from B^{11} as well as C^{12} in terms of the optical model presents difficulties. The present investigation, however, is a definite demonstration of the value and sensitivity with which the mechanism of stripping reaction may be tested by means of n-γ angular correlation.

It seems that the dominant mechanism of observed stripping reaction can be analyzed in detail by observing stripped nucleon angular distribution along with n-γ angular correlation and/or stripped nucleon polarization.

The present investigation also casts some light on the observed difficulty of explaining the neutron angular distributions feeding ground, 4.43-MeV, and 12.73-MeV states of C^{12} by the (d,n) reaction on B^{11}. The fact that these neutron groups deviate radically from the plane-wave approximation, while the neutrons feeding the 15.11-MeV state show remarkable "good stripping" pattern, need not be puzzling, if one considers the significant distortion effects demonstrated by the present investigation.

ACKNOWLEDGMENTS

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Decay of Pt^{197}†

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The decay of $_{78}Pt^{197}$ (20 h) to $_{79}Au^{197}$ was studied by means of gamma-ray scintillation spectrometry. Three gamma-ray transitions of 77, 191, and 269 keV exist. The energy of the third transition was found to be (269.2±0.5) keV, instead of the previously reported value of 279 keV. A new decay scheme is proposed with only two excited states, at 77 and 269 keV. The possible effects of these results on the interpretation of measurements of the Coulomb excitation of Au^{197} and of the decay of Hg^{197} are discussed.

I. INTRODUCTION

THE primary purpose of this study was to remeasure the energy and relative intensity of the highest energy gamma ray in the decay of Pt^{197} (20 h).[1] Previously, this energy had been reported to be 279 keV.[2,3] This value is inconsistent with the interpretation of this transition as the cross over from the 269-keV level which is depopulated by a cascade made up of transitions of 191 and 77 keV. The level scheme proposed in Ref. 2 is shown in Fig. 1.

The low-energy levels of Au^{197} are also populated by the decay of Hg^{197m} (24 h), Hg^{197} (65 h), and the Coulomb excitation of Au^{197}. Also shown in Fig. 1 are the decay schemes[1,4–7] associated with these processes. These results establish the existence of levels in Au^{197} at about 269 and 279 keV. (Conversion-electron measurements[4,6] definitely show that these are distinct levels.)

The samples used in this study consisted of platinum metal enriched in Pt^{196} (2% Pt^{198}, 66% Pt^{196}, 26% Pt^{195}, 6% Pt^{194}). The samples were irradiated in the Materials Testing Reactor in a flux of 2×10^{14} neutrons-sec^{-1}-cm^{-2} for about 12 h. After the Pt^{199} (30 min) activity had decayed several half-lives, the daughter activity Au^{199} was observable. The gold was then removed by solvent extraction of the chloride in ethyl acetate. The platinum was further purified by precipitation as ammonium chloroplatinate.[8] Gamma-ray spectra taken subsequently did not reveal the presence of any residual gold in the platinum.

Gamma-ray spectra are measured with a scintillation spectrometer consisting of a 3-in.×3-in. cylindrical NaI(Tl) crystal, DuMont 6363 photomultiplier, preamplifier, A-8 amplifier, and a 512-channel pulse-height analyzer. The crystal is mounted near the center of a

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[1] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences–National Research Council, Washington 25, D. C.), NRC 5-1-17 to 5-1-19, and 5-1-21 to 5-1-28. See data on Au^{197}, Pt^{197}, and Hg^{197}.

[2] V. R. Potnis, C. E. Mandeville, and J. S. Burlew, Phys. Rev. **101**, 753 (1956).

[3] M. C. Joshi and B. V. Thosar, in *Proceedings of the International Conference on Nuclear Structure, Kingston, Canada*, edited by D. A. Bromley and E. W. Vogt (University of Toronto Press, Toronto, 1960), p. 623.

[4] J. W. Mihelich and A. de-Shalit, Phys. Rev. **91**, 78 (1953).

[5] See references in Table IV.2 of K. Alder, A. Bohr, T. Huus, B. Mottelson, and A. Winther, Rev. Mod. Phys. **28**, 432 (1956).

[6] D. H. Rester, M. S. Moore, F. E. Durham, and C. M. Class, Nucl. Phys. **22**, 104 (1961).

[7] P. H. Stelson and F. K. McGowan, Phys. Rev. **99**, 112 (1955).

[8] The author wishes to express his appreciation to L. D. McIsaac for carrying out the chemical separations.

