High-Energy Alpha Particles and Tritons from the Spontaneous Fission of Californium-252*

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The energy spectra of alpha particles and tritons emitted in the spontaneous fission of californium-252 have been measured using an $E-dE/dx$ cesium iodide scintillator-proportional counter detector. The alpha-particle energy spectrum peaks at 16 Mev, with a full width at half maximum of about 15 Mev. The tritons peak at about 8 Mev, with a half-width of 7 Mev. One alpha particle is observed per 345±20 fission events, one triton per 4500±900 fission events.

SINCE first reported by Alvarez in 1944,[1] the high-energy, low-mass particles emitted in connection with the fission process have been studied by several experimenters.[2–4] A summary of these results is the following; In the neutron-induced fission of uranium and plutonium, alpha particles are emitted with a strong angular correlation near 90° to the fission axis, and with energies approximately determined by a Gaussian with a peak at 10 Mev, and full width at half maximum of about 10 Mev. The frequency of emission is about one alpha particle per 300 fission events. Recently, a nuclear emulsion study on the alpha particles from californium-252 was reported.[5]

The detector used in this experiment was the $E-dE/dx$ detector described previously by Anderson *et al.*[6] It consists of a cesium iodide crystal and photomultiplier mounted directly behind a gas proportional counter. Pulses are extracted from both counters, amplified, and displayed on the x and y axes of a fast oscilloscope from which the trace is normally blanked off. A coincidence between the two pulses is arranged to provide a pulse which momentarily unblanks the oscilloscope trace at a time when the two amplified pulses reach their maximum values, and the resulting spot is photographed for later analysis. Since the product of E and dE/dx is approximately constant for a given particle, different particles plot as separated near-hyperbolas.

The californium source was generously loaned by A. Friedman of Argonne Laboratory. It was mounted in an evacuated chamber about one inch in front of the 900-μg/cm^2 nickel proportional counter window.

Calibration was accomplished in the following manner. With the proportional counter evacuated, the pulse heights in the cesium iodide of alpha particles from a thorium C-C′ source, after correction[7] for the nickel window, provided two calibration points. The published curves of relative pulse height versus energy[8] were then used to determine the rest of the energy scale. The energy scale for tritons is based on the assumption that the pulse-height response for tritons of these energies is the same as for protons. The energy scale was then determined by straightforward application of the range energy and pulse height curves.

The thickness of the foil and gas were such as to prevent fission fragments from reaching the crystal. However, the counting rate of the proportional counter for the fission fragments was measured. The counting rate for alpha particles and tritons was determined from the number of spots and known exposure times (typically a few hours) of the pictures. The quoted errors in the resulting ratios of alphas and of tritons are largely statistical and due to the low counting rates.

The energy distributions for alpha particles and tritons are shown in Figs. 1 and 2. These represent a total of 34 tritons and 445 alpha particles. The identification of the tritons was made from the location of

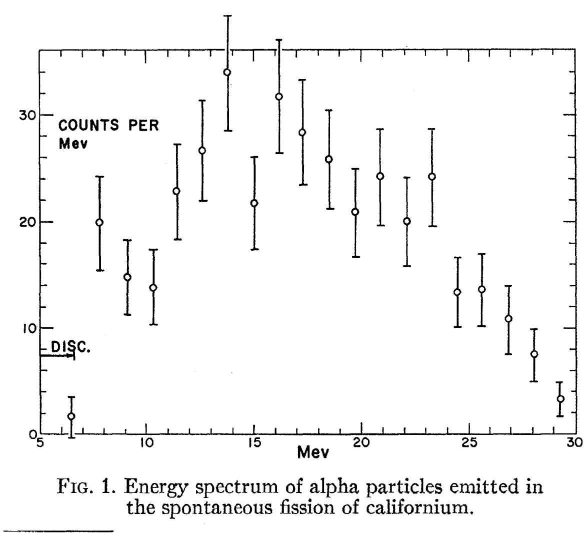

FIG. 1. Energy spectrum of alpha particles emitted in the spontaneous fission of californium.

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[3] D. L. Hill, Phys. Rev. **87**, 1049 (1952).
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[5] E. W. Titterton and T. A. Brinkley, Nature **187**, 229 (1960).
[6] C. E. Anderson, A. R. Quinton, W. J. Knox, and R. Long, Nuclear Instr. and Methods **7**, 1 (1960).
[7] W. Whaling, *Handbuch der Physik*, edited by S. Flügge (Springer-Verlag, Berlin, 1957), Vol. 34, p. 210.
[8] A. R. Quinton, C. E. Anderson, and W. J. Knox, Phys. Rev. **115**, 886 (1959).

the locus of the spots. The resolution of the system in this region is sufficient to resolve without ambiguity a triton curve from the possible neighboring H^2 and He^3 curves.

The ratios of counting rates were:

one alpha particle per 345±20 fission events;

one triton per 4500±900 fission events.

The highest observed alpha particle energy (31 Mev) is approximately equal to twice the barrier of one of the fission fragments for an alpha particle. This, together with the observed angular correlations with the fission axis, suggests a mechanism for the emission of the particles.[9] They are pictured as being formed in the neck of the nuclear matter at the time of scission. The particle is left behind by the two departing fragments. Immediately afterwards, the particle is at a high electrostatic potential in the fields of the two fission fragments. It then accelerates down the potential hill, the path of steepest descent providing the correlation with the fission axis. The relatively high binding energy of the alpha particle, and its consequent greater probability of pre-existence in the nucleus at least qualitatively explain the higher number of alpha particles.

[9] D. L. Hill and J. A. Wheeler, Phys. Rev. 89, 1102 (1953).

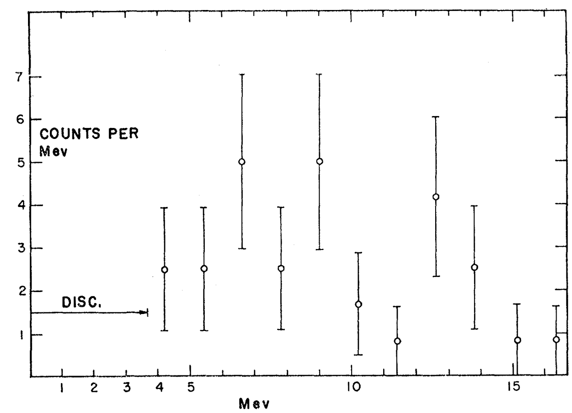

FIG. 2. Energy spectrum of tritons emitted in the spontaneous fission of californium.

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