^+ state in Ref. 13.

energies, 460.3 and 520.6 keV, respectively, with the corresponding transitions in ^{186}Pt, 464.3 and 514.6 keV, indicates a similar quasi-rotational spacing. Very recently, a study[9] of the β decay of ^{188}Tl yielded a level at 1207.3 keV (4^+) which is interpreted as the next lower member of this deformed band and supports the assumption of a shape transition in ^{188}Hg near the 6^+ level. The isomeric state at 2918.3 keV, which we tentatively assign as a 12^+ state, may have the configuration ($\nu i^{-2}_{13/2}$). Unfortunately, no B(E2) value for the decay could be measured to test this possibility. Probably a measurement of the g-factor of this state would give the best indication. But if this assumption turns out to be correct, the levels in this one nucleus provide examples of a collective (vibrational) band, of a collective rotational band having large deformation, and of a band built on a j^{-2} configuration.

In any case, it appears that there is a change in the way that these Hg nuclei carry angular momentum in the yrast band a few units of spin above the ground state, and that there is a marked difference in this higher spin mode of excitation depending upon whether the mass number is greater, or less, than A = 190.

The states of the negative-parity bands could be followed up to the 11^- states in ^{194}Hg and ^{198}Hg and possibly to the 13^- state in ^{196}Hg. The negative-parity states in the mercury nuclei have first been reported in Ref. 2, and similar states are also known in lead[5,14,15] and platinum[3-5] nuclei and in other regions of the nuclidic chart. Negative-parity states can be considered generally as two-particle (two-hole) states, where one particle occupies the unique-parity high-spin orbit within a major shell and the other moves in one of the low-spin orbits with the opposite parity.

The nucleon-nucleon interaction--attractive in the singlet-even state--brings the states with natural parity lowest in energy, and so only the odd-spin states are observed.[16] It happens generally that in nuclei just below a magic number, the available low-j orbitals allow the formation of a 5^- state as the lowest negative-parity spin state, whereas with the low-j orbitals in nuclei above a magic number, a 3^- state can be formed as the lowest spin state with negative parity. The systematic occurrence of the 5^- bands, and the occasional very close spacing of levels ($7^- \rightarrow 5^-$ in the mercury nuclei) support such an interpretation. Also the discovery in ^{195,197,199}Hg of states where an $i_{13/2}$ neutron is coupled to the 5^- band to give a $21/2^-$ band indicates that an $i_{13/2}$ neutron is one partner in the negative-parity states in the even-even nuclei. This is because the blocking of the completely aligned ($\alpha = 13/2$) orbit by this neutron allows the additional $i_{13/2}$ neutron to add only 11/2 units of spin along the spin axis, resulting in total spins which are one unit less than would otherwise be expected (21/2 instead of 23/2).[1] The first forbidden EC-decay of the 7^+ isomer $[\nu i_{13/2}, \pi s_{1/2}]_{7^+}$ in ^{198}Tl to the 7^- member of the negative-parity band in ^{198}Hg (Ref. 2) and the allowed β-decay of the 12^- isomer $[\pi h_{11/2}, \nu i_{13/2}]_{12^-}$ in ^{200}Au to the 11^- member in ^{200}Hg (Ref. 3) likewise indicate that the $i_{13/2}$ neutron is an important constituent of the negative-parity bands in the even-even Hg nuclei. A two-neutron-hole description has been applied to the negative-parity states in the even-even lead nuclei.[14] Although the state energies could be reproduced satisfactorily, the calculated $B(E2;9^- \rightarrow 7^-)$ values underestimate the experimental ones considerably. It is clear that the 5^- bands exhibit some collective quadrupole nature, and probably also have some collective E5 moment. It can be seen in Fig. 8 that the B(E2;$7^- \rightarrow 5^-$) values in the Pt and Hg nuclei almost reach the values for the B(E2;$2^+ \rightarrow 0^+$) in these nuclei and also the B(E2;$9^- \rightarrow 7^-$) values in the Pb isotopes rapidly gain collectivity with decreasing neutron number. It would be interesting to see whether this collectivity could be accounted for by taking proton excitation $[\pi h_{11/2},\pi j]$, as well as the already mentioned neutron excitation, into account, with strong mixing of the members of the higher spin multiplets with the lower ones, and coupling of these mixed two-particle states to the $I = 0^+, 2^+, 4^+, \cdots$ core states.

Finally, it should be noted that at least two of the three interesting features observed in these even-even Hg nuclei, namely the $5^-, 7^-, 9^-, \cdots$ band and the tendency of the yrast band in the heavier nuclei to go towards a j^2 configuration, are not limited to these nuclei, but appear in other near-closed-shell nuclei. For example, the recently established[17] level scheme of ^{110}Cd is very similar to those presented here, except that the level spacings are somewhat greater as would be expected in such a light nucleus. The negative-parity band there probably involves the $[\nu h_{11/2},\nu j]$ configuration. The small spacing observed between the 10^+ and 8^+ states of the ground band appear to indicate that again $h_{11/2}$ particles are involved in a stretched j^2 configuration, but that this time it is a pair of neutrons, rather than protons.

5. Conclusion

Information on the low-lying high-spin states is now available for almost all even-even and odd-A mercury nuclei from A = 184 through 200. The results of the present study add information on ^{188}Hg, ^{194}Hg, ^{196}Hg, and ^{198}Hg. In the mercury isotopes, which lie in the transition region between the strongly deformed rare-earth and the spherical lead nuclei, one might expect both collective and single-particle properties. The Hg nuclei with

$190 \leqslant A \leqslant 200$ are believed to be of oblate deformation, and the $B(E2;2^+ \rightarrow 0^+)$ values indicate moderate collectivity in these nuclei, of a type historically called vibrational. However, the 10^+ states, with their small transition energies to the 8^+ states and their small $B(E2;10^+ \rightarrow 8^+)$ values, seem to be mainly due to $(\pi h_{11/2}^{-2})$ excitation. With the neutron-deficient Hg isotopes, $A < 190$, a very different transformation appears at higher spin. There is evidence for a change to large prolate deformation (small values of $\hbar^2/2\mathcal{J}$ and large $B(E2)$ values) for states above a spin value which decreases with decreasing neutron number from 6^+ in ^{188}Hg to 2^+ in ^{184}Hg. Thus, the high-spin states of the yrast band show one type of behavior for $A > 190$, and a different type for $A < 190$. In either case, these nuclei with small deformation find it necessary to change the nature of their yrast band at higher spins, to either large prolate deformation ($A < 190$) or to a stretched pair of high-j particles ($A > 190$), in order to accomodate larger amounts of angular momentum more economically.

