

by measurement of the vapor pressure of the bath. The measurement of the thermoelectromotive force consisted in a determination of the difference in voltages before and after application of the magnetic field. By this procedure, any extraneous thermoelectromotive forces in the circuit were canceled.

It was observed that when the power applied to the heater was not sufficient to keep the hot junction well inside the shield, this junction occurred in the part of the tin wire emerging from the top of the shield where a strong field gradient exists. This junction was then at some temperature between 3.72°K and the bath temperature and resulted in the observed electromotive force being too low.

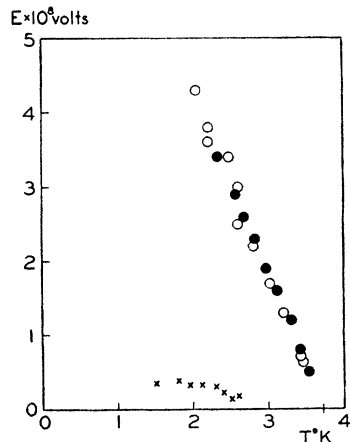


FIG. 1. Thermoelectromotive force of the superconducting-normal junction of tin as a function of temperature; O these data, ● Steele (reference 1), X Keesom and Matthijs (reference 2).

The values of thermoelectromotive forces determined in this way are shown in Fig. 1 and compared with the results of Steele and of Keesom and Matthijs. All values of  $E$  shown in Fig. 1 are relative to the thermoelectromotive force of the superconducting-normal junction at the transition temperature (3.72°K) which was set equal to zero. The agreement with the results of Steele is excellent. The data of Keesom are lower by a factor of approximately ten.

Further work is in progress and will be reported at a later date.

<sup>1</sup> M. C. Steele, Phys. Rev. **78**, 308 (1950).

<sup>2</sup> W. H. Keesom and C. J. Matthijs, Physica **5**, 437 (1938).

### Decay of Hg<sup>197</sup>

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PREVIOUS measurements<sup>1,2</sup> have indicated that Hg<sup>197</sup> exists in two isomeric states Hg<sup>197</sup> (23 hr.) and Hg<sup>197</sup> (65 hr.) decaying independently by  $K$ -capture into Au<sup>197</sup>. About 96 percent of the transitions of Hg<sup>197</sup> (23 hr.) are associated with a cascade of two strongly converted gamma-rays  $\gamma_1$  and  $\gamma_2$  with energies  $E_1=164$  and  $E_2=133$  kev. The half-life of the intermediate state<sup>3,4</sup> and the angular correlation of the successive conversion electrons<sup>5</sup> have been measured recently.

To determine the conversion coefficients of these gamma-rays and especially the ratio  $N_K/N_L$ , we measured the spectrum (Fig. 1) of the conversion lines of Hg<sup>197</sup> with a magnetic lens spectrometer.<sup>6</sup> Thin sources were prepared with the previously described evaporation technique.<sup>5</sup>

The lines designated as 164<sub>K</sub>, 164<sub>L</sub>, 164<sub>M</sub>, and 133<sub>K</sub>, 133<sub>L</sub>, 133<sub>M</sub> are the conversion lines of  $\gamma_1$  and  $\gamma_2$ , respectively. From the accurately determined ( $K-L$ ), and especially ( $K-M$ ) differences, we must conclude that these gamma-rays are converted in Hg

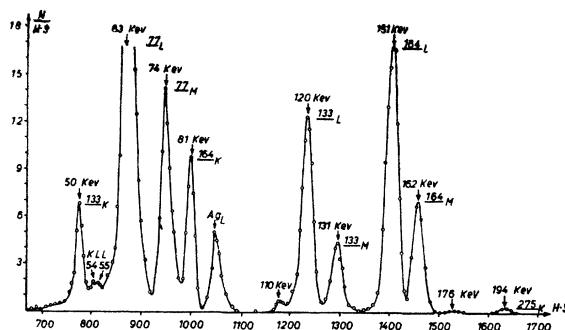


FIG. 1. Spectrum of the conversion electrons from Hg<sup>197</sup>. The counter window is 1.30 mg/cm<sup>2</sup> mica and the thickness of the source and backing is 0.25 mg/cm<sup>2</sup>.

and not, as previously assumed, in Au. The complete interpretation of Fig. 1 is listed in Table I.

TABLE I. Interpretation and intensity ratios of the measured lines of Hg<sup>197</sup>.

Decaying nucleus	Conversion lines	Converted in	Energy of $\gamma$ -ray in kev	$N_K$	$N_L$	$N_M$	$N_K : N_L : N_M + N^c$
Hg <sup>197</sup> (23 hr.)	164 <sub>K,L,M</sub>	Hg	$E_1=164$	100	223	100	
	133 <sub>K,L,M</sub>	Hg	$E_2=133$	71	181	62	
	275 <sub>K,L</sub> <sup>b</sup>	Au	$E_3=275$	4.8	1.4		
Hg <sup>197</sup> (65 hr.)	77 <sub>L,M</sub>	Au	$E_4=77$		680	190	
Hg <sup>197</sup> (23 and 65 hr.)	KLL		Auger electrons				
Cd <sup>107</sup> (6.7 hr.) <sup>a</sup> (contamination)	AgL		AgK masked by 77 <sub>L</sub>				

<sup>a</sup> Bradt, Gugelot, Huber, Medicus, Preiswerk, Scherrer, and Steffen, Helv. Phys. Acta **20**, 153 (1947).

