no appreciable change in effective mass nor in the electrical properties.

Superconductivity arises from interactions for which the energy denominators are small and for which the second-order perturbation theory breaks down. The condition

$$\Sigma_{k'}|a_{kk'}|^2 > \sim 1 \qquad (8)$$

requires first that the temperature be sufficiently low, otherwise $\coth[(\epsilon_{k'}-\epsilon_k)/2\kappa T]$ is large, and second that the matrix elements be sufficiently large compared with $(\hbar\omega_{kk'})_{\mathrm{Av}}$. The second of these conditions is *essentially the same as the criterion* (5) and the interactions involved are those for which $|\epsilon_{k'}-\epsilon_k| < \sim\Delta E$. Those for which $|\epsilon_{k'}-\epsilon_k| > \sim\Delta E$ and for which the perturbation theory is valid are expected to be the same in the normal and superconducting states and can be taken into account by redefining the Bloch functions as in Eq. (6).

The wave functions in the superconducting phase at $T=0°\mathrm{K}$ have been taken to be of the form[1]

$$\Psi_k = N_k(q_r)(\psi_k + \Sigma_{k'} b_{kk'} q_{kk'} \psi_{k'}), \qquad (9)$$

where the sum is over k' such that $|\epsilon_{k'}-\epsilon_k| < \Delta E$. Normalization is given by the factor $N_k(q_r)$, the $b_{kk'}$ are chosen to give a minimum energy, and the $\psi_{k'}$ are Bloch functions modified as indicated above. The minimum is now obtained when k' runs only over the normally unoccupied states. The wave functions are similar to those previously discussed; the energies of states near E_F are depressed to give a small effective mass as shown in Fig. 1. Electrical properties are similar to those of a metal with a small concentration of electrons (actually holes, since the configuration is similar to that of an almost filled band) with small effective mass. We have shown that such a model leads to the London equations.[4]

Nevertheless, the theory is unsatisfactory. If, as previously assumed, the interactions in Eq. (9) do not occur in any way in the normal phase, the calculated energy difference between the normal and superconducting phases is too large.[1] This suggests that these interactions do occur in the normal phase, but in such a way that the effective mass is not altered. An adequate theory for the transition, including a criterion for superconductivity, requires better wave functions for both the normal and superconducting phases.

[1] J. Bardeen, Phys. Rev. **80**, 567 (1950). This reference may be used for definitions of the symbols used above.

[2] H. Fröhlich, Phys. Rev. **79**, 845 (1950).

[3] Private communication.

[4] J. Bardeen, Phys. Rev. **79**, 167 (1950); Phys. Rev. **81**, 829 (1951). The cooperative nature of the phenomenon is believed to come from the fact that such an energy reduction will depend markedly on the distribution of electrons in *k*-space.

[5] The derivation will be published elsewhere. The matrix elements should be determined by a self-consistent field procedure as was done for the calculation of the conductivity of monovalent metals. See J. Bardeen, Phys. Rev. **52**, 688 (1937).

Complex Alpha-Spectrum of U^{235}

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It has been possible to resolve the alpha-particle radiation emitted by U^{235} into at least three groups by use of our alpha-pulse analyzer. The material used for this work had been highly enriched relative to U^{234} as well as U^{238}, so that the alpha-radiation from U^{234} was only about 35 percent of the total activity.

The sample used for pulse analysis consisted of approximately 100 μg of uranium electrodeposited onto an area 15 mm in diameter on a thin platinum plate. A collimator consisting of a brass ring, 3 mm high and 27 mm in diameter, was placed around the sample so that the sample area was centered. The purpose of the collimator is to eliminate from detection those alpha-particles which emerge from the sample at a small angle relative to the plane of the sample mounting; these are the particles which contribute most to the low energy straggling observed at 2π-geometry because of sample self-absorption and backscattering. This type of collimator enables one to obtain 35 percent geometry with an almost negligible low energy straggling; for a thin sample the low energy "tail" is down to *ca* 0.1 percent at a point approximately 150 kev lower than the peak.

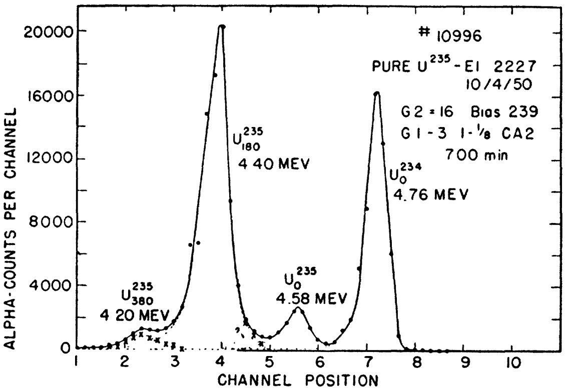
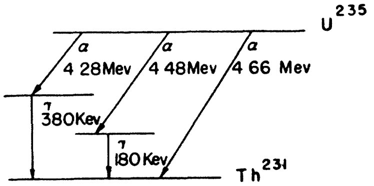


FIG. 1. Pulse analysis of U^{235} alpha-particles.

A typical pulse analysis obtained with our 48-channel differential alpha-pulse analyzer is shown in Fig. 1. By comparison with a pulse analysis of radioactively pure samples of U^{234} and U^{238}, it can be shown by a process of elimination that the isotope U^{235} is responsible for the peaks at 4.58, 4.40, and 4.20 Mev. The 4.58-Mev peak had previously been suspected because of a 180-kev gamma-ray which has been observed[1-4] in high abundance associated with U^{235}. The 4.20-Mev peak is a new group, and the low abundance 380-kev gamma-ray which would be associated with it has not been reported by any workers in this field. The possibility of a fourth alpha-particle group at 4.47 Mev is suggested by the shape of the main U^{235} peak when it is compared with the U^{234} peak.

FIG. 2. Proposed decay sequence of U^{235}.



The abundances of the various groups[5] and their consequent partial alpha-half-lives are as follows:

U_0^{235}	4.58 Mev	10.2 percent	6.99×10^9 years
U_{180}^{235}	4.40 Mev	85.6 percent	8.33×10^8 years
U_{380}^{235}	4.20 Mev	4.2 percent	1.70×10^{10} years.

These are calculated on the basis of Nier's value for the total half-life of U^{235} of 7.13×10^8 years.[6]

The decay sequence of U^{235} is presumably that given in Fig. 2.

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[1] M. H. Studier, reported in Metallurgical Laboratory Report CC-3056 (July, 1945), unpublished.

[2] R. L. Macklin and W. S. Miller, Uranium Project Report A-3640 (April, 1946), unpublished.

[3] B. F. Scott, Argonne National Laboratory Report CC-3715 (January 1947), unpublished.

[4] R. L. Macklin, Phys. Rev. **76**, 595 (1949).

[5] In the interest of clarity, a new nomenclature is suggested for the subscript labeling of alpha-energy groups. Such subscripts would denote the energy difference in kev between the ground state and each group; thus, for U^{235} the ground-state transition is indicated as U_0^{235}, the next highest energy group which would normally be called U_I^{235} is now labeled as U_{180}^{235}, and similarly U_{II}^{235} is called U_{380}^{235}.

[6] A. O. Nier, Phys. Rev. **55**, 150 and 153 (1939).