Finally, the negative-parity band built on the 5^- state shows both considerable collective quadrupole character (enhanced $B(E2)$ values among the members) and a strong two-particle component, particularly of $[\nu i_{13/2}, \nu j]$. The order of the levels (including having the natural parity members lowest and starting with 5^-) is given correctly by a shell-model calculation including residual interactions,[16] but the enhancement of the $B(E2)$ values requires additional mixing of the states so obtained with each other, and with the collective motion of the core.

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Table 1. Information[a] on γ Transitions Assigned to ^{188}Hg.

E_γ (keV)	I_γ(IB)	I_γ(OB)	I_γ ^{188}Tl-decay	A_2(IB)	A_2(OB)	Mult.	E_x(i) (keV)	I(i)	E_x(f) (keV)	I(f)
196.7	17±2	16±2		−0.38±0.15	−0.34±0.15	(E1)	2918.3	(12^+)	2721.6	(11^-)
232.9	19.5±2	16±2		0.10±0.10	0.09±0.10	(E1)	2721.6	(11^-)	2488.7	10^+
412.6	100	17±2	100	0.43±0.10	0.26±0.10	E2	412.6	2^+	0	0^+
460.3	$\leqslant$ 49[b]	16±2	5±2	0.37±0.15	0.29±0.10	E2	1968.1	8^+	1507.8	6^+
503.8	50±3	15±2	25±3	0.34±0.10	0.34±0.10	E2	1507.8	6^+	1004.0	4^+
520.6	45±3	14±2		0.29±0.10	0.25±0.10	E2	2488.7	10^+	1968.1	8^+
591.4	92±4	16±2	60±4	0.31±0.10	0.22±0.10	E2	1004.0	4^+	412.6	2^+

[a] From ^{172}Yb(^{20}Ne,4n) at 105 MeV. A_2 coefficients were obtained from I_γ at 0° and 90° in the reaction plane.

[b] From excitation-function measurements; a γ transition of 460 keV has also been assigned to ^{189}Hg.

Table III. Information[a)] on γ Transitions Assigned to ^{196}Hg.

E_γ (keV)	I_{tot}(IB)	A_2(IB)	E_x(i) (keV)	I(i)	E_x(f) (keV)	I(f)
84.0	not observed		1840.8	7^-	1756.8	5^-
97.0	13±3	0.6±0.2	2359.6	10^+	2262.6	8^+
222.9	15±3	0.46±0.15	2063.7	9^-	1840.8	7^-
404.8	6±2	0.6±0.2	2764.4	12^+	2359.6	10^+
426.1	100	0.48±0.10	426.1	2^+	0	0^+
477.7	26±3	0.56±0.15	2262.6	8^+	1784.9	6^+
556.5	7±2	0.6±0.2	2620.2	11^-	2063.7	9^-
635.3	88±4	0.45±0.10	1061.4	4^+	426.1	2^+
693	3±1		(3313.2	13^-)	2620.2	11^-
695.4	41±4	-0.11±0.15	1756.8	5^-	1061.4	4^+
723.5	32±3	0.50±0.15	1784.9	6^+	1061.4	4^+

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a) From $^{194(195)}$Pt + α at 34 MeV. A_2 coefficients were obtained from I_γ at 45° and 90° in the reaction plane.

Table II. Information[a)] on γ Transitions Assigned to ^{194}Hg.

E (keV)	I_γ(IB)	I_γ(OB)	A_2(IB)	A_2(OB)	Mult.	α	I_{tot}(IB)	I_{tot}(OB)	E_x(i) (keV)	I(i)	E_x(f) (keV)	I(f)
58.2		not observed							2423.1	10^+	2364.9	8^+
96.6[b)]	< 5.6	< 8	0.47±0.15	0.44±0.15	E2	6.4	< 41	< 59	1910.7	7^-	1814.1	5^-
110.8	4±1	6±1	-0.16±0.10	0.03±0.10	E1	0.33	5±1	8±1	1910.7	7^-	1799.9	6^+
232.7	24±3	25±2	0.45±0.15	0.24±0.10	E2	0.24	30±4	31±2	2143.4	9^-	1910.7	7^-
279.7	9±3	32±2	0.02±0.20	-0.28±0.10	E1	0.03	9±3	32.5±2	2423.1	10^+	2143.4	9^-
412.8	16±3	-	0.56±0.15		E2		16±3	-	2835.9	12^+	2423.1	10^+
428.4[b)]	< 100	< 100	0.45±0.05	0.16±0.05	E2	0.04	< 100	< 100	428.4	2^+	0	0^+
544.7	18±3	-	0.45±0.10	-	E2		18±3	-	2688.1	11^-	2143.4	9^-
565.0	16±3	34±2	0.37±0.15	0.13±0.10	E2		16±3	34±2	2364.9	8^+	1799.9	6^+
636.8[b)]	< 93	< 94	0.45±0.05	0.16±0.05	E2		< 93	< 93	1065.2	4^+	428.4	2^+
734.7	28±3	43±4	0.42±0.10	0.16±0.10	E2		28±3	43±4	1799.9	6^+	1065.2	4^+
748.9	40±4	44±4	-0.10±0.10	-0.17±0.10	E1		40±4	44±4	1814.1	5^-	1065.2	4^+

[a)] From $^{194(195)}$Pt + α at 47 MeV. A_2 coefficients were obtained from I_γ at 45° and 90° in the reaction plane. The intensities I_γ have been normalized to the 428.4 keV transition.

[b)] Transitions of similar energies also occur in ^{196}Hg.

Table IV. Information[a)] on γ Transitions Assigned to ^{198}Hg.

