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SPONTANEOUS FISSION OF Am^{241}

V. L. MIKHEEV, N. K. SKOBELEV, V. A. DRUIN, and G. N. FLEROV

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AMONG the nuclei which undergo spontaneous fission those with an odd number of protons or neutrons are usually distinguished by the low probability of such fission, their half-lives being a few orders of magnitude longer than those of neighboring even-even isotopes.

Most of our information about the spontaneous fission of odd nuclei was obtained at different times by groups at Los Alamos and Berkeley. Segre and his group[1] determined the spontaneous fission half-lives of $U^{233,235}$, $Np^{237,239}$, Pu^{239}, and Am^{241}. In most instances they gave only the upper limit of the fission probability, because of the small samples available and the difficulty of working with these isotopes, whose low fission probability is accompanied by large specific α activity. Ghiorso and his group[2] studied the spontaneous fission of Bk^{249}, Cf^{249}, $E^{253,254}$ and Fm^{255}. Their careful experiments enabled them to determine the half-lives to within 25%; only in the case of Fm^{255} was merely the lower limit of $T_{1/2}$ established.

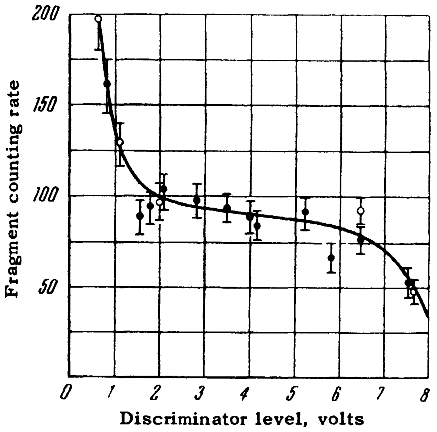
The recent development of a technique[3,4] employing detectors with high resolving power and millimicrosecond pulses permits experimentation under more favorable conditions. The work can now be done with large samples and an appreciable effect can be observed in a considerably shorter time.

The fragment detector used in the present work was a gaseous scintillation counter, with a xenon-filled chamber constructed of the high-vacuum materials copper and teflon. A photomultiplier was mounted in contact with a glass-covered window of the chamber; a layer of quaterphenyl ($\sim 50\ \mu g/cm^2$) on the inner surface of the glass served to transform ultraviolet radiation into visible light. Reflection from the magnesium oxide coating of the chamber wall enhanced light collection. The seal between the glass and the chamber was a teflon gasket. The chamber was evacuated to 5×10^{-6} mm Hg and was filled with xenon to 2 atmos. During vacuum conditioning, the chamber was heated by water vapor. A thin layer of americium was deposited electrolytically on a platinum backing; the amount of material ($\sim 60\ \mu g$ on an area of $1.8\ cm^2$) was determined by measuring the α activity of the layer.

A FEU-33 photomultiplier with $\sim 3 \times 10^{-9}$ sec resolution was used. Fission fragments were detected against the large alpha-particle background by means of a high-speed discriminator of the Moody type.[5] A DGTs-7 crystal diode was the nonlinear element of the circuit, which was triggered by a LP-34 secondary-emission tube sensitive to small signals.

A preliminary test was conducted with a Pu^{240} target, using the same geometry as with Am^{241} in the subsequent experiments. 1.20×10^{11} years was obtained for the spontaneous fission half-life of this plutonium isotope, in good agreement with other data.[6] A 30% reduction of pulse amplitude was observed after a month of work.

For the work with Am^{241} the apparatus was calibrated by placing in the chamber a target ($\sim 200\ \mu g$) of U^{235}, which possesses a large slow-neutron fission cross section. The entire counter was surrounded by paraffin, and a (Po + Be) neutron source was used to study the counting response (see the figure). The response was found to be essentially the same for Pu^{240} and for Am^{241}, when fragments were counted against a strong α-particle background. These experiments estab-



Counting response for two runs: ○ – at the beginning of the experiment with Am^{241}; ● – at the end of the experiment.

lished the optimum conditions for counting fission fragments from Am^{241}. Measurements with Am^{241} (~ 60 μg) were conducted for 160 hours with a 4-volt discriminator threshold. Twenty-six pulses were recorded; control experiments showed that at least 18 of these belonged to the background. The corresponding lower limit of the spontaneous fission half-life of Am^{241} is 2×10^{14} years.

The counter was surrounded by a layer of cadmium and paraffin in order to obviate neutron-induced fission. Imitation of the observed effect by the spontaneous fission of Cm^{242} impurity is excluded since an estimate showed that not more than 10^{-10}% of Cm^{242} could have been present.

In Segre's experiment[1] on the spontaneous fission of Am^{241} the target consisted of only $\sim 10^{-7}$ g and in 2700 hours three pulses from fission fragments were registered; this led to the lower limit $T_{1/2} \geq 1.4 \times 10^{13}$ years. The enhanced sensitivity of our technique resulted in a value of $T_{1/2}$ which is greater by a factor of ~ 15; this result is $\sim 10^5$ times greater than would be expected for an even-even nucleus with the given value of Z^2/A.

Approximately the same factor of lifetime increase was observed for the spontaneous fission of Pu^{239}, Bk^{249}, Cf^{249}, and $Es^{253,254}$. The spontaneous fission probabilities of the other odd nuclei must evidently be determined more precisely.

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ANGULAR ANISOTROPY OF GAMMA QUANTA THAT ACCOMPANY FISSION

V. M. STRUTINSKIĬ

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A certain anisotropy relative to the direction of fragment divergence was recently observed for the gamma quanta that accompany nuclear fission.[1] The gamma intensity is greatest in the direction of fragment divergence, and the magnitude of the anisotropy $[W_\gamma(180°) - W_\gamma(90°)]/W_\gamma(180°)$ amounts to 9 and 5% for the fission of Pu^{239} and U^{235} respectively by thermal neutrons. Leachman's review[1] mentions also one of the possible causes of the angular anisotropy, namely that the initial deformations of the fragments, and consequently also the initial electric moments of the fragments, are correlated in a definite manner with the fission direction. This explanation, however, is subject to the objection that the time required for the nucleus to radiate gammas with energies on the order of 1 Mev is too long for any reasonable value of the electric moments. The quanta are therefore emitted by the fragments apparently already after thermal equilibrium has been established and after the neutron evaporation. This is also confirmed by the fact that both the shape of the gamma spectrum and the number of gammas (~ 4 or 5 per fragment) are close to what is observed for gammas that accompany the capture of thermal neutrons.[2]

Another possible cause of angular anisotropy of the quanta may be the presence of a large fragment angular momentum correlated with the fission direction. The momentum dependence of the density of nuclear levels leads in this case to anisotropy of the quanta even if complete thermal equilibrium is established in the nucleus.[3,4] A fragment momentum of large magnitude, oriented relative to the