values $\kappa_1^{tot}=N_e/(N_e+N_\gamma)\sim 0.9_5$ and $\kappa_2^{tot}\sim 0.7_0$, or in terms of the K-conversion coefficients $\alpha_1^K=N_K/N_\gamma\sim 4.5$ and $\alpha_2^K\sim 0.53$. These values, compared with the tables of Rose, Goertzel, Spinard, Harr, and Strong[7] for K-conversion coefficients seem to indicate $\Delta l=5$ or 4 for the γ_1-transition and $\Delta l=2$ for γ_2. With these values, the corresponding energies of the transitions, and the half-lives 23 hr. of γ_1 and 7.10^{-9} sec. for γ_2, a good fit is obtained with the lines for nuclear isomers given by Axel and Dancoff.[8] 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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* Hebrew University, Jerusalem.

[1] G. Friedlander and C. S. Wu, Phys. Rev. **63**, 227 (1943).
[2] Huber, Steffen, and Humbel, Helv. Phys. Acta **21**, 192 (1948).
[3] F. K. McGowan, Phys. Rev. **77**, 138 (1950).
[4] M. Deutsch and W. E. Wright, Phys. Rev. **77**, 139 (1950).
[5] Frauenfelder, Walter, and Zünti, Phys. Rev. **77**, 557 (1950).
[6] W. Zünti, Helv. Phys. Acta **21**, 179 (1948).
[7] Rose, Goertzel, Spinrad, Harr, and Strong (privately circulated report).
[8] D. Axel and S. M. Dancoff, Phys. Rev. **76**, 892 (1949).

Electron Spectrum* of Pa^{233}

H. B. KELLER† AND J. M. CORK
University of Michigan, Ann Arbor, Michigan
AND
Argonne National Laboratory, Chicago, Illinois
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THE protoactinium used in this investigation was derived from the 23-min. Th^{233} 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;[1] it was later questioned by Hahn and Strassman,[2] 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.[3] Haggstrom[4] and Levy[5] 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[6] 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[4] and Levy;[5] no trace of a harder beta-component such as that reported by Fulbright[6] was found.

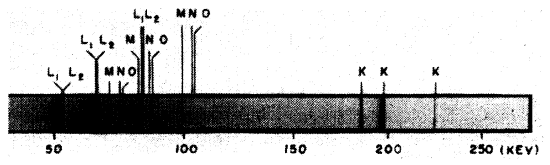

FIG. 1. Predominant lines in the low energy conversion spectrum of Pa^{233}.

TABLE I. Interpretation of the conversion spectrum of Pa^{233}.

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

[a] M or N lines could not be seen because of interferences of the very strong lines at 53.8 and 54.7 kev.

Since Pa^{233} 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

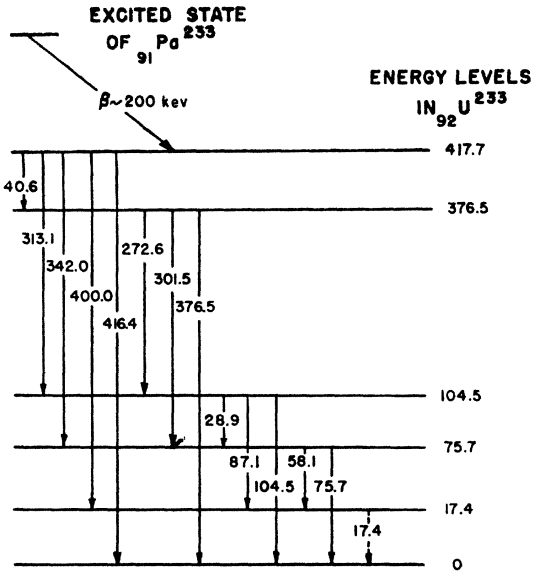

FIG. 2. Proposed level scheme (kev) for U^{233} following beta-emission from Pa^{233}.

self-consistent. Unfortunately, this gamma-ray lies below the lower detection limits of the apparatus.

The facilities of the Argonne National Laboratory were kindly put at our disposal for this work.

* This investigation was made possible by the joint support of the ONR and AEC.

† Phoenix Project Fellow, University of Michigan.

[1] Meitner, Strassman, and Hahn, Zeits. f. Physik **109**, 538 (1938).
[2] O. Hahn and F. Strassman, Naturwiss. **28**, 543 (1940).
[3] Seaborg, Gofman, and Kennedy, Phys. Rev. **59**, 321 (1941); Grosse, Booth, and Dunning, Phys. Rev. **59**, 322 (1941).
[4] E. Haggstrom, Phys. Rev. **59**, 322 (1941).
[5] P. W. Levy, Phys. Rev. **72**, 352 (1947).
[6] H. W. Fulbright, P.P.R. CP-1954 (August 1944, unpublished).

