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SPONTANEOUS-FISSION HALF LIVES OF Cf^{254}, Fm^{255}, AND Cf^{250}

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ABSTRACT

The remeasured spontaneous-fission half life of Cf^{254} is 60.5 ± 0.2 days. The spontaneous-fission half life of Fm^{255} is determined to be $(1.0^{+0.6}_{-0.3}) \cdot 10^4$ y. The remeasured alpha-to-fission ratio in the decay of Cf^{250} is (1330 ± 45). The remeasured electron-capture/β^--decay branching ratio in E^{254m} is (0.078 ± 0.006)%.

SPONTANEOUS FISSION HALF LIVES OF Cf^{254}, Fm^{255}, AND Cf^{250}*

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INTRODUCTION

Larger amounts of short-lived fermium, einsteinium, and californium isotopes became available recently when they were separated from a mixture of curium isotopes that had been reirradiated in the Materials Testing Reactor at Idaho Falls, Idaho (MTR). This has made it possible to remeasure the spontaneous fission half lives of Cf^{254} and Cf^{250} with greater precision.

In addition, the spontaneous-fission half life of Fm^{255} was determined for the first time, and the Fm^{255} alpha half life remeasured. The electron capture branching ratio of metastable E^{254} was also remeasured.

EXPERIMENTAL PROCEDURES

The Cf^{254} source, which contained only 1.3% Cf^{250} fission activity at the beginning of the Cf^{254} fission half-life measurement, was prepared by irradiating isotopically pure E^{253} at the MTR. Standard chemical procedures were used to purify and prepare the Cf^{254} sample[1]. The Cf^{254} sample contained less than 0.05% of Cf^{252} fission activity.

Neutron bombardment of E^{253} produces E^{254m}, which then decays to produce the daughters Fm^{254} and Cf^{254}, as shown below:

$$E^{253} \quad (n, \gamma)\ E^{254m} \xrightarrow{\beta^-,\ 37\text{-}h,\ E.C.} \begin{cases} Fm^{254} \xrightarrow[3\ h]{\alpha} Cf^{250} \\ Cf^{254} \xrightarrow{S.F} \end{cases} \qquad (1)$$

The electron-capture branching ratio of E^{254m} was measured by separating Fm^{254} and Cf^{254}, which grew in from a pure sample of the E^{254m} parent, on a column of Dowex 50X12% cation-exchange resin by using ammonium α-hydroxy isobutyrate as the eluant. The rates of alpha emission and spontaneous fission in pure Fm^{254} and Cf^{254} fractions were measured in a windowless proportional counter.

The Fm^{255} sample was obtained by separating it from its parent E^{255}, which had been chemically separated from other elements. The Fm^{255} sample was counted for alpha particles and fission fragments in two independent counting systems. The decay of the Fm^{255} fission activity was observed for about 100 h (five half lives).

The Cf^{250} sample was obtained by separating it from an isotopically pure sample of E^{254} ($t_{1/2}$ = 480 days). The Cf^{250} daughter had been growing into the parent sample for nearly one year before separation. The Cf^{250} alpha/fission ratio was measured in a windowless proportional counter.

RESULTS

The measured Fm^{255} fission/alpha ratio is $(2.4^{+1.1}_{-0.9}) \times 10^{-7}$. The remeasured Fm^{255} alpha half life is 19.9 ± 0.3 h. This agrees well with a recent measurement by Asaro[2]. Our remeasured value for the Fm^{255} alpha half life was used to calculate the Fm^{255} spontaneous-fission half life of $(1.0^{+0.6}_{-0.3}) \cdot 10^4$ y. This value agrees well with Johansson's estimated value of 2×10^4 y[3]. It also fits smoothly into the spontaneous-fission systematics as developed by Swiatecki[4].

The new value for the electron-capture/β^--decay branching ratio in E^{254m} is (0.078 ± 0.006)%.

The experimental value for the Cf^{250} alpha/fission ratio is (1330 ± 45). The Cf^{250} spontaneous-fission half life is $(1.73 \pm 0.06) \times 10^4$ y, based on a 13-y alpha half life for Cf^{250} (5).