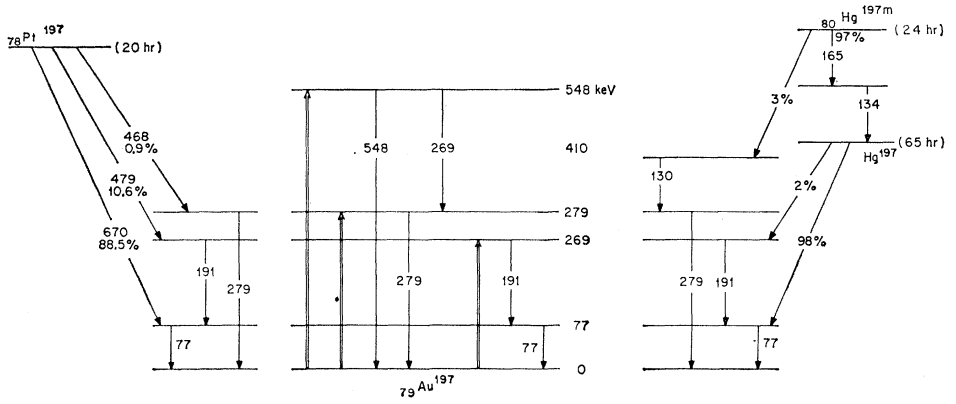

FIG. 1. Level structure of Au^{197} as observed in the Coulomb excitation of Au^{197} and the decay of Pt^{197}, Hg^{197}, and Hg^{197m}. (See Refs. 1–7.) All energies are in keV.

32-in.×32-in.×32-in. lead shield which is lined with cadmium. Most of the spectra are measured with the source 10 cm from the flat face of the crystal and on the crystal axis. An electron absorber of beryllium (1.18 g/cm^2) is usually used. In some cases, an absorber of tantalum (0.015-in. or 0.6 g/cm^2) was also used in order to reduce the intensity of the 77-keV gamma ray.

In general, to measure accurately the energy of a gamma-ray transition by means of scintillation spectrometry, the relationship between the gamma-ray energy and the observed pulse height must be known. This relationship for this complete spectrometer system[9] is shown in Fig. 2. (It is interesting to note that this response curve is the same as the response measured for NaI(Tl) crystals.[10] Thus, this result does not indicate the presence of any nonlinearity in our electronic system.)

The energy of a gamma ray can also be measured by comparing its pulse height with that of another gamma ray of known energy and nearly the same pulse height. In this case the data in Fig. 2 are only needed to determine the change in the "average keV/channel" between the two photopeaks. In either method the stability of the "zero" of the pulse-height scale places a limit on the accuracy of the results. The zero of the multichannel analyzer has been adjusted to be at -0.5 ± 0.1 channel. Long-term checks have not revealed any drift. It is believed that these checks would detect shifts of 0.1 channel or more. It is felt that the short-term drift is less than this amount.

II. EXPERIMENTAL RESULTS

The primary effort in this study was to obtain an accurate measurement of the energy of the 269-keV transition. This was done by comparing the pulse height of this gamma ray with that of the (279.12±0.05) keV [11] gamma ray from Hg^{203}. In order to eliminate the problem of gain shift in the photomultiplier or any other portion of the system, a spectrum of Pt^{197} and Cs^{137}, together, was measured. Then a spectrum of Hg^{203} and Cs^{137} was recorded. These are shown in Fig. 3. Visually, one can see that the two Cs^{137} photopeaks are almost exactly at the same pulse height, which indicates that the gains of the two spectra are the same (≈5 keV/channel). It is also clear that the Hg^{203} peak lies about 2 channels higher in pulse height than the corresponding platinum peak. Therefore, the Pt^{197} gamma ray must have an energy of about 269 keV.