E_γ (keV)	I_γ(IB)	A_2(IB)	Mult.	α	I_{tot}	E_x(i) (keV)	I(i)	E_x(f) (keV)	I(f)
47.8		not observed				1683.5	7^-	1635.7	5^-
97.3[b)]	< 7±3	0.4±0.2	E2	6.1	< 50±20	2435.2	10^+	2337.9	8^+
143.0	20±2	0.5±0.1	E2	1.1	42±4	2578.2	12^+	2435.2	10^+
227.3	38±3	0.5±0.1	E2	0.26	48±4	1910.8	9^-	1683.5	7^-
348.0	35±3	0.5±0.1	E2	0.07	37±3	2926.2	14^+	2578.2	12^+
411.8	100	0.41±0.05	E2	0.04	100	411.8	2^+	0	0^+
522.1	32±3	0.4±0.1	E2		32±3	2337.9	8^+	1815.8	6^+
524.4	14±2	-0.2±0.1	E1		14±2	2435.2	10^+	1910.8	9^-
556.5[b)]	< 23	0.58±0.15	E2		< 23	2467.3	11^-	1910.8	9^-
587.2	53±3	-0.05±0.10	E1		53±3	1635.7	5^-	1048.5	4^+
636.7[b)]	<140	0.42±0.05	E2		<140	1048.5	4^+	411.8	2^+
767.3	33±3	0.56±0.15	E2		33±3	1815.8	6^+	1048.5	4^+

[a)] From $^{198(196)}$Pt + α at 47 MeV. A_2 coefficients were obtained from I_γ at 45° and 90° in the reaction plane.

[b)] Transitions of similar energies also occur in ^{196}Hg.

Figure Captions

Fig. 1. Gamma ray spectra from the bombardment of a target (60% ^{194}Pt, 30% ^{195}Pt and 10% ^{196}Pt) with α particles of 47 MeV, in-beam (top) and off-beam (bottom). Detection angle was 45°. The labeled lines are transitions in ^{194}Hg.

Fig. 2. Partial γ spectra taken at 45° and 90° from (a) $^{194(195)}$Pt + α of 47 MeV and (b) $^{198(196)}$Pt + α of 47 MeV. IB (top) and OB (bottom) spectra are shown. The labeled lines are transitions in (a) ^{194}Hg and (b) ^{196,198}Hg.

Fig. 3. Example of γ-γ coincidence spectra taken with a planar and a coaxial Ge(Li) detector for various transitions in ^{198}Hg.

Fig. 4. The level and decay schemes of the low-lying high-spin states in mercury nuclei with A = 188, 194, 196, and 198 as they follow from previous studies and the present work.

Fig. 5. Out-of-beam γ-ray spectrum from the β decay of ^{188}Tl, produced in the reaction ^{165}Ho(^{28}Si,5n) at 155 MeV. The transitions between the low-lying high-spin states in ^{188}Hg are labeled.

Fig. 6. Two delayed γ-ray spectra from the bombardment of ^{172}Yb with ^{20}Ne of 104 MeV, (a) shortly after the beam burst (∿ 20 nsec) and (b) with an additional delay of 100 nsec. The transitions among the low-lying yrast states in ^{188}Hg which are fed by an isomer are indicated. The 196.7 keV transition is believed to depopulate the isomeric state; the 265.9 keV line is the $2^+ \rightarrow 0^+$ transition in ^{188}Pt which is populated by the β decay chain, $^{188}\mathrm{Hg} \xrightarrow{\beta} {}^{188}\mathrm{Au} \xrightarrow{\beta} {}^{188}\mathrm{Pt}$.

Fig. 7. Four examples of delayed coincidence spectra, from which the half-lives of the 10^+ states in (a) ^{196}Hg and (b) ^{194}Hg were determined. In Fig. 4a two prompt time curves with gates on two fast transitions in ^{195}Hg (371.2 keV, top, and 710.1 keV, bottom) are also shown. The values of $t_{1/2} = 7\pm1$ nsec (^{196}Hg) and 10 ± 2 nsec (^{194}Hg) were obtained from a total of six spectra in each case, with energy windows on various transitions in the respective Hg nuclei.

Fig. 8. Systematics of B(E2) values for various transitions in Pb, Hg, and Pt nuclei as a function of mass number on a semi-logarithmic plot. The two $B(E2;10^+ \rightarrow 8^+)$ values are results of our own measurements, the other values are taken from the literature. S.P.U. is the single particle unit, equal to $1.2^4/4\pi(3/5)^2\ A^{4/3}$ in units of e^2fm^4.

