TABLE I. Calculated half-lives and conversion coefficients $E3$ transition in uranium.

Energy (kev)	Partial γ decay half-life (sec)	Conversion coefficient	Total half-life (sec)
10	1.1×10^{7}	10^{8}	0.1
5	1.4×10^{9}	10^{10}	0.1
1	1.1×10^{14}	10^{14}	1
0.5	1.4×10^{16}	10^{16}	1
0.1	1.1×10^{21}	10^{20}	10

deformed well, suggests that the most likely assignments consistent with all information are $\frac{1}{2}+$ (asymptotic quantum numbers $N=6$, $n_z=3$) and $\frac{7}{2}-$ ($N=7$, $n_z=4$). The isomeric transition would accordingly be $E3$.

The transition energy is deduced to be 2.2 kev or less assuming N_{II}, N_{III} conversion according to the following reasoning: if the electrons are taken to be 1 kev and they resulted from M-shell conversion (largely M_{II} and M_{III} levels), there should also be sizable numbers of electrons from N-shell conversion; these would have energies of about 5 kev. Neither Shliagin's electron spectrum nor our absorption measurements gave evidence for such electrons. Consequently, the soft electrons must come from conversion in N shell or higher. With less confidence the similar argument can be made that the electrons are not converted in the N shell because the N and O edges differ by $\sim$1 kev. If the observed electrons come from O-shell conversion, the transition energy would be 1.2 kev or less. Obviously, more information must be obtained before the isomeric transition energy can be decided.

Interestingly enough, the calculated lifetime for this transition is almost independent of decay energy in the energy range of interest. The gamma-ray emission half-lives based on the single-proton transition relations of Moszkowski[13] are shown in Table I for a series of gamma energies, and also listed are internal conversion coefficients obtained by extrapolating Rose's[14] M-shell coefficients and assuming three-fold decrease for the N shell and for each successive shell. It is seen that the estimated decay half-lives change by an order of magnitude for a change in energy of a factor of 10. If we assume that for the U^{235m} case the measured half-life should be 1 second, this $E3$ transition is then slower than the calculated single-proton transition by a factor of 10^3. Such a degree of retardation is quite normal for $E3$ transitions (see Goldhaber and Sunyar[15]) although the great extrapolations involved in the present case probably mean that the agreement is fortuitous.

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27-Minute Isomer of U^{235}†

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THE favored alpha-decay transitions in odd-A nuclei systematically populate the rotational band for which the orbit of the last odd nucleon remains unchanged.[1] Since Pu^{239} has a measured spin[2] of $\frac{1}{2}$, the favored 5.150-Mev alpha-particle group of Pu^{239} is expected to populate an $I=\frac{1}{2}$ excited state of U^{235}, and by analogy with other odd-A nuclei, the α transition to the $\frac{7}{2}$ ground state[3] of U^{235} should be hindered by a large factor. On this model one also expects the 5.137-Mev and 5.099-Mev α groups of Pu^{239} to populate rotational members ($I=\frac{3}{2}$ and $\frac{5}{2}$) of the $K=\frac{1}{2}$, $I=\frac{1}{2}$ base state. Transitions from the $K=\frac{1}{2}$, $I=\frac{3}{2}$ and $\frac{5}{2}$ rotational states to the $K=\frac{7}{2}$, $I=\frac{7}{2}$ state are K-hindered ($\Delta K=3$) and one predicts these states to decay predominantly by $E2$ and $M1$ radiations to members of the rotational band. From the experimental observation that the above three α groups make up essentially all the Pu^{239} α transitions,[4] one predicts one low-energy transition with $\Delta I=3$ near the ground state of U^{235} for each Pu^{239} α disintegration (see Fig. 1).

An upper limit of four months for the half-life of the $I=\frac{1}{2}$ excited state of U^{235} was deduced from a spin measurement on U^{235}, produced by Pu^{239} alpha decay.[5] Counting experiments with scintillation and proportional spectrometers eliminated half-lives of less than or equal to four months for possible isomeric transitions in U^{235} with sufficient energy to convert in the M shell. We concluded, therefore, that the γ rays following the 5.150-Mev alpha particles were converting in the N shell or beyond with a half-life of less than four months.[5]