In order to obtain more accurate values for the positions of these photopeaks, a Gaussian function was fitted to each of the photopeaks by use of the least-

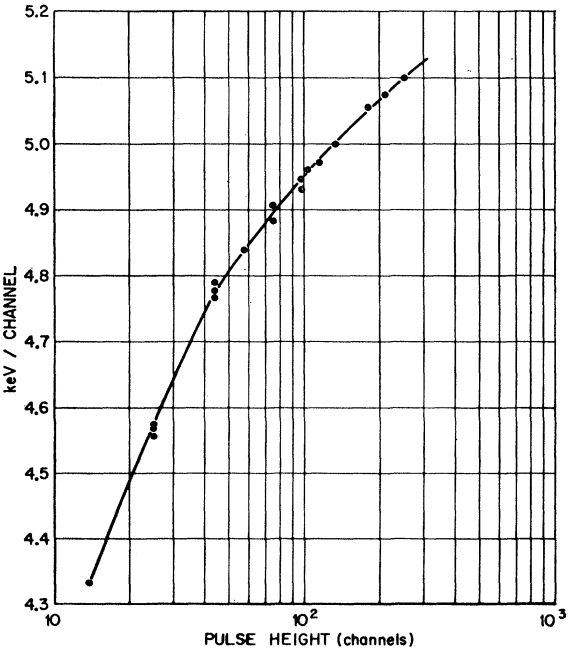

FIG. 2. Energy versus pulse-height relationship for gamma-ray scintillation spectrometer as reported in Ref. 9. (This figure includes some additional data that was not available when this reference was published. Also, both coordinates have been rescaled to correspond to 5 keV per channel at the Cs^{137} photopeak.)

[9] R. L. Heath, IRE Trans. Nucl. Sci. **9**, 294 (1962).

[10] D. Engelkemeir, Rev. Sci. Instr. **27**, 589 (1956); and W. Managan and C. E. Crouthamel, in *Applied Gamma-Ray Spectrometry*, edited by C. E. Crouthamel (Pergamon Press, Inc., New York, 1960).

[11] K. Edvarson, K. Siegbahn, and A. H. Wapstra, quoted in G. J. Nijgh, A. H. Wapstra, L. T. M. Ornstein, N. Salomons-Grobben, J. R. Huizenga, and O. Almen, Nucl. Phys. **9**, 528 (1958).

TABLE I. Comparison of energies of Hg^{203} and Pt^{197} gamma rays.

Experimental data	Run No. 1		Run No. 2	
Source	$Hg^{203}+Cs^{137}$	$Pt^{197}+Cs^{137}$	$Hg^{203}+Cs^{137}$	$Pt^{197}+Cs^{137}$
Cs^{137} peak (channels)	131.16±0.04	131.11±0.05	131.60±0.03	131.42±0.06
Hg^{203} peak (channels)	57.17±0.01		57.43±0.01	
Pt^{197} peaks (channels)		55.14±0.03		55.30±0.07
		39.98±0.01		40.15±0.01
Comparison of 269- and (279.12±0.05)-keV transitions				
keV/channel at 279 and 269 keV		4.88±0.01		4.86±0.01
difference $Hg^{203}-Pt^{197}$ (channels)		2.02±0.04		2.08±0.08
(keV)		9.86±0.20		10.11±0.40
Average pulse heights on standard gain scale (Cs^{137} peak in channel 132.324)				
Hg^{203} peak		57.71±0.03		
Pt^{197} peaks		55.66±0.05		
		40.39±0.03		

squares technique. As a check on the results, the experiment was carried out with a second source. The results of these two measurements are given in Table I. The errors quoted in the Table are those derived from the results of the least-squares fits and do not include any estimate of possible systematic errors.

From the data in Table I and Fig. 2, the energy of the 191-keV transition is found to be (191.8±0.5) keV, which agrees well with an average of (191.6±0.3) keV for the values from conversion-electron measurements listed in Ref. 1.

For the 269-keV transition, the data in Table I yield an energy of (269.2±0.2) keV by comparison with Hg^{203}. This uncertainty includes only those errors listed in Table I which are from the least-squares fit. When reasonable values for errors not considered in this analysis of the data are included, the final value for the energy of this transition is (269.2±0.5) keV.

The sum of the energies of the two cascade transitions is (191.8±0.5)+(77.345±0.004)=(269.1±0.5) keV. (The value 77.345 keV is from Ref. 12.) Therefore, the three transition energies are consistent with the inter-