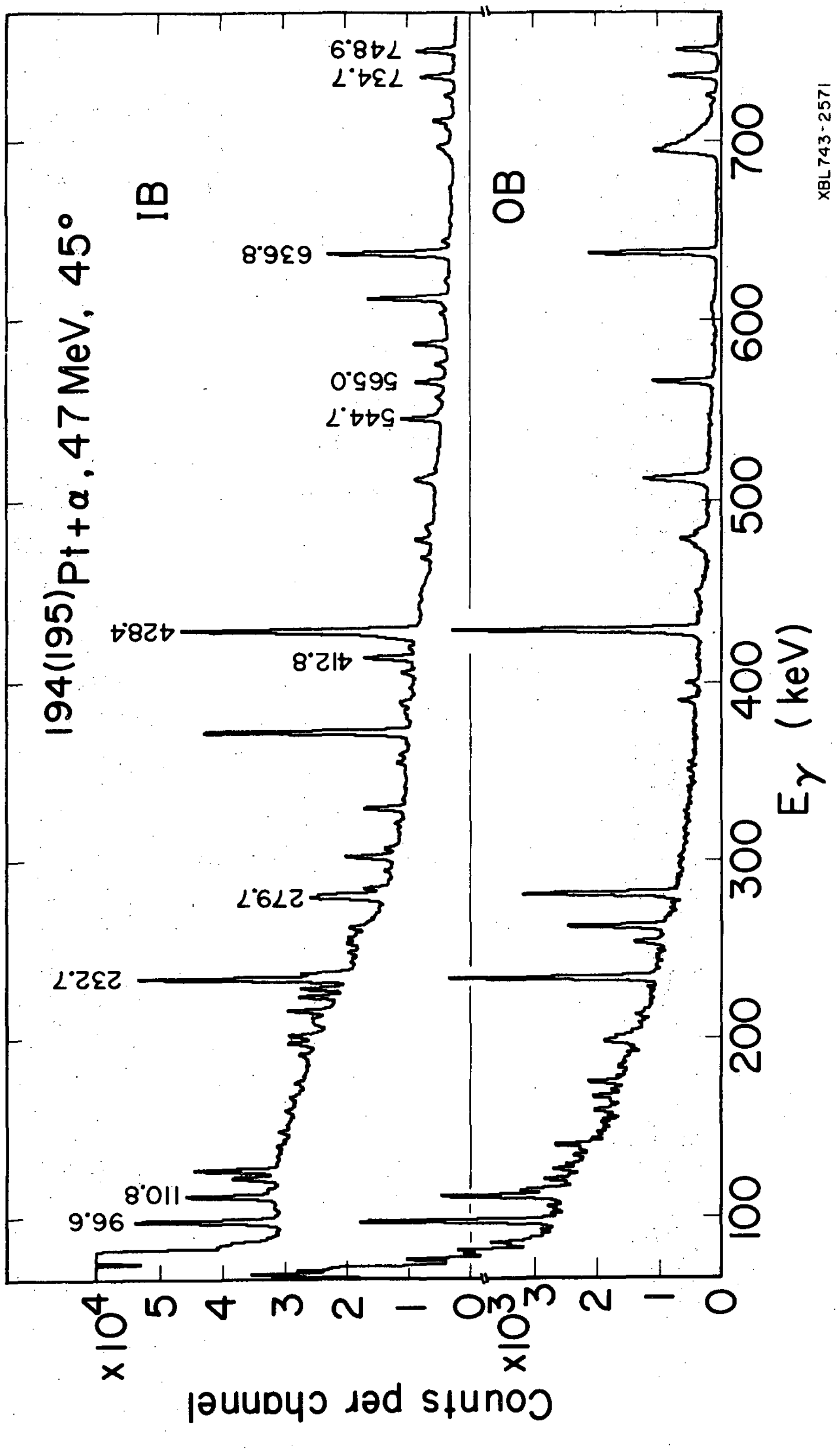

194(195)Pt + α, 47 MeV, 45°
IB
0B
96.6
110.8
232.7
279.7
412.8
428.4
544.7
565.0
636.8
734.7
748.9
x10^4
5
4
3
2
1
0
x10^3
3
2
1
0
Counts per channel
100
200
300
400
500
600
700
Eγ (keV)
XBL743-2571

Fig. 1

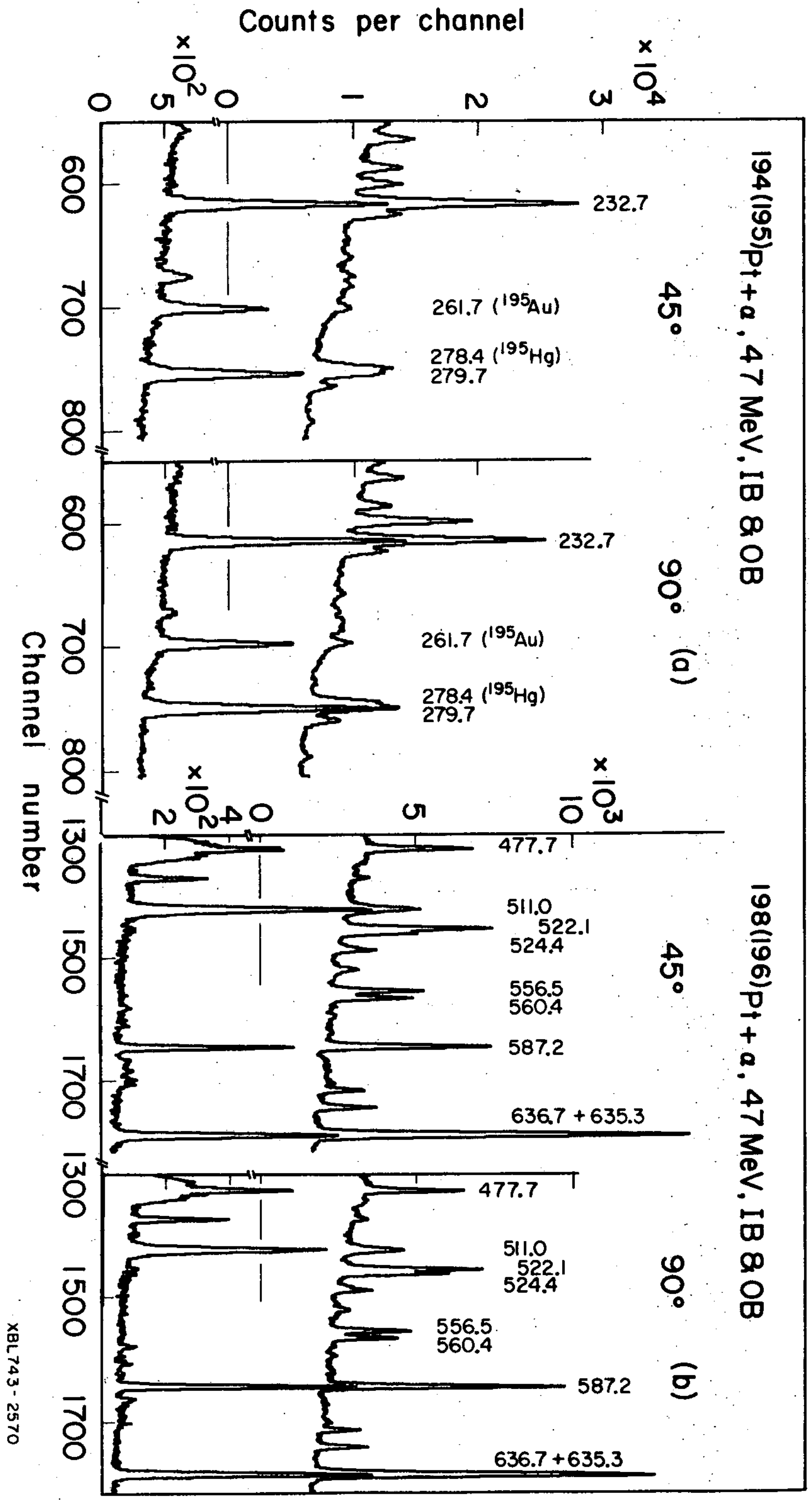
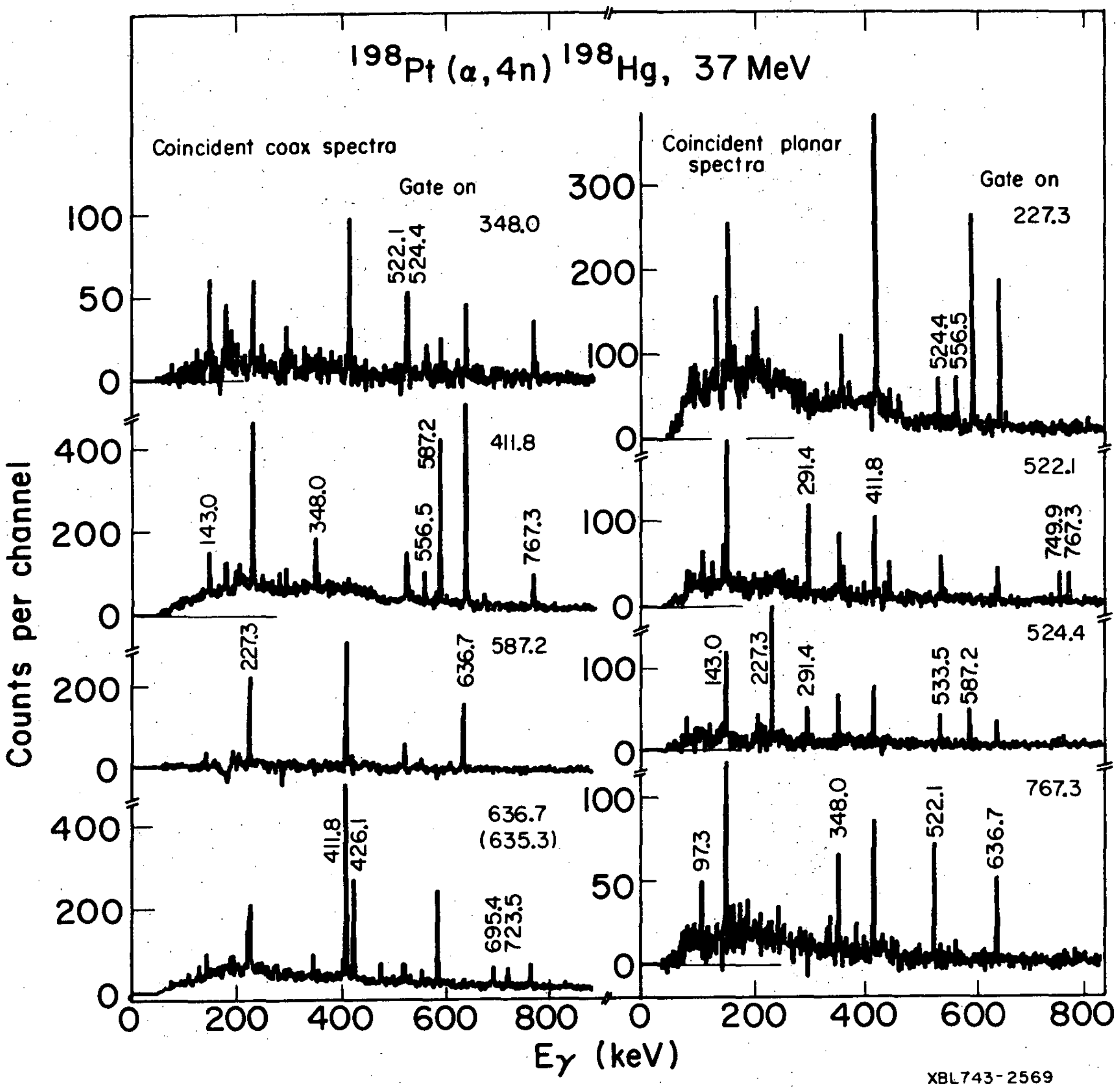