<sup>b</sup> See reference 2.

<sup>c</sup> The ratios  $N_K:N_L:N_M$  are corrected for absorption in the counter window.

In addition, we measured the decay curve of the 77<sub>L</sub> and 77<sub>M</sub> conversion electrons in the spectrometer. They both show a genetic relation between Hg<sup>197</sup> (23 hr.) and Hg<sup>197</sup> (65 hr.), namely, except for four percent that decays by  $K$ -capture to Au<sup>197\*</sup> (7.4 sec.),<sup>2</sup> the Hg<sup>197</sup> (23 hr.) decays by an isomeric transition to Hg<sup>197</sup> (65 hr.). If the spectrometer measurements  $N_{133}^{\text{tot}}/N_{164}^{\text{tot}}=0.73$  are combined with counter coincidence results, the conversion coefficients of  $\gamma_1$  and  $\gamma_2$  can be determined. We find the

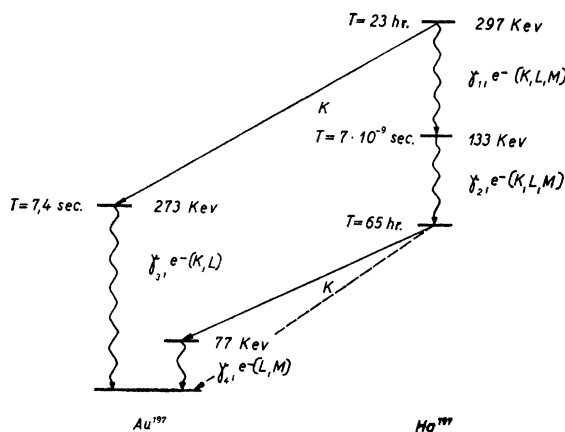


FIG. 2. Decay scheme of Hg<sup>197</sup>.

values  $\kappa_1^{tot} = N_e/(N_e + N_\gamma) \sim 0.9$ , and  $\kappa_2^{tot} \sim 0.7$ , or in terms of the  $K$ -conversion coefficients  $\alpha_1^* = N_K/N_\gamma \sim 4.5$  and  $\alpha_2^* \sim 0.53$ . These values, compared with the tables of Rose, Goertzel, Spinard, Harr, and Strong<sup>7</sup> for  $K$ -conversion coefficients seem to indicate  $\Delta l = 5$  or 4 for the  $\gamma_1$ -transition and  $\Delta l = 2$  for  $\gamma_2$ . With these values, the corresponding energies of the transitions, and the half-lives 23 hr. of  $\gamma_1$  and  $7.10^{-9}$  sec. for  $\gamma_2$ , a good fit is obtained with the lines for nuclear isomers given by Axel and Dancoff.<sup>8</sup> The proposed decay scheme is shown in Fig. 2.

Accurate values of the conversion coefficients and details of the experiments will appear in the *Helvetica Physica Acta*.

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<sup>1</sup> G. Friedlander and C. S. Wu, Phys. Rev. **63**, 227 (1943).

<sup>2</sup> Huber, Steffen, and Humbel, Helv. Phys. Acta **21**, 192 (1948).

<sup>3</sup> F. K. McGowan, Phys. Rev. **77**, 138 (1950).

<sup>4</sup> M. Deutsch and W. E. Wright, Phys. Rev. **77**, 139 (1950).

<sup>5</sup> Frauenfelder, Walter, and Zünti, Phys. Rev. **77**, 557 (1950).

<sup>6</sup> W. Zünti, Helv. Phys. Acta **21**, 179 (1948).

<sup>7</sup> Rose, Goertzel, Spinard, Harr, and Strong (privately circulated report).

<sup>8</sup> D. Axel and S. M. Dancoff, Phys. Rev. **76**, 892 (1949).

### Electron Spectrum\* of Pa<sup>233</sup>

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THE protoactinium used in this investigation was derived from the 23-min. Th<sup>233</sup> which was produced in the Oak Ridge pile by neutron capture in stable thorium. It was kindly made available to us by Dr. M. H. Studier of the Argonne National Laboratory.

The existence of a 27.4-day activity in protoactinium was first proposed by Meitner, Strassman, and Hahn;<sup>1</sup> it was later questioned by Hahn and Strassman,<sup>2</sup> and assigned to an isotope of zirconium. The final assignment to an isotope of protoactinium of mass number 233 was made and verified by other investigators.<sup>3</sup> Haggstrom<sup>4</sup> and Levy<sup>5</sup> have both previously investigated the conversion spectra and the beta-continuum using a 180° constant radius-type beta-spectrometer. Both found the end point of the beta-spectrum masked by conversion electrons but estimated it to be about 200 kev. Fulbright<sup>6</sup> proposed a beta-component with end point about 700 kev.