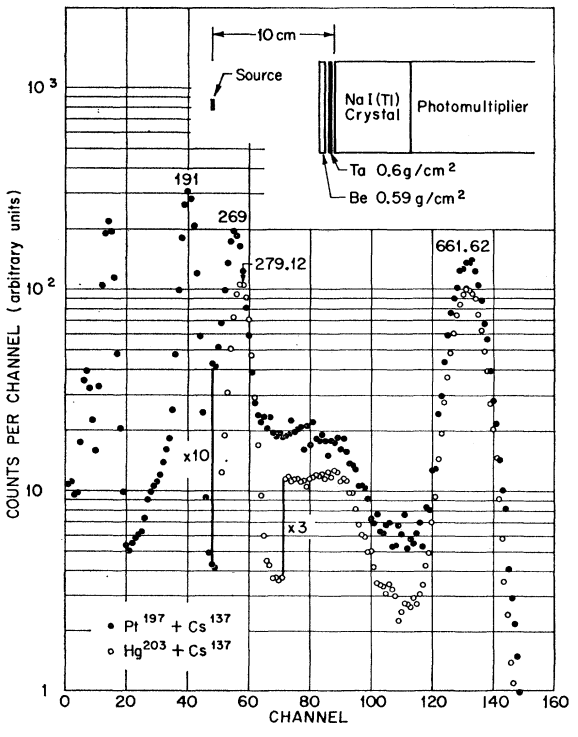

FIG. 3. Gamma-ray spectra of $Pt^{197}+Cs^{137}$ and $Hg^{203}+Cs^{137}$. Energies are in keV.

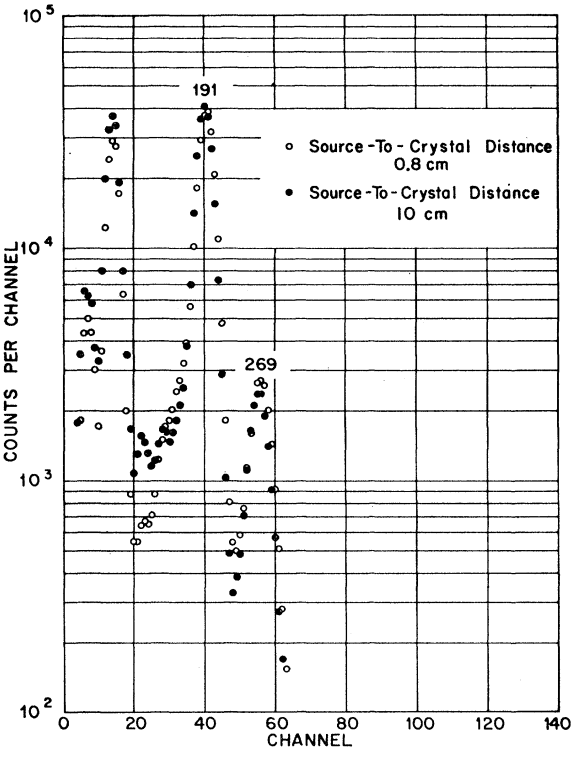

FIG. 4. Gamma-ray spectra of Pt^{197} measured with source-to-crystal distances of 10 and 0.8 cm. The geometric arrangement is the same as shown in Fig. 3, except for the source-to-crystal distance.