Counts per channel
×10⁴
0
1
2
3
×10²
0
5
194(195)Pt+α, 47 MeV, IB & OB
45°
232.7
261.7 (195Au)
278.4 (195Hg)
279.7
90° (a)
232.7
261.7 (195Au)
278.4 (195Hg)
279.7
600
700
800
×10³
5
10
×10²
0
2
4
198(196)Pt+α, 47 MeV, IB & OB
45°
477.7
511.0
522.1
524.4
556.5
560.4
587.2
636.7 + 635.3
90° (b)
477.7
511.0
522.1
524.4
556.5
560.4
587.2
636.7 + 635.3
1300
1500
1700
Channel number
XBL743-2570

Fig. 2



^{198}Pt (α,4n) ^{198}Hg, 37 MeV
Coincident coax spectra
Coincident planar spectra
Gate on
348.0
522.1
524.4
411.8
143.0
348.0
556.5
587.2
767.3
587.2
227.3
636.7
636.7 (635.3)
411.8
426.1
695.4
723.5
227.3
524.4
556.5
522.1
291.4
411.8
749.9
767.3
524.4
143.0
227.3
291.4
533.5
587.2
767.3
97.3
348.0
522.1
636.7
Counts per channel
0
50
100
200
400
300
Eγ (keV)
0
200
400
600
800
XBL743-2569

