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DECAY PROPERTIES OF THE NEW ISOTOPES 2i|-3cf AND 244Cf

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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.

1. T. Sikkeland and A. Ghiorso, previous Letter.

2. J. R. Huizenga and R. Vandenbosch, in Nuclear Reactions, edited by P. M. Endt and P. B. Smith (North-Holland Publishing Company, Amsterdam, 1962).

3. B. M. Foreman, Jr., and G. T. Seaborg, J. Inorg. Nucl. Chem. 1, 305 (1958).

4. E. K. Hyde, I Perlman, and G. T. Seaborg, The Nuclear Properties of Heavy Elements (Prentice Hall, Englewood Cliffs, New Jersey, 1964), p. 843.

5. A. Chetham-Strode, Jr., G. R. Choppin, and B. G. Harvey, Phys. Rev. 102, 747 (1956).

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).

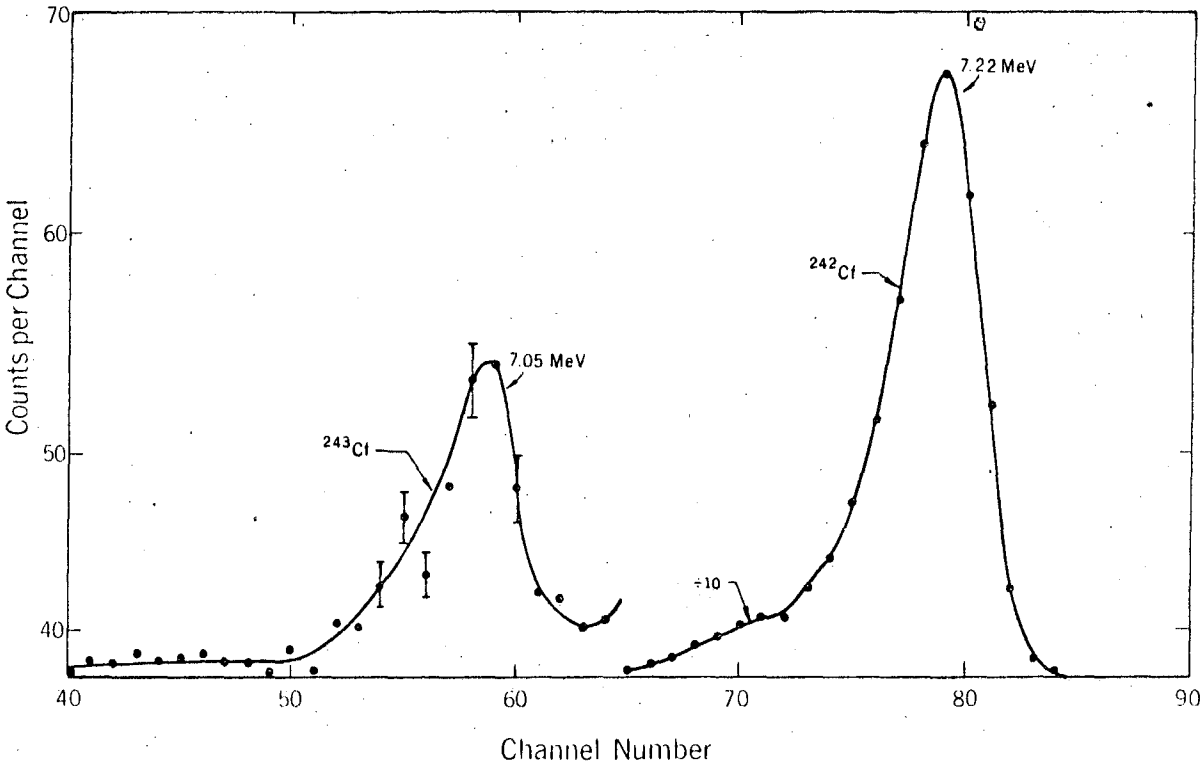
70
60
50
40
Counts per Channel
40
50
60
70
80
90
Channel Number
7.22 MeV
242Cf
7.05 MeV
243Cf
÷10

Fig. 1