In the present investigation, a permanent magnet-type photographic beta-spectrometer was employed. Field strengths of approximately 200 and 600 gauss were used, which made it possible to cover continuously the energy range from 19 kev to 1.5 Mev. The photographic plates used were Eastman Kodak, Type NTB with emulsions 25μ thick. They were processed in Eastman Kodak Type D-8 developer for maximum contrast. In all, 46 conversion and three weak Auger lines were observed, all of which are confined to energies less than 411 kev. Absorption of the gamma-rays in lead revealed no gamma-radiation harder than 400 kev. Absorption in beryllium and aluminum gives a beta-end point agreeing with that found by Haggstrom<sup>4</sup> and

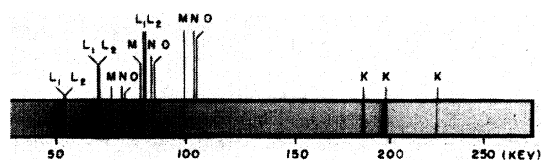


FIG. 1. Predominant lines in the low energy conversion spectrum of Pa<sup>233</sup>.

TABLE I. Interpretation of the conversion spectrum of Pa<sup>233</sup>.

Electron energy	Proposed interpretation	Energy sum (kev)	Gamma-energy (kev)
23.5	$M^{II,II,III}$	28.9	28.9
24.6	$M^{IV^1}$	28.9	
27.5	$N^1$	28.9	
28.5	$O^1$	28.9	
19.6	$L_{II}^2$	40.6	40.6
35.2	$M^{II,II,III}$	40.6	
39.1	$N^2$	40.5	
36.3	$L_{II}^3$	58.1	58.1 <sup>a</sup>
37.1	$L_{II}^3$	58.1	
53.8	$L_{II}^4$	75.6	75.7
54.7	$L_{II}^4$	75.7	
70.2	$M^{II,II,III}$	75.6	
74.3	$N^4$	75.7	
75.3	$O^4$	75.7	
65.2	$L_{II}^5$	87.0	
66.1	$L_{II}^5$	87.1	
81.7	$M^{II,II,III}$	87.1	87.1
85.7	$N^5$	87.1	
86.8	$O^5$	87.2	
82.6	$L_{II}^6$	104.4	104.5
83.5	$L_{II}^6$	104.5	
99.0	$M^{II,II,III}$	104.4	
103.2	$N^6$	104.6	
104.1	$O^6$	104.5	
156.6	$K^7$	272.6	272.6
250.9	$L^7$	272.7	
185.6	$K^8$	301.6	301.5
279.6	$L^8$	301.4	
296.1	$M^8$	301.5	
197.5	$K^9$	313.5	313.1
291.3	$L^9$	313.1	
307.5	$M^9$	312.9	
311.5	$N^9$	312.9	
226.6	$K^{10}$	342.6	342.0
320.2	$L^{10}$	342.0	
336.0	$M^{10}$	341.4	
340.1	$N^{10}$	341.5	
260.6	$K^{11}$	376.6	376.5
354.5	$L^{11}$	376.4	
283.8	$K^{12}$	399.8	399.9
378.1	$L^{12}$	399.9	
394.6	$M^{12}$	400.0	
300.4	$K^{13}$	416.4	416.4
394.6	$L^{13}$	416.4	
411.0	$M^{13}$	416.4	
88.8	Auger $L_I$	110.6	$K-M$
93.4	Auger $L_I$	115.2	$K-N$
108.8	Auger $M$	114.2	$K-N$

\*  $M$  or  $N$  lines could not be seen because of interferences of the very strong lines at 53.8 and 54.7 kev.

Levy;<sup>5</sup> no trace of a harder beta-component such as that reported by Fulbright<sup>6</sup> was found.

Since Pa<sup>233</sup> decays by beta-emission, the  $K-L-M$  x-ray differences employed in determining the energy of the gamma-rays will be characteristic of uranium. In the low energy portion of the spectrum, where the resolution of the instrument used is greatest, the  $L$  shell fine structure can be resolved into two components whose separation is 0.8 kev. It is important to mention, however, that no conversion could be detected in the  $L_{III}$  sub-shell. A photographic reproduction of the low energy spectrum appears in Fig. 1; the observed electron lines along with their interpretation is summarized in Table I. No satisfactory interpretation could be found for the line at 139.5 kev. It was consequently deleted from Table I. All gamma-rays listed fit well into the proposed level scheme of Fig. 2. While no claim to uniqueness for such a scheme is possible at this time, it is to be noted, however, that all possible transitions were observed with two exceptions. The least energetic of these is dotted in on the level scheme, since it is necessary to the scheme if it is to be