Fig. 3

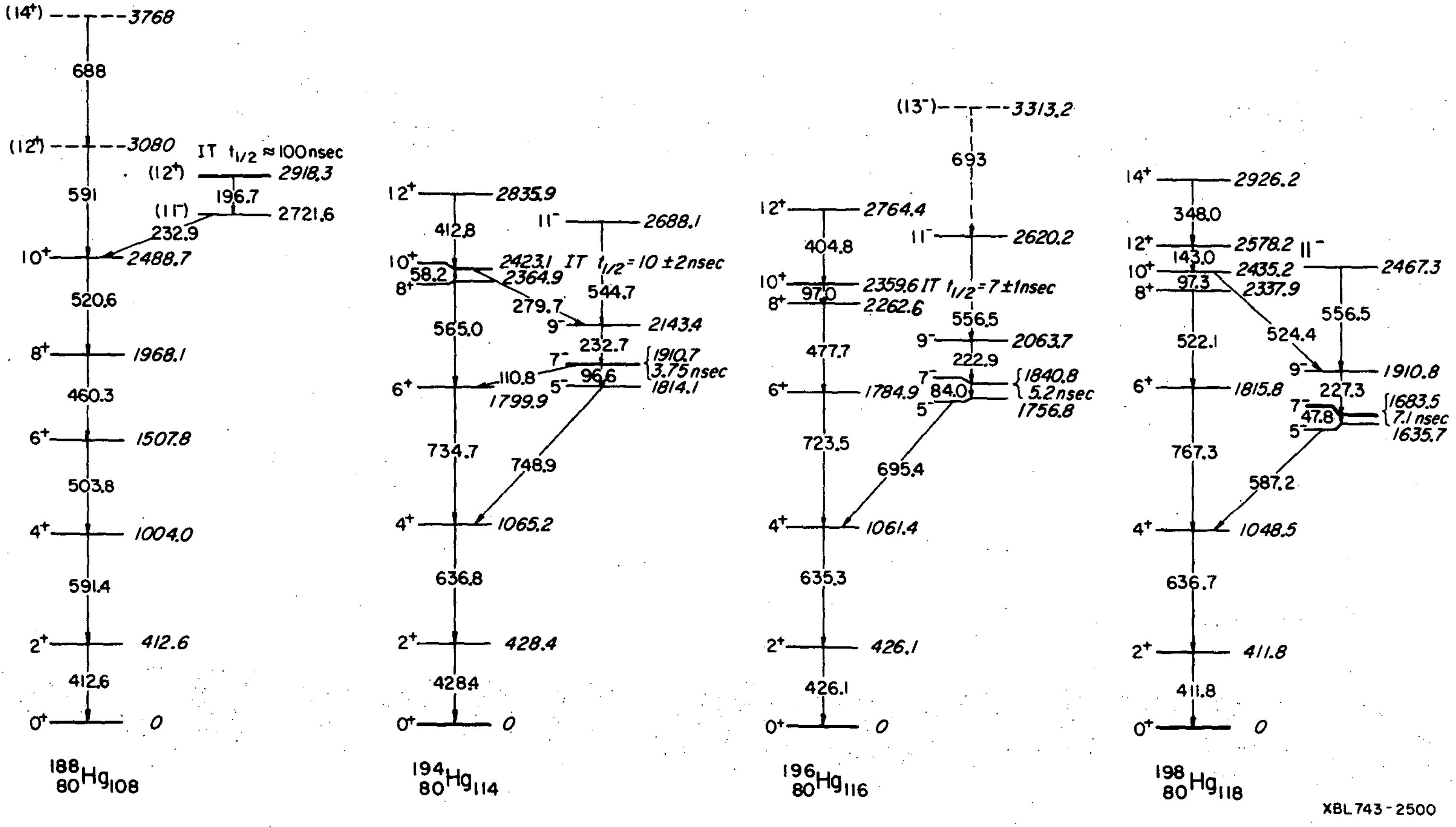
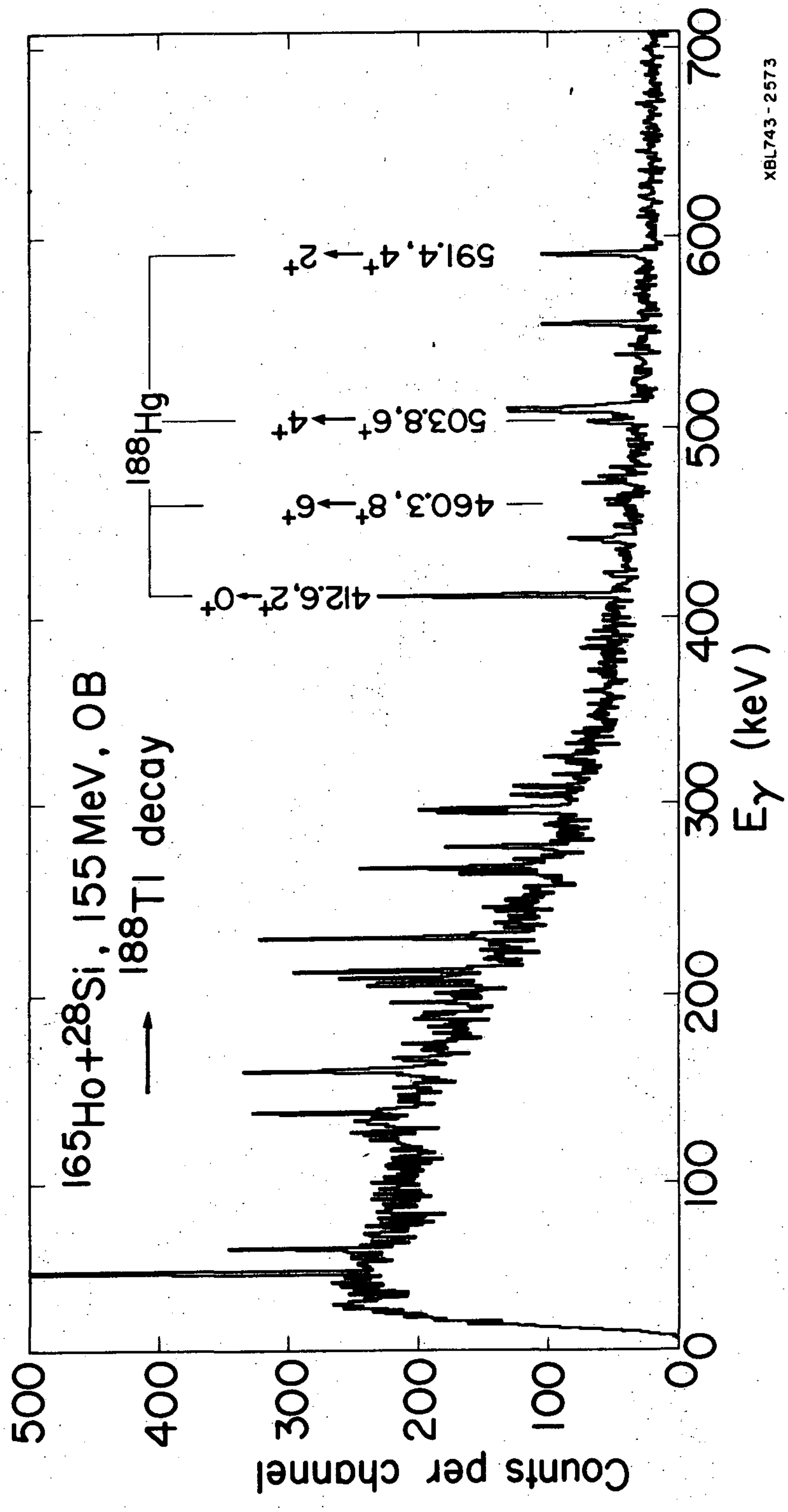