A least-squares analysis of the data obtained by following the spontaneous-fission decay of Cf^{254} over a period represented by four half lives yields a value for the Cf^{254} half life of 60.5 ± 0.2 days. This result includes a correction for the spontaneous-fission activity (1.3%) from a small amount of Cf^{250}. The presence of Cf^{250} in a sample of Cf^{254} separated from E^{254m} is unavoidable, as may be seen from Eq. (1). The correction involved measurement of the amount of Cf^{250} present in the source by means of an alpha-particle pulse-height analyzer. From our value for the alpha/fission ratio of (1330 ± 45) we obtain a corrected least-squares value of 60.5 days for the Cf^{254} spontaneous-fission half life. Because of the uncertainty in the Cf^{250} correction, an uncertainty of ± 0.2 days is reported for the Cf^{254} half life. This is twice the standard deviation of ± 0.1 day calculated directly by the least-squares analysis.

It might be interesting to note, that Burbidge et. al. suggested that Cf^{254} might have supplied the energy responsible for the exponential part of the light curves of Type-I supernovae which decays with a (55 ± 1)-day half life(6), since the hitherto-reported half life for Cf^{254} was (56.2 ± 0.7) days(7). In a more recent study, Hoyle et. al. suggest that this problem might be more complicated(8). This suggestion is supported by the fact that the half life of Cf^{254} does not agree with the above-mentioned decay of the light curves of Type-I supernovae.

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FOOTNOTES AND REFERENCES

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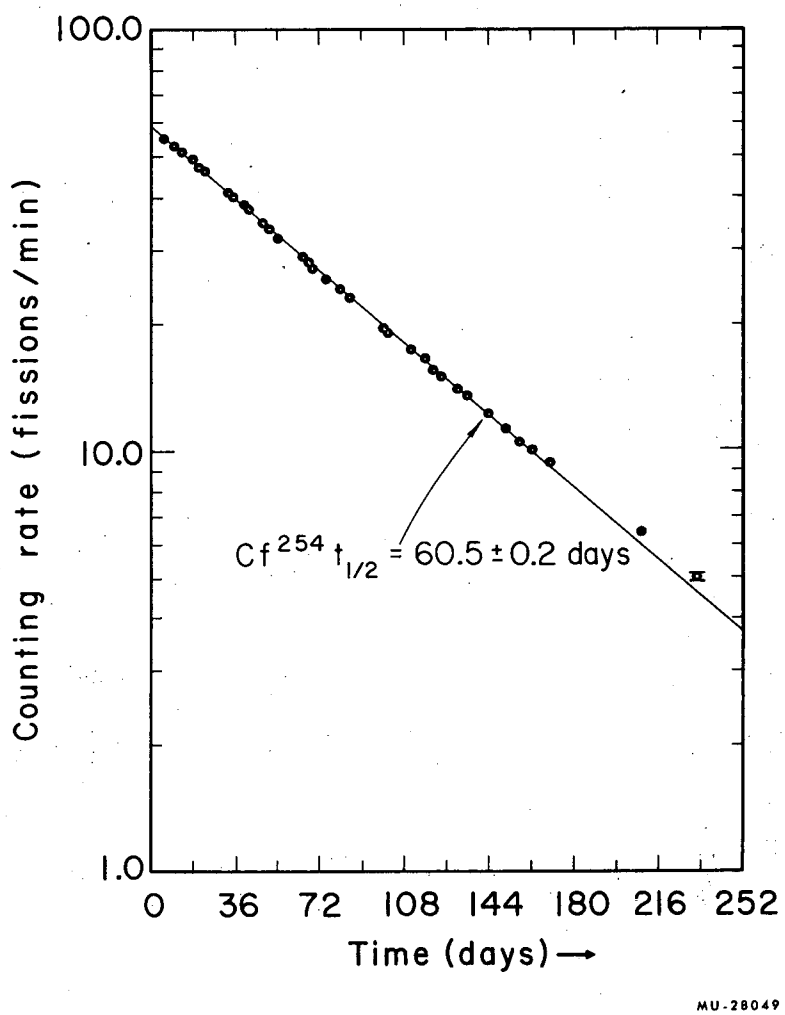

Fig. 1. Spontaneous-fission half life of Cf^{254}.

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