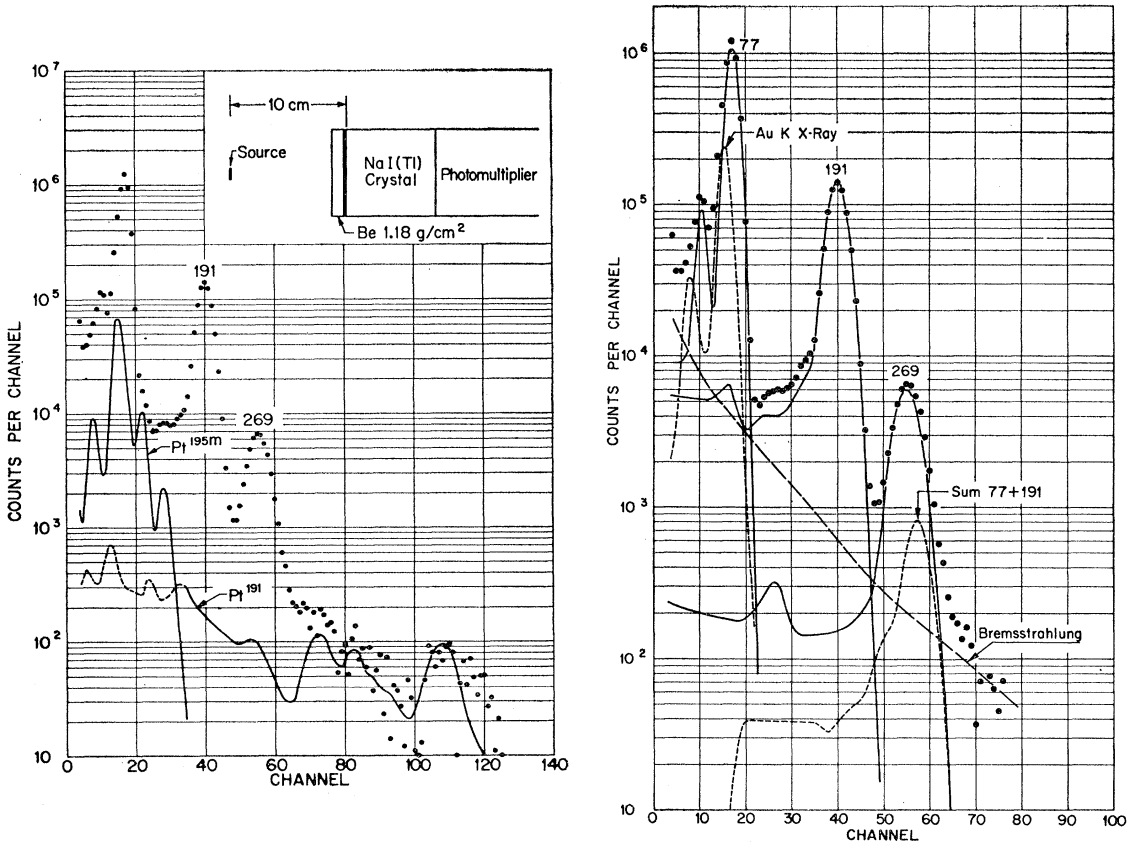

FIG. 5. (a) Gamma-ray spectrum of Pt^{197}. The contributions from Pt^{195m} and Pt^{191} were determined from spectra of aged samples (b) Gamma-ray spectrum of Pt^{197} after the subtraction of the Pt^{195m} and Pt^{191} contributions. The various components which make up the spectrum are shown. The energies are in keV.

pretation of the 269-keV transition as the crossover from a level at 269.1 keV.

The spectra in Fig. 4 were measured in order to demonstrate that the coincidence summing, real and accidental, between the 191- and 77-keV gamma rays does not affect the above energy measurements. This conclusion follows from the low intensity of this sum peak with the source at a distance of only 0.8 cm, and the fact that the intensity of this peak relative to that of the 191-keV gamma ray is approximately proportional to the solid angle subtended by the crystal. The fact that there is so little summing between these coincident radiations, even with the source at 0.8 cm, is due to the presence of the tantalum absorber. This reduces the intensity of the 77-keV gamma ray, and thus the sum peak, by more than an order of magnitude relative to the 191-keV gamma ray.

The relative gamma-ray intensities which are given in Table II were determined from the spectra shown in Fig. 5. The amounts of Pt^{191} (3.0 day) and Pt^{195m} (4.1 day) present are shown in Fig. 5(a). These intensities were determined from spectra of aged samples. The decomposition of the Pt^{197} spectrum into individual gamma rays is shown in Fig. 5(b). The spectral distributions for the single gamma rays were estimated from those of Hg^{203} (279 keV), In^{114m} (192 keV), and Co^{61} (68 keV).[13] The Au K x-ray shape was estimated from

TABLE II. Experimental results for gamma-ray transitions.

Energy (keV)	Photon intensity (relative to 191)	Transition intensity (relative to 77)
Au K x rays	550±50	110[a]
77		440	100[b]
191.8±0.5	100	20[c]
269.2±0.5	6.4±0.8	0.6[d]

[a] This value is based on $\alpha_K(191)=2.0$ as reported in Ref. 3.
[b] This value is based on $\alpha=4.2$ as quoted in Ref. 1.
[c] This value is based on $\alpha_K=2.0$ and $K/L=6.0$ as reported in Ref. 3.
[d] This value is based on $\alpha=0.3$ which is the theoretical value for an $M1$ transition.

[12] I. Marklund and B. Lindstrom, Arkiv Fysik **22**, 422 (1962).
[13] The Tl K x rays in the Hg^{203} spectrum were removed by comparison of this spectrum with that of Cr^{51}. The 0.55- and 0.72-MeV gamma rays from In^{114m} were subtracted by use of gamma-ray distributions obtained from our shape generation program discussed in Ref. 9. The escape peak in the 77-keV shape was reduced by the amount corresponding to the energy difference of 9 keV.

that of the Pt K x ray in the spectrum from Pt^{195m}. The bremsstrahlung distribution was assumed to be the same as that measured for a source of Kr^{85} (end-point energy=670 keV). The sum spectrum was calculated by convoluting the distributions for the 77- and 191-keV gamma rays.[9]

The intensity of the sum spectrum was computed relative to the intensity of the 191-keV gamma ray from a knowledge of the crystal efficiency and the conversion coefficient of the 77-keV transition ($\alpha=4.2$ from Ref. 1). The K x-ray intensity was computed relative to that of the 191-keV gamma ray on the basis of the measured K-conversion coefficient of 2.0.[3] The intensities of the 3 gamma rays and the bremsstrahlung were computed by least-squares fits.