(14+) 3768
688
(12+) 3080
IT t1/2 ≈ 100nsec
(12+) 2918.3
196.7
(11-) 2721.6
591
232.9
10+ 2488.7
520.6
8+ 1968.1
460.3
6+ 1507.8
503.8
4+ 1004.0
591.4
2+ 412.6
412.6
0+ 0
188 80 Hg 108
12+ 2835.9
412.8
11- 2688.1
10+ 2423.1 IT t1/2 = 10 ± 2nsec
58.2
8+ 2364.9
544.7
279.7
565.0
9- 2143.4
232.7
7- 1910.7
3.75 nsec
110.8
96.6
6+ 1799.9
5- 1814.1
734.7
748.9
4+ 1065.2
636.8
2+ 428.4
428.4
0+ 0
194 80 Hg 114
(13-) 3313.2
693
12+ 2764.4
11- 2620.2
404.8
10+ 2359.6 IT t1/2 = 7 ± 1nsec
97.0
8+ 2262.6
556.5
9- 2063.7
477.7
222.9
7- 1840.8
5.2 nsec
6+ 1784.9
84.0
5- 1756.8
723.5
695.4
4+ 1061.4
635.3
2+ 426.1
426.1
0+ 0
196 80 Hg 116
14+ 2926.2
348.0
12+ 2578.2
11- 2467.3
143.0
10+ 2435.2
97.3
8+ 2337.9
556.5
524.4
522.1
9- 1910.8
227.3
6+ 1815.8
7- 1683.5
47.8
7.1 nsec
5- 1635.7
767.3
587.2
4+ 1048.5
636.7
2+ 411.8
411.8
0+ 0
198 80 Hg 118
XBL 743-2500

