$$\int \exp[-a(r_1^2+r_2^2)]\frac{r_1^3r_2^3\cos\theta_{12}\sin^2\theta_{12}}{r_{12}}d\mathbf{r}_1d\mathbf{r}_2 = 16\pi^{\frac{5}{2}}(2a)^{-11/2}. \quad \text{(A-5)}$$

These integrals (and other simpler ones) were evaluated by differentiating

$$I'=\int \frac{\exp\{-(ar_1^2+br_2^2+cr_{12}^2)\}}{r_{12}}d\mathbf{r}_1d\mathbf{r}_2$$

with respect to the parameters a and b, and by iterations of the operator $\mathcal{O}\equiv\frac{1}{2}(\partial/\partial a+\partial/\partial b-\partial/\partial c)$ which is seen to be equivalent to multiplication of an integrand by $r_1r_2\cos\theta_{12}$. The use of the operator $\mathcal{O}$ was suggested to the author by Professor G. Breit.

Many Gaussian integrals of the form

$$I''[\ ]=\int \exp\{-(ar_1^2+br_2^2+cr_{12}^2)\}[\ ]d\mathbf{r}_1d\mathbf{r}_2$$

were evaluated in a similar manner.

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Production and Properties of the Nuclides Fermium-250, 251, and 252†

S. Amiel,* A. Chetham-Strode, Jr.,‡ G. R. Choppin,§ A. Ghiorso, B. G. Harvey, L. W. Holm,|| and S. G. Thompson
Radiation Laboratory and Department of Chemistry, University of California, Berkeley, California

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The nuclides Fm^{250}, Fm^{251}, and Fm^{252} were produced by alpha bombardment of Cf^{249}. The excitation functions for their formation, as well as some of their nuclear properties, were measured.

INTRODUCTION

In a previous paper from this laboratory[1] the production of some einsteinium isotopes by alpha bombardment of a target of Bk^{249} was described. Bk^{249} decays with a half-life of 280 days by beta emission to the 5×10^2-year alpha-emitting Cf^{249}. This paper will describe some studies of reactions of the type (α,xn) brought about by bombarding Cf^{249} with helium ions in the energy region 20 to 40 Mev. The experimental technique, which was fully described earlier,[1] involved catching the reaction products recoiling from the thin target in a separate gold foil. Thus, it is possible to use the same target for several bombardments. The target used in the present experiments was the same one as used in the irradiations of Bk^{249} although it now contained about 10^{13} atoms of Cf^{249} grown in from the original 3×10^{13} atoms of Bk^{249}. In fact, this target has been subjected to about 100 bombardments or a total of roughly 1000 μa-hr.

The chemical purification and separation of the products involved mainly ion exchange techniques and electroplating as described before.[1]

RESULTS

The fermium isotopes produced and studied in these experiments were Fm^{250}, Fm^{251}, and Fm^{252}. Of these, Fm^{250} was produced earlier at Stockholm and later at Berkeley by oxygen bombardment of uranium,[2] and Fm^{252} was produced at Berkeley by several of the above authors by alpha bombardment of targets containing the isotopes Cf^{249}, Cf^{250}, Cf^{251}, and Cf^{252}. However, the mass assignments are not certain on the basis of this work.

The element identification was established by means of a cation exchange column separation using alpha-hydroxy isobutyric acid as eluant.[3] Mass assignments were based on the excitation functions. The properties of these nuclides are summarized in Table I. The half-lives given are good to about $\pm10\%$ and the alpha particle energies to ±0.05 Mev.

The amounts of Fm^{250} produced correspond to about 40 alpha counts per minute at the end of the bombard-

Table I. Nuclear properties of light fermium isotopes.

Isotope	Type of decay	Half-life	Alpha-particle energy	Branching ratio electron capture/alpha
Fm^{250}	α, E.C.?	30 min	7.43	E.C. not observed
Fm^{251}	E.C., α	7 hr	6.89	$\sim$100
Fm^{252}	α	30 hr	7.05	β-stable[a]

[a] Glass, Thompson, and Seaborg, J. Inorg. Nuclear Chem. 1, 3 (1955).

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* On leave from the Israel Atomic Energy Commission, Weizmann Institute of Science, Rehovoth, Israel.
‡ Present address: Oak Ridge National Laboratory, Oak Ridge, Tennessee.
§ Present address: Florida State University, Tallahassee, Florida.
|| On leave from the Nobel Institute of Physics, Stockholm 50, Sweden.
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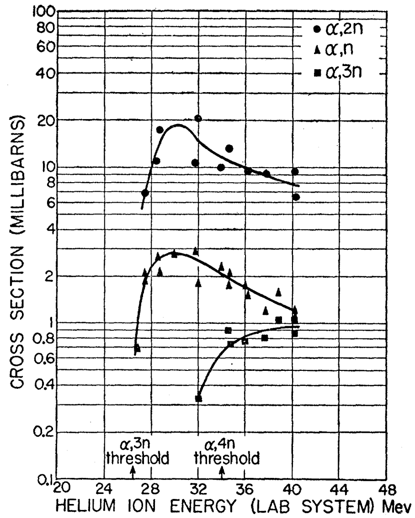

FIG. 1. Excitation functions for the formation of fermium isotopes.

ment in the best experiments. After the comparatively long time (2 to 2.5 hr) required to make a complete chemical separation from fission products and other activities, no electron-capture activity with a 30-minute half-life was found. Thus, the branching ratio (E.C./α) for Fm^{250} is probably less than 10, in agreement with predictions.[4]

[4] Glass, Thompson, and Seaborg, J. Inorg. Nuclear Chem. **1**, 3 (1955).

Figure 1 shows the excitation functions for the formation of Fm^{250}, Fm^{251}, and Fm^{252} through (α,n), $(\alpha,2n)$, and $(\alpha,3n)$ reactions. The curve for the $(\alpha,3n)$ reaction is a lower limit since it was calculated as if Fm^{250} were β-stable, which certainly is not true. The similarity both qualitatively and quantitatively between these curves and the corresponding ones for the einsteinium isotopes[1] is striking. They show the same long "tails" towards high energies, suggesting direct interaction mechanisms. The difference in shape between the excitation function for formation of Fm^{250} and that for E^{250} is due mainly to the fact that the former is formed only through an $(\alpha,3n)$ reaction whereas other processes, mainly (α,t), contribute to the yield of E^{250}.

The fact that no Fm^{249} was observed does not contradict the prediction of its properties ($t_{\frac{1}{2}}=5$ min; E.C./$\alpha=\frac{1}{6}$)[4] if one assumes the cross section for the $(\alpha,4n)$ reaction to be not greater than that for the $(\alpha,3n)$ reaction.

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