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DECAY PROPERTIES OF THE NEW ISOTOPE  $^{243}\text{Cf}$  AND  $^{244}\text{Cf}$

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ERRATUM

TO: All recipients of UCRL-17363  
FROM: Technical Information Division  
Subject: UCRL-17363, "Decay Properties of the New Isotopes  $^{243}\text{Cf}$  AND  $^{244}\text{Cf}$ ,"  
Torbjorn Sikkeland, Albert Ghiorso, Jaromir Maly, and Matti J. Nurmi,  
February 1967.

Please change title on cover, title page, and page 1 of UCRL-17363  
to read:

DECAY PROPERTIES OF THE NEW ISOTOPE  $^{243}\text{Cf}$  AND  $^{244}\text{Cf}$  ✓

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Torbjorn Sikkeland, Albert Ghiorso, Jaromir Maly, and Matti J. Nurmia

February 1967

DECAY PROPERTIES OF THE NEW ISOTOPES  $^{243}\text{Cf}$  AND  $^{244}\text{Cf}^*$ 

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A new isotope of californium  $^{243}\text{Cf}$  has been produced in the bombardments of  $^{235}\text{U}$ ,  $^{236}\text{U}$ , and  $^{238}\text{U}$  with  $^{12}\text{C}$  ions. At the same time new values for the half-life and  $\alpha$  energy observed in the decay of  $^{244}\text{Cf}$  were obtained.

The experimental arrangement was identical to that used in the discovery<sup>1</sup> of  $^{242}\text{Cf}$  in which various uranium isotopes were bombarded with  $^{12}\text{C}$ .

Figure 1 shows a typical  $\alpha$  spectrum obtained in the bombardment of  $^{236}\text{U}$  with  $^{12}\text{C}$ . We shall here discuss in some detail the  $\alpha$  group at 7.05 MeV, that in the previous report was tentatively assigned to  $^{243}\text{Cf}$ , and the group at 7.21 MeV that was assigned to  $^{244}\text{Cf}$ .

1.  $^{243}\text{Cf}$ . A least-square analysis of the decay of the  $\alpha$  group at  $7.05 \pm 0.02$  MeV in which about 300 events were used gave a half-life of  $10.3 \pm 0.5$  min. The assignment of the emitter to  $^{243}\text{Cf}$  was based on the excitation functions of its production in  $^{12}\text{C}$  reactions on  $^{235}\text{U}$  and  $^{236}\text{U}$ . In the former, the shape of the function corresponded to a ( $^{12}\text{C}$ , 4n) reaction, and in the latter to a ( $^{12}\text{C}$ , 5n) reaction. We also observed this activity in a  $^{238}\text{U}({}^{12}\text{C}, 7n)$  reaction, although here it was partly masked by the tail of an intense group at 7.14 MeV from  $^{245}\text{Cf}$ . Indirect experimental evidence that  $^{243}\text{Cf}$  also has other decay modes was obtained from cross-section systematics for ( $^{12}\text{C}$ , xn) reactions as shown in

the following. At a particular value of  $x$ , the maximum cross section,  $\sigma_x$ , for such reactions is, to a good approximation, proportional to the quantity  $(\bar{\Gamma}_n/\bar{\Gamma}_t)^x$ . Here  $\bar{\Gamma}_n/\bar{\Gamma}_t$  is the geometric mean of the relative level widths for neutron emission for the nuclides in the cascade of  $x$  neutrons. For these nuclides the quantity  $\log(\bar{\Gamma}_n/\bar{\Gamma}_t)$  is expected to vary very nearly linearly with  $\bar{A}$ , the average mass number of the nuclei in that cascade.<sup>2</sup> Hence one can set

$$\log \sigma_x = C_x + xC_0\bar{A}, \quad (1)$$

where  $C_x$  is a constant dependent only on  $x$ , and  $C_0$  is independent of both  $\bar{A}$  and  $x$ .

These constants were determined from the measured maximum cross sections for ( $^{12}\text{C}$ , 4n) reactions with  $^{234}\text{U}$ ,  $^{236}\text{U}$ , and  $^{238}\text{U}$  as targets, and for ( $^{12}\text{C}$ , 5n) reactions with the targets  $^{235}\text{U}$  and  $^{238}\text{U}$ . The calculated maximum cross sections for  $^{235}\text{U}(\text{}^{12}\text{C}, 4n) \text{}^{243}\text{Cf}$  and  $^{236}\text{U}(\text{}^{12}\text{C}, 5n) \text{}^{243}\text{Cf}$  were found to be larger than the measured cross sections for the 7.05-MeV 10-min  $\alpha$  activity, by a factor of  $9 \pm 2$  and  $12 \pm 2$ , respectively. The weighted average of these values is  $10 \pm 2$ . Hence, the partial  $\alpha$  half-life for this group is  $100 \pm 20$  min, which corresponds to an unhindered  $\alpha$  decay.

The energy of the ground-state transition  $\alpha$ 's in the decay of  $^{243}\text{Cf}$  is predicted<sup>3</sup> to be about 7.17 MeV. According to the energy-level diagram of Nilsson,<sup>4</sup> the odd neutron for the ground state of the nuclide  $^{243}\text{Cf}$  is in the state  $1/2+[631]$ , and that of the daughter  $^{239}\text{Cm}$  is in the state  $7/2-[743]$ , and hence the transition between these two states will be unfavored.

An excited-neutron level,  $1/2+[631]$ , in the daughter is expected, to which a favored decay will take place. The 7.05-MeV  $\alpha$  group apparently is a manifestation of that transition, and the level  $1/2+[631]$  in  $^{239}\text{Cm}$  then is about 120 keV above the ground state.