Fig. 4



XBL743-2573

Fig. 5

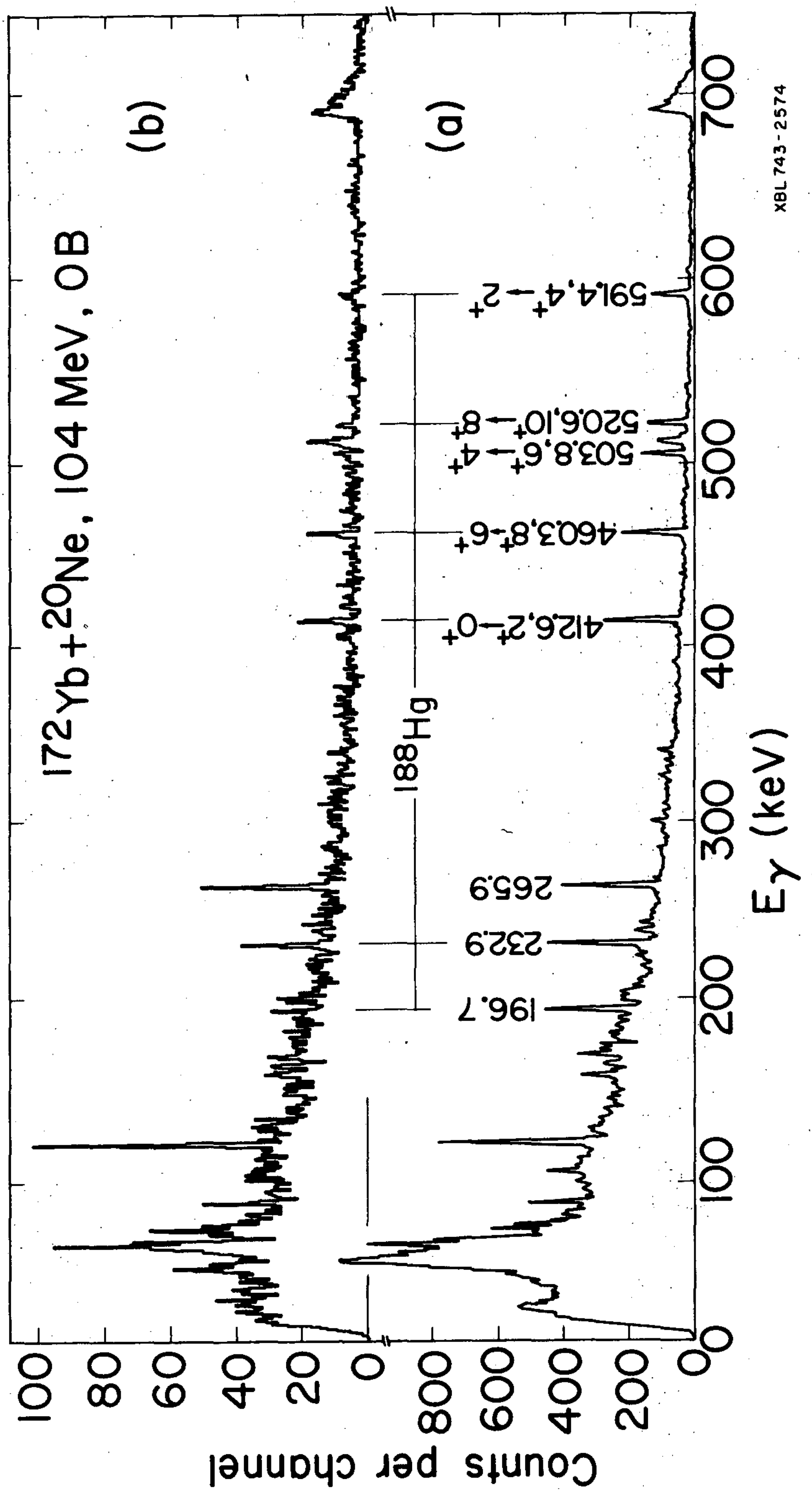
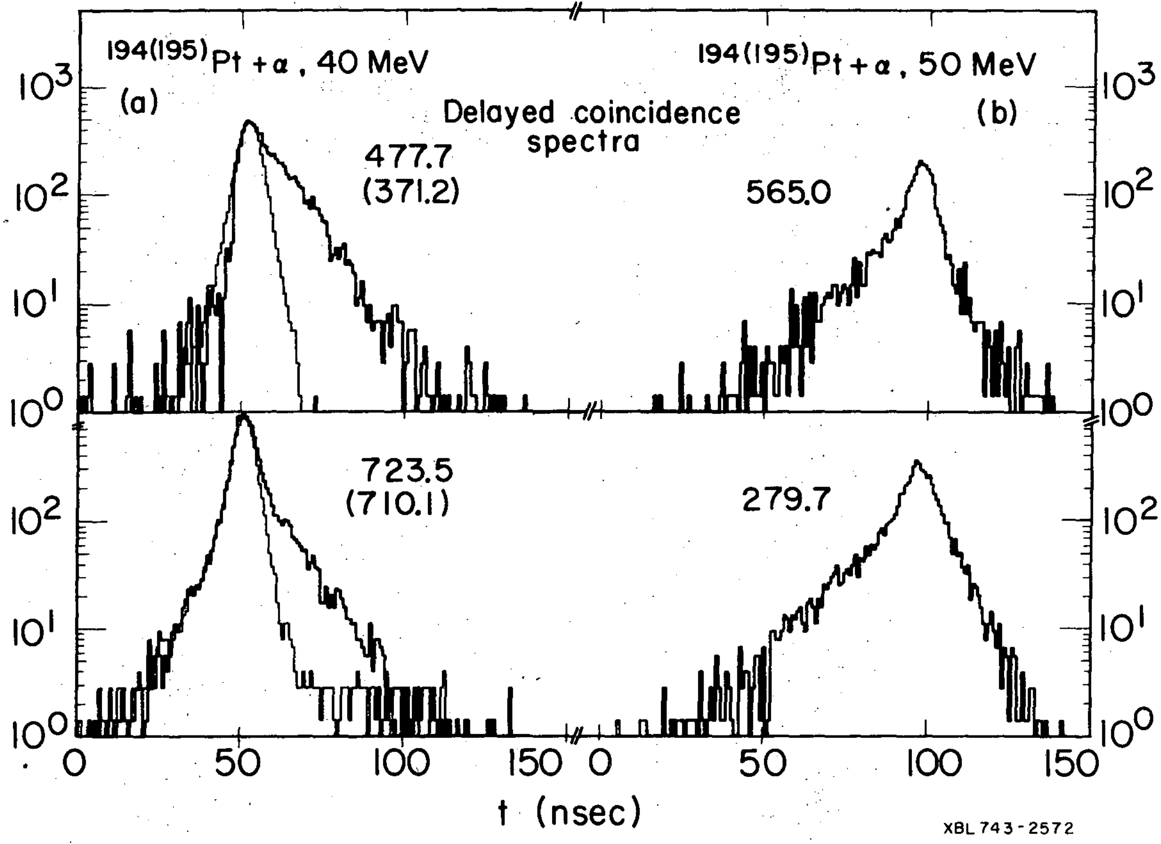
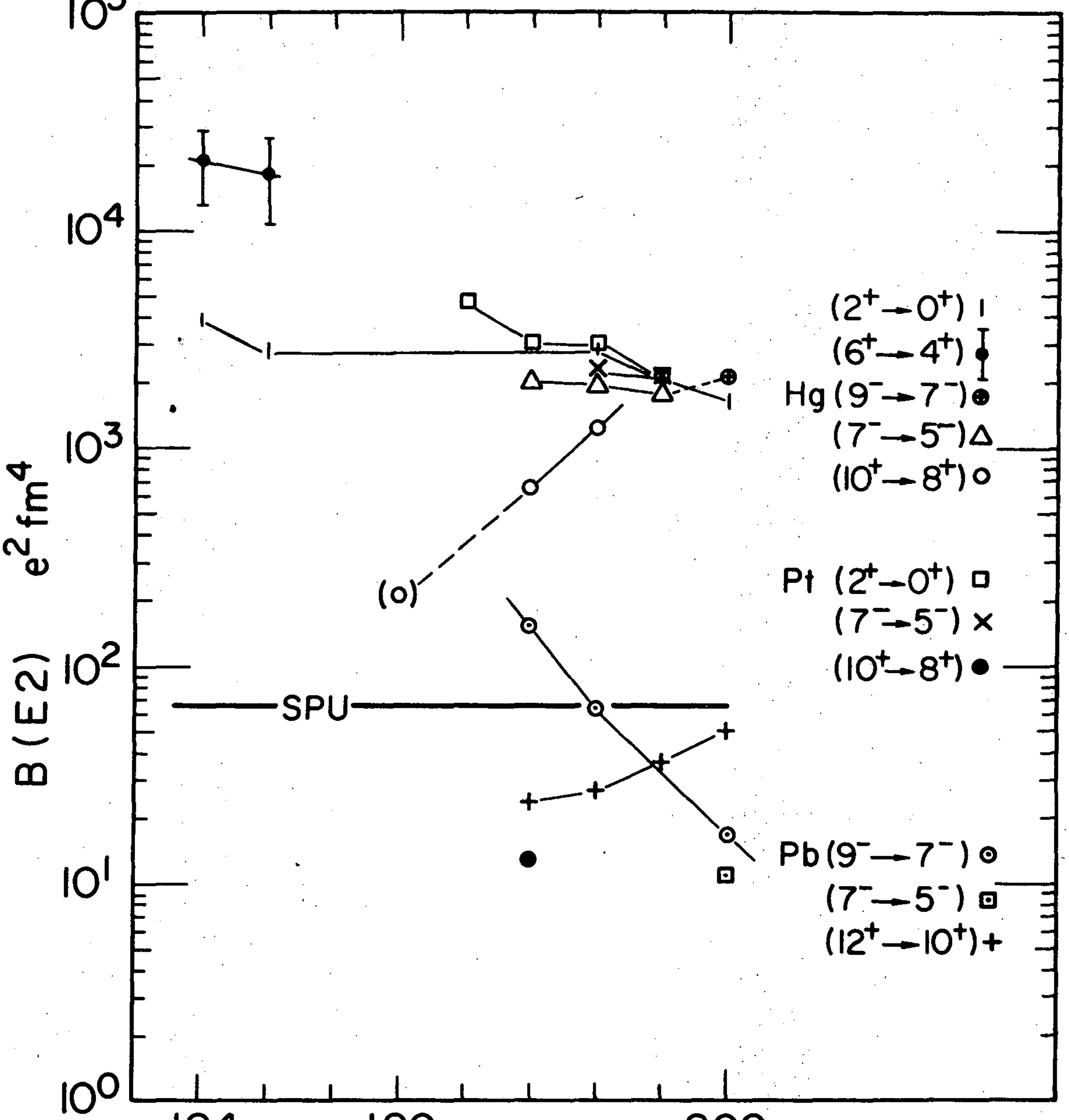

^{172}Yb+^{20}Ne, 104 MeV, 0B
(b)
(a)
^{188}Hg
196.7
232.9
265.9
412.6,2$^+$→0$^+$
460.3,8$^+$→6$^+$
503.8,6$^+$→4$^+$
520.6,10$^+$→8$^+$
591.4,4$^+$→2$^+$
Counts per channel
100
80
60
40
20
0
800
600
400
200
0
0
100
200
300
400
500
600
700
E$_\gamma$ (keV)
XBL 743-2574

Fig. 6



194(195)Pt + α, 40 MeV
(a)
194(195)Pt + α, 50 MeV
(b)
Delayed coincidence spectra
477.7
(371.2)
565.0
723.5
(710.1)
279.7
10^3
10^2
10^1
10^0
0
50
100
150
t (nsec)
XBL 743-2572

Fig. 7



XBL743-2499

Fig. 8

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