absorber (radiation pressure). In the case where the absorption of energy is by free carriers, this radiation pressure is exactly the acoustoelectric effect. It follows that the ratio of attenuation constant to acoustoelectric field is determined entirely by wave dynamics and is independent of the detailed mechanism of the process.

From this reasoning, one finds that

$$\alpha = encE_{ae}/S,$$

where α is the attenuation per unit length, n the density of carriers, E_{ae} the acoustoelectric field, and S the power density of the wave (E_{ae}/S is independent of S). Using the value of E_{ae}/S observed by Weinreich and White,[2] one obtains for the logarithmic decrement

$$\alpha\lambda\approx 10^{-21}\, n \text{ at } 60 \text{ Mc/sec},$$

where λ is $(2\pi)^{-1}$ times the acoustic wavelength. This value is in agreement with Blatt's, but it is to be noted that it applies to liquid-air temperature (that being the temperature at which E_{ae}/S was measured). At higher temperatures, the effect will decrease not as $1/T$, as stated in reference 1, but as τ/T, where τ is the intervalley scattering time; the decrease of the latter is quite sharp, being characterized by a phonon activation energy of the order of 200°K.

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Isomeric State of Uranium-235

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THERE has been an apparent inconsistency in the data concerning the energy levels of U^{235} ever since it was noted that

(1) the ground state spin of U^{235} determined from optical-spectrum hyperfine structure is $\frac{7}{2}$,[1,2] and this is in agreement with Coulomb excitation studies;[3]

(2) the lowest lying state of U^{235} populated in the alpha-decay of Pu^{239} apparently has spin $\frac{1}{2}$, since it and the sequence of levels above it have the characteristics of a Bohr-Mottelson rotational band with spin $\frac{1}{2}$ base state;[4–6] and

(3) there is no obvious gamma-ray transition from the $\frac{1}{2}$ state to the $\frac{7}{2}$ state, even though virtually all Pu^{239} alpha transitions populate the spin $\frac{1}{2}$ state directly or indirectly.

This information suggests that Pu^{239} decays to an isomeric state of U^{235} which is either very long lived (to explain the failure to find the abundant $\frac{1}{2}\rightarrow\frac{7}{2}$ gamma-transition) or two states lie so close together that the radiation is not observable by usual methods. For an $E3$ transition in a heavy element it is improbable that the lifetime can be long, since, as will be pointed out at the end of this note, no matter how low the energy becomes, the conversion coefficient becomes correspondingly large. Nevertheless, on the supposition that the radiation was measurable but long lived, careful γ ray and conversion-electron measurements[7] were made in this Laboratory on a sample of Pu^{239} which had aged for several years and failed to show any radiations other than those previously seen. In addition, a chemical separation of uranium was made; this also gave no evidence for the isomeric transition.[8] Very recently Huizenga, Engelkemeir, and Tompkins[9] have looked at the optical spectrum of U^{235} removed from Pu^{239} and found only the $\frac{7}{2}$ state, setting a lower limit of six months for the half-life of an isomer of spin $\frac{1}{2}$. The alternate explanation that the radiation was too soft to be detected under the means employed therefore seemed more attractive; some evidence for this appeared to come from the measurement of the conversion-electron spectrum by Shliagin[10] who found 2-kev electrons which were fairly prominent. As will appear below, we have found the isomeric state decaying by the emission of very soft electrons, but these seem to be of even lower energy than those reported by Shliagin.

The isomeric state confirming these conclusions was found by collecting recoils from the alpha-decay of Pu^{239} and counting the U^{235m} in a windowless proportional counter. The samples were first collected on aluminum foils, using 600-volt negative potential to deposit the ions which had dissipated their recoil energy in air. Several samples so collected contained about 3000 counts per minute, which decayed to the background of 20 counts with a half-life of 26.5 ± 0.2 min. In one experiment a chemical separation of uranium from plutonium yielded a sample with the same decay characteristics, but the apparent yield was low because of self-absorption of the extremely soft electrons. By the recoil method from a sample of Pu^{239} which had a surface density of 1.5 micrograms/cm^2, the yield of soft electrons from the U^{235m} corresponded with 1 electron for each five Pu^{239} alpha-emission events. A sample of plutonium somewhat thicker ($\sim$7 μg/cm^2) gave an intensity of soft electrons of only 1%, so it is entirely reasonable that every Pu^{239} decay event goes through this isomeric transition.

A rough measure of the energy of the electrons was made by an absorber technique in which recoils were caught on thin plastic films and counted, with the sample alternately facing upward and downward. The "range" so determined indicated that the energy of the electrons is less than 1 kev. A plastic film of 2.5 micrograms/cm^2 thickness cut down the counting rate by a factor greater than 100, so there does not seem to be an appreciable number of electrons with energy even as high as 2 kev.

An examination of possible assignments of the two U^{235} levels according to Nilsson particle states[11,12] in a

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]