It appears from our experiments that other  $\alpha$  groups from  $^{243}\text{Cf}$  must have intensities less than that of 7.05 MeV. Hence, we conclude the dominant mode of decay of  $^{243}\text{Cf}$  to be by electron capture (EC) to  $^{243}\text{Bk}$ , and the branching ratio EC/ $\alpha$  to be about 10.

2.  $^{244}\text{Cf}$ . This nuclide was produced in  $^{235}\text{U}(^{12}\text{C}, 3n)$ ,  $^{236}\text{U}(^{12}\text{C}, 4n)$  and  $^{238}\text{U}(^{12}\text{C}, 6n)$  reactions. In the last system the 7.14-MeV alphas from  $^{245}\text{Cf}$ , produced simultaneously, interfered with the  $\alpha$  spectrum from  $^{244}\text{Cf}$ . In the bombardment of  $^{236}\text{U}$  with 69-MeV  $^{12}\text{C}$ , the yield of  $^{245}\text{Cf}$  was about two orders of magnitude less than that of  $^{244}\text{Cf}$ , and this system was used to study the decay properties. The decay of 2000 events of  $^{244}\text{Cf}$  was followed over 8 half-lives and a least-square-fit analysis gave a half-life of  $19.4 \pm 0.6$  min.

In separate experiments, the energy spectrum of the  $\alpha$ 's from  $^{244}\text{Cf}$  was studied in greater detail, with the 7.070-MeV  $\alpha$ 's from  $^{217}\text{At}$  and the 7.680-MeV  $\alpha$ 's from  $^{214}\text{Po}$  used as calibration sources.

With 2.5 keV/ch, the group at 7.21 MeV was resolved into two, one at 7.214 MeV and the other  $40 \pm 4$  keV lower. The ratio of the intensity of the former group to that of the latter was  $3.0 \pm 0.3$ . Apparently the former consists of  $\alpha$ 's from a ground-state transition and the latter of  $\alpha$ 's from a transition to the 2+ rotational level associated with the ground state. The FWHM of the group at 7.214 MeV was measured to be 21 keV.

$^{244}\text{Cf}$  has been reported to emit alphas with an energy of  $7.17 \pm .01$  MeV and a half-life of  $25 \pm 3$  min.<sup>5</sup>

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‡ On leave of absence from the Department of Physics, University of Helsinki, Finland.

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Fig. 1. Alpha spectrum from eight 20-min bombardments of  $500 \mu\text{g}/\text{cm}^2$  of  $^{236}\text{U}$  with about 80 MeV  $^{12}\text{C}$  of intensity  $6 \mu\text{A}/\text{cm}^2$  (+6 ions).

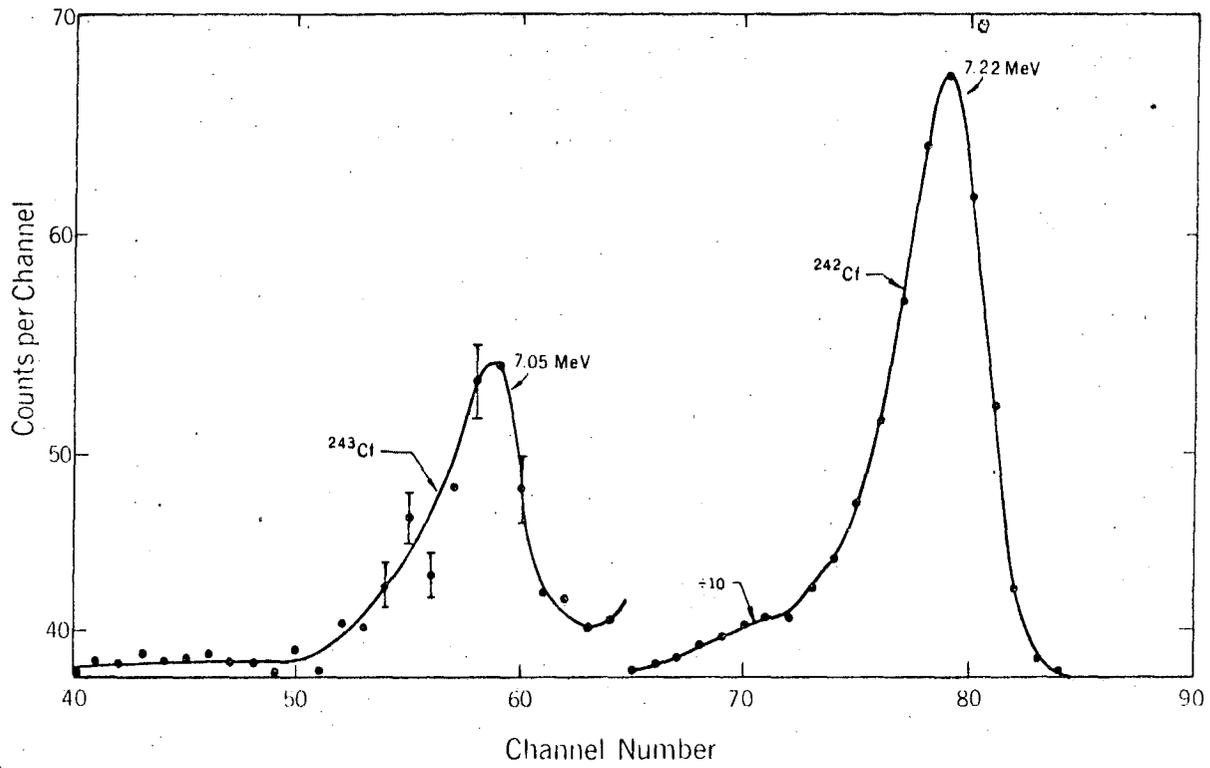


Fig. 1

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