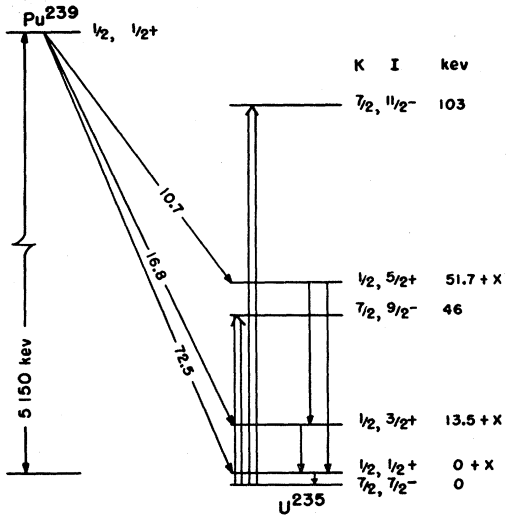

FIG. 1. Low-energy excited states of U^{235}. From α systematics the 27-min isomer of U^{235} is assumed to be the $K=\frac{1}{2}$, $I=\frac{1}{2}$ level, approximately 2 kev ($X\approx 2$ kev) above ground state. The three α groups shown (labeled with their percentage abundances) populated the rotational band, $I=\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$. An α group with calculated energy of 5.067 Mev has not been observed but is expected to populate the $K=\frac{1}{2}$, $I=\frac{7}{2}$ level in low intensity. Levels at 46 and 103 kev are reached by Coulomb excitation (J. O. Newton, private communication) and are assumed to be rotational members of the $K=\frac{7}{2}$, $I=\frac{7}{2}$ ground state.

A uranium sample was separated in a few minutes from Pu^{239} by (1) an ether extraction of U from a Pu^{239} solution reduced with Fe^{++} and saturated with ammonium nitrate, (2) equilibration of the ether with several similar washes, and (3) evaporation of the ether containing the U on a platinum plate. The samples were counted in a Bradley *PC*-11 proportional counter with a loop wire electrode. Least-squares analyses of decay curves give a half-life of 26.6 ± 0.3 minutes for the U^{235} isomer.[6] The error is the standard error calculated from the least-squares analysis. The counting rate in the Bradley counter increased sharply with applied voltage, a phenomenon characteristic of soft radiations. By adding a few alpha counts/min of uranium tracer, we calculated a yield of about one disintegration of the 27-min activity per 10 Pu^{239} disintegrations. Absorption experiments with U^{235m} samples prepared by a recoil technique on thin films serve to show that the electrons are of very low energy, $\lesssim 2$ kev. The low yield of the 27-min activity, $\approx 10\%$, is probably due to the failure of our counter to detect all the U^{235m} radiations, and we assume most of the Pu^{239} α transitions (see Fig. 1) populate the $I=\frac{1}{2}$, 27-min level in U^{235}. Experiments to determine more precisely the energy of the conversion electrons are in progress. Since U^{235m} decays predominantly by internal conversion in the N shell and beyond, it is an interesting case for observing the effects of electronic environment on half-life.

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Two-Pion Exchange Potential

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THE adiabatic nuclear potential involving the exchange of at most two pions has been studied extensively. It is possible to express this potential in terms of the scattering cross sections for pions;[1,2] thereby the self-mesonic field of each nucleon is treated exactly.[3] Since this form of the potential is a definite improvement over previous calculations, results of the numerical evaluations will be reported here.

The potential

$$V(x)=V_2+V_4+V_{sp}+V_{ss}$$

in reference 1 has been evaluated as follows. Functions $F_{\lambda\mu}(y,z)$ and $G_{\lambda\mu}(y,z)$ and their derivatives with respect to y and z were numerically integrated by transforming the integration path into the one along the imaginary axis and round the branching point $i\mu$. The quantity $f^2/4\pi$ was taken as 0.08. The total cross section σ_{33} and the scattering lengths a_i were derived from the phase shifts given by Anderson.[4] No cut-off function was employed in the calculation.

The results are shown in Figs. 1(a) and (b). In these curves, the S-wave contributions are rather small as compared to the P-wave part for $x\gtrsim 0.7$, the largest one being $V_{sp}=-0.027$ (at $x=1$) for charge singlet states.

The applicability of this potential is necessarily limited for two reasons, the neglect of three- or more-pion exchange and the adiabatic approximation. For the latter to hold, the kinetic energy of nucleons must be smaller than the total energy of exchange pions, that is, $V/\mu\ll 1$. At $x\sim 0.7$, our potential $V\approx\mu$ in some states. Thus, in such cases, it may be necessary to modify our results. In the region $x\gtrsim 0.7$, multiple pion exchange