Superfluidity and Thermomechanical Effect in the Absorbed Helium II Film

EARL LONG AND LOTHAR MEYER
Institute for the Study of Metals, University of Chicago, Chicago, Illinois
July 7, 1950

DURING measurements on the adsorption of He gas below 2.19°K, in which the formation of the Rollin film from the unsaturated vapor was indicated,[1] the observed speed of approach to equilibrium suggested that superfluidity occurs even in the adsorbed film, without the presence of bulk liquid. This was investigated by measuring the rate of flow through superleaks, in the manner previously described for liquid HeII,[2] except that the superleaks were usually connected to a copper-stainless steel chamber containing 75 g of adsorbent (Fe_2O_3), the assembly being one of considerable heat capacity. Several different leak geometries were used, either 0.013- or 0.008-cm diameter×2.5-cm long Pt wires sealed into Pyrex glass, or a leak made by pressing together two optically flat stainless steel circular plates of 1 cm diameter, the bottom plate having a central exit hole of 0.08 cm diameter. The widths of the leaks were determined by gas flow measurements at the helium boiling point; they varied from 1 to 9×10^{-5} cm. The onset of superfluidity could be established by measuring the quantity of He passing through the leaks in a given time as a function of the temperature T and the saturation P/P_0, P being the pressure in the adsorption system, and P_0 the vapor pressure of the liquid.

Superfluidity does indeed occur in the adsorbed films, and in a rather striking manner. The temperature at which superflow is observed is not only a function of P/P_0 (i.e., the number of adsorbed layers), but is also determined by the pressure difference (Δp) across the superleak. With a small pressure difference across the leak ($\Delta p \ll P$), it is found that superflow occurs at all saturations above $P/P_0 \sim 0.15$, corresponding to $1\frac{1}{2}$ statistical layers, at all temperatures[3] below 2.186°K.

These results suggest that superfluidity occurs (within our accuracy of ±0.002°) at the λ-temperature of the bulk liquid, independent of the number of layers adsorbed, i.e., that the temperature at which the properties of HeII appear is independent of the number of layers.[4] This could be confirmed by a simple experiment. The adsorption system was loaded with a certain P/P_0 at HeII temperatures, and was slowly warmed; the saturation stayed substantially constant up to the normal λ-point, then changed practically discontinuously when passing the λ-point. The effect has been observed down to $P/P_0=0.35$, and is especially conspicuous at $P/P_0>0.95$ (more than 30 layers adsorbed). The pressure difference between the adsorption system and the bath (~3 cm on a differential oil manometer) disappears abruptly when warming through the λ-point, and reappears again on cooling back to the HeII region. These results suggest the possibility that the transition HeII—HeI becomes first order in the adsorbed layers.

The superflow is extremely sensitive to the slight fluctuations of the bath temperature. A normal rate of flow from the adsorption system to the collection system could be either greatly *increased* or even *reversed* by raising or lowering the bath temperature by a few ten-thousandths of a degree.

A typical experiment is shown in Fig. 1, for a system at 2.173°K and $P/P_0=0.26$ (~2 adsorbed layers), in which the bath vapor pressure variation (dotted curve) and the change of pressure in the collection system (solid curve) are plotted against time. The

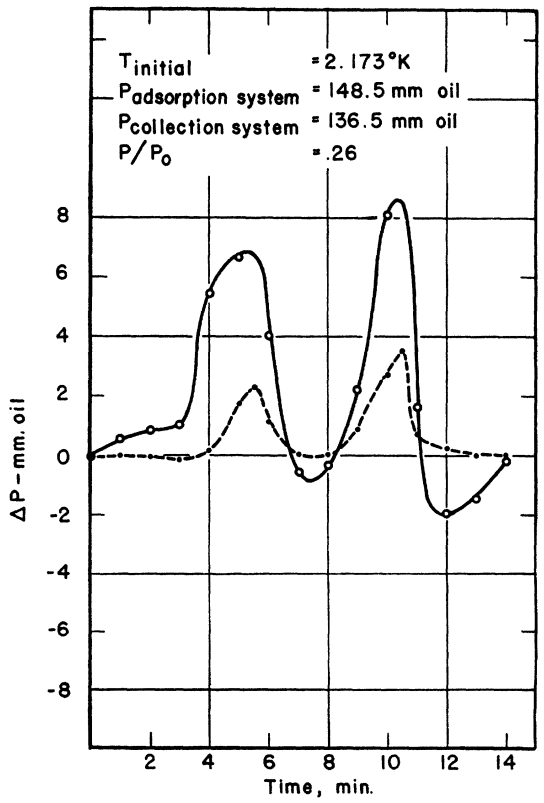

FIG. Variations of the bath vapor pressure and the pressure change in the collection system.

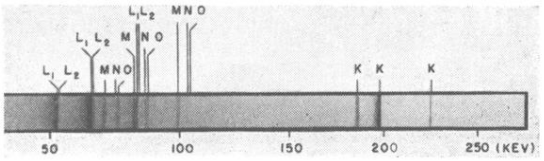

FIG. 1. Predominant lines in the low energy conversion spectrum of Pa^{233}.