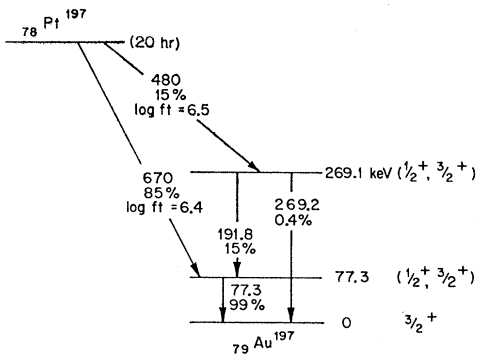

FIG. 6. Proposed decay scheme for Pt^{197}. The gamma-ray transition intensities are from Table II. The beta-ray energies are from Ref. 3. The spin assignments are discussed in Ref. 1 and in the text.

III. DECAY SCHEME

The proposed decay scheme for Pt^{197} is shown in Fig. 6. The placement of the 77- and 191-keV transitions has been determined by previous coincidence, intensity, and Coulomb excitation measurements.[1] The energy measurements reported herein rule out the possibility that the 269-keV transition goes from the 279-keV level to the ground state. Therefore, this transition is interpreted as the cross over from the 269-keV level to the ground state. The gamma-ray transition intensities are from Table II. Since no beta-ray branch to the ground state has been observed,[1] the data were used to calculate the beta branching in percent of decays. The beta energies are from Ref. 3.

IV. DISCUSSION

The spin of the ground state of Au^{197} has been measured[1] to be $\frac{3}{2}$. In the independent-particle model of the nucleus[14] the 79th proton is in a $d_{3/2}$ level. Therefore, it is presumed that this ground state has positive parity. Conversion-electron coefficient measurements[1] indicate that the multipolarity of the 77-keV transition is $M1+E2$. This fact, together with the log ft value of the electron-capture branch to this level from Hg^{197}, indicates that the 77-keV state has positive parity and a spin of $\frac{1}{2}$ or $\frac{3}{2}$. There is some preference for spin $\frac{1}{2}$.[1] The most recent conversion-coefficient measurements indicate that the 191-keV transition has $E0+M1$ character.[3] (Some other measurements[1] are consistent with an $M1$ character.) If this result is correct, it requires that the 269-keV level have the same spin and parity as the 77-keV state. It would then follow that the multipolarity of the 269-keV transition is $M1$ or $M1+E2$.

The same levels in Au^{197} are populated by Coulomb excitation of Au^{197} and the decay of Hg^{197} and Pt^{197}. If the proposed decay scheme is correct, the 269-keV transition must also occur in the decay of Hg^{197} (65 h). Preliminary measurements[15] do indicate the presence of the 269-keV transition in the decay of Hg^{197}. The failure to observe the conversion electrons from this transition in the past was probably due to their low intensity.

In Coulomb excitation experiments, both 279- and 269-keV transitions have been observed.[5–7] However, the 269-keV transition was not interpreted as the cross over from the 269-keV level but as a transition from the 548- to the 279-keV state. (See Fig. 1.) This interpretation was based on two arguments. First, no such transition from the 269-keV level had been reported in the decay of Pt^{197} or Hg^{197}. Second, Stelson and McGowan[7] had observed coincidences between two gamma rays of about 275 keV in their Coulomb excitation experiments. The new decay scheme for Pt^{197} would require that the observed 269-keV transition be reinterpreted as a combination of the transitions from the 548- and 269-keV levels. Since there have been no measurements of the conversion coefficients of the two 269-keV transitions and there are no published data on the relative electron intensities of the 191- and 269-keV transitions observed in Coulomb excitation, it is not possible to determine if the excitation data are consistent with our interpretation.

[14] M. G. Mayer and J. H. D. Jensen, *Elementary Theory of Nuclear Shell Structure* (John Wiley & Sons, Inc., New York, 1955).

[15] R. G. Helmer (unpublished).