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

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Berkeley, California

AEC Contract No. W-7405-eng-48

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ERRATUM

TO: All recipients of UCRL-17363

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February 1967

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

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

The experimental arrangement was identical to that used in the discovery[1] of ^{242}Cf in which various uranium isotopes were bombarded with ^{12}C. Figure 1 shows a typical α spectrum obtained in the bombardment of ^{236}U with ^{12}C. We shall here discuss in some detail the α group at 7.05 MeV, that in the previous report was tentatively assigned to ^{243}Cf, and the group at 7.21 MeV that was assigned to ^{244}Cf.

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

the following. At a particular value of x, the maximum cross section, σ_x, for such reactions is, to a good approximation, proportional to the quantity $(\overline{\Gamma_n/\Gamma_t})^x$. Here $\overline{\Gamma_n/\Gamma_t}$ 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 $\log (\overline{\Gamma_n/\Gamma_t})$ is expected to vary very nearly linearly with $\bar{A}$, the average mass number of the nuclei in that cascade.[2] Hence one can set

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

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

The energy of the ground-state transition α's in the decay of ^{243}Cf is predicted[3] to be about 7.17 MeV. According to the energy-level diagram of Nilsson,[4] the odd neutron for the ground state of the nuclide ^{243}Cf is in the state 1/2+[631], and that of the daughter ^{239}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 α group apparently is a manifestation of that transition, and the level 1/2+[631] in ^{239}Cm then is about 120 keV above the ground state.

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

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

In separate experiments, the energy spectrum of the α's from ^{244}Cf was studied in greater detail, with the 7.070-MeV α's from ^{217}At and the 7.680-MeV α's from ^{214}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 ± 4 keV lower. The ratio of the intensity of the former group to that of the latter was 3.0 ± 0.3. Apparently the former consists of α's from a ground-state transition and the latter of α'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}Cf has been reported to emitt alphas with an energy of 7.17 ± .01 MeV and a half-life of 25 ± 3 min.[5]

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†On leave of absence from the Institute of Nuclear Research, Prague, Czechoslovakia.

‡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 $\mu g/cm^2$ of ^{236}U with about 80 MeV ^{12}C of intensity 6 $\mu A/cm^2$ (+6 ions).

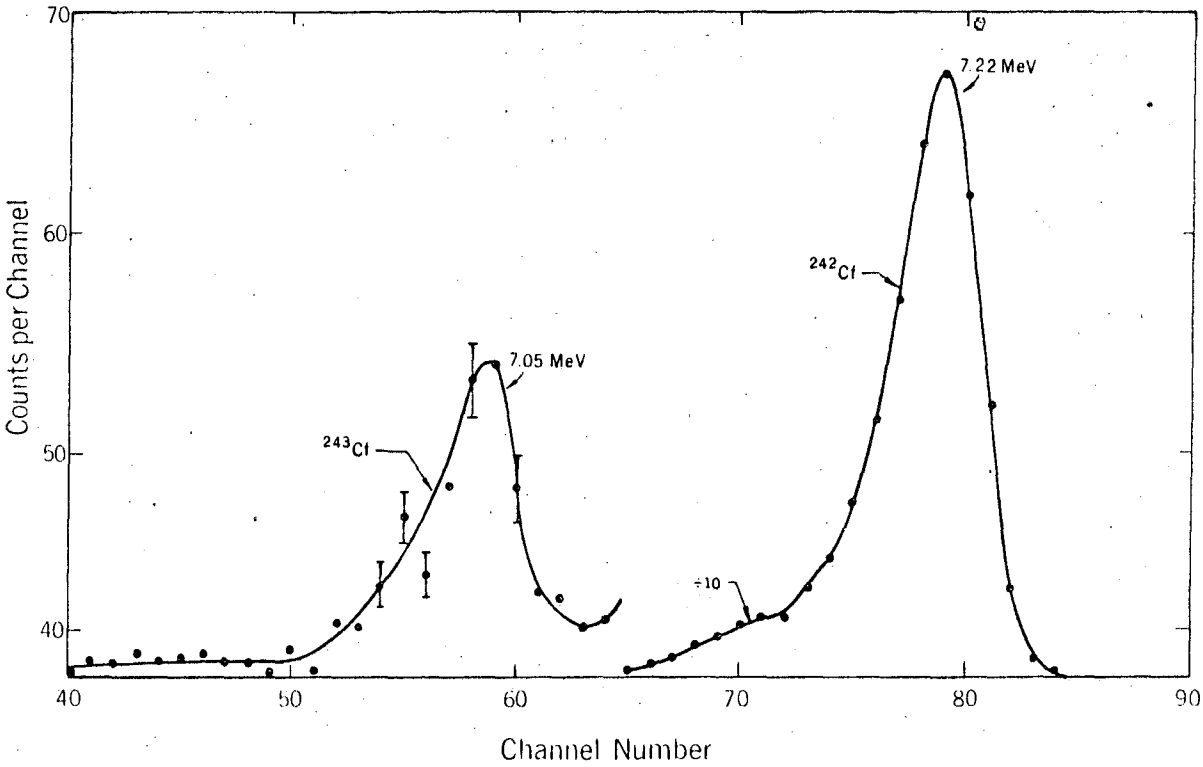
70
60
50
40
Counts per Channel
40
50
60
70
80
90
Channel Number
7.22 MeV
242Cf
7.05 MeV
243Cf
÷10

Fig. 1