

# Prompt Neutrons from the Spontaneous Fission of Fermium-254†

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The average number of prompt neutrons emitted during the spontaneous fission of fermium-254 has been measured to be  $4.05 \pm 0.19$  (standard error).

## INTRODUCTION

THE average numbers of prompt neutrons,  $\bar{\nu}$ , emitted during spontaneous fission have been measured for a number of nuclides,<sup>1-3</sup> and a general increase with increasing atomic number and weight of the fissioning nucleus has been observed up to and including californium-252. In the experiment reported here, the average number of neutrons from the spontaneous fission of fermium-254 has been measured, with a cadmium-loaded liquid scintillator tank of the type developed at Los Alamos as a detector.<sup>4</sup>

## APPARATUS AND METHOD

The apparatus and method have been described in a previous article.<sup>2</sup> Either of two similar parallel-plate ionization chambers could be placed at the center of the liquid scintillator tank, one containing the sample of Cf<sup>252</sup>, which we use as a secondary neutron standard, and the other the Fm<sup>254</sup>. With a discriminator set so that all fissions were counted, the fission chamber pulses were used to trigger an oscilloscope, and the fission, prompt gamma ray, and neutron-capture pulses were recorded photographically. Background and californium standard data were taken before and after the fermium run, which was continued through 3.4 half-lives ( $T_{1/2} = 3.2$  hours for alpha decay).<sup>5</sup>

## FERMIUM SAMPLE

The fermium was produced in the Materials Testing Reactor by neutron irradiation of Cf<sup>252</sup>.<sup>6</sup> Separation of the fermium fraction from einsteinium and californium was achieved with an ion-exchange resin column using

ammonium  $\alpha$ -hydroxy isobutyrate as the elutant.<sup>7</sup> By measuring the fission rate after the complete decay of the fermium we determined that the sample contained sufficient californium-252 to yield  $0.186 \pm 0.007$  spontaneous fission per minute. When this background fission rate is subtracted, the measured decay of the sample is consistent with the expected 3.2-hour half-life.

## DATA AND ANALYSIS

The neutrons from 3360 Cf<sup>252</sup> fissions in the secondary standard fission counter were counted. Using  $\bar{\nu}(\text{Cf}^{252}) = 3.82 \pm 0.12$ ,<sup>2</sup> we found the over-all neutron-detection efficiency during the measurements to be  $60.1 \pm 2.1\%$ ; the efficiency had fallen gradually over a period of several months from the original value of 80% because of the slow separation of part of the cadmium compound from the main body of the scintillation liquid.

A total of 870 fissions was recorded from the fermium plus californium sample, giving the distribution of fissions *vs* numbers of observed neutrons shown in Table I.

TABLE I. Numbers of fissions with  $\nu$  observed neutrons.

$\alpha$	0	1	2	3	4	5	6	7
Fissions	42	160	255	265	110	28	8	2

After correcting for the resolution of the apparatus and a background of 0.0050 pulse per fission, as described in reference 2, and after subtracting the contribution from the californium contamination, we obtained the ratio  $\bar{\nu}(\text{Fm}^{254})/\bar{\nu}(\text{Cf}^{252}) = 1.061 \pm 0.037$  (standard error). With the above value for  $\bar{\nu}(\text{Cf}^{252})$ , the average number of prompt neutrons from the spontaneous fission of fermium-254 is  $4.05 \pm 0.19$ .

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<sup>7</sup> Choppin, Harvey, and Thompson, *J. Inorg. and Nuclear Chem.* (to be published).

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<sup>1</sup> Diven, Martin, Taschek, and Terrell, *Phys. Rev.* **101**, 1012 (1956).

<sup>2</sup> Hicks, Ise, and Pyle, *Phys. Rev.* **101**, 1016 (1956). References to earlier work were included in this article.

<sup>3</sup> Crane, Higgins, and Bowman, *Phys. Rev.* **101**, 1804 (1956).

<sup>4</sup> Reines, Cowan, Harrison, and Carter, *Rev. Sci. Instr.* **25**, 1061 (1954).

<sup>5</sup> Fields, Studier, Mech, Diamond, Friedman, Magnusson, and Huizenga, *Phys. Rev.* **94**, 209 (1954); Choppin, Thompson, Ghiorso, and Harvey, *Phys. Rev.* **94**, 1080 (1954).

<sup>6</sup> Harvey, Thompson, Ghiorso, and Choppin, *Phys. Rev.* **93**, 1129 (1954).