ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E6 - 3992

W.Kusch, Z.Szeglowski

THE ALPHA DECAY OF ^{245}Cf

ЛАБОРАТОРИЯ ЯДЕРНЫХ РЕАКЦИЙ

1968

E6 - 3992

W.Kusch,* Z.Szeglowski**

THE ALPHA DECAY OF ^{245}Cf

* On leave from Institute for Nuclear Research, Warsaw.

** On leave from Institute of Nuclear Physics, Cracow.

Introduction

The isotope ^{245}Cf was produced in 1950 by Thompson, Street, Ghiorso and Seaborg /1/, by the reaction $^{242}Cm(\alpha,n)^{245}Cf$, as the first isotope of element 98, then was investigated by Chetham-Strode, Choppin and Harvey /2/.

Their measurements led to the conclusion that ^{245}Cf decays with a half-life of 44 minutes by emission of 7.11 ± 0.01 MeV alpha-particles (30%) and by orbital electron capture (70%).

The cross section for the production of californium isotopes 244, 245 and 246 by the reaction $^{238}U(^{12}C,xn)Cf$ was investigated by Ghiorso and Sikkeland (unpublished) and by Volkov and co-workers /3/.

The peak cross-section for the ^{245}Cf production according to the results of these two groups amounts to 55 μb at 75 MeV and 80 μb at 78 MeV, respectively.

Californium 245, an isotope of an even number of protons and odd number of neutrons, is of interest since its alpha spectrum may provide a basis for determining one-particle neutron states in ^{241}Cm.

Data concerning Nilsson states in the region of the transuranium elements are incomplete and their importance for understanding the systematic of the heaviest nuclei is obvious. Stephens, Asaro and Perlman in 1959 /4/ published a compilation of known odd-neutron and odd-proton level assignments for heavy nuclei from Ra to Fm. As for neutron states, to date this list has been completed only with data for ^{251}Cf , obtained on the basis of alpha decay of ^{255}Fm /5/. The spin of the ground state of ^{255}Fm was also determined in their work.

Table I presents that data which refers to the alpha decay of ^{245}Cf .

The regularity of occurrence of the ground state of nuclei with 147 neutrons in state 5/2 + [622] gives reason to expect that the ground state of ^{245}Cf is also characterized by 5/2 + [622] Nilsson quantum number. Preferred alpha decay would then populate the same state which should occur in ^{241}Cm as a neutron-excited state.

Experiment

In our experiment the ^{245}Cf was produced by the reaction $^{238}U(^{12}C, 5n)^{245}Cf$. A thick layer of U_3O_8 deposited onto a water-cooled support was irradiated in 1-hour cycles with ^{12}C ions from the JINR heavy ion cyclotron. A beam energy of 80 MeV was chosen, according to the results of the Dubna group /3/ and the current was about 20 μ A.

The short lifetime of the isotope made it necessary to reduce the time of radiochemical operation to the minimum. After the target was dissolved U, Np, Pu, and some elements of the forth, fifth and sixth groups were rejected by means of tri-n-butyl-phosphate and tri-n-octyl-phosphine oxide. Then Cf with rare-earths was extracted using bis (2-etyl hexyl phosphate) in toluen. Finally the extraction to water phase with the help of concentrated hydrochloric acid was carried out. The solution obtained was neutralized and electrolitic deposition of Cf onto the polished platinum backing was performed.

The alpha spectrum was measured by means of one of two detectors which differed in size: the small detector (0.5 cm^2) of

19 KeV resolution with a standard ^{241}Am source and a bigger one (2.0 cm^2) of 25 KeV resolution.

A charge preamplifier, a linear amplifier, a threshold amplifier and a 256-channel analyzer were used in the experiment.

Results

Four 1-hour irradiations permitted spectra to be obtained for six series of measurements. The alpha activity of the source in the fourth irradiation was measured three times in succession in order to get information about the lifetimes.

Figure 1 presents the results of measurement made with the small detector in the third series, whereas Fig.2 illustrates the data of series 4 obtained with the large detector. The results of all series have been compiled in Table II. The figures in columns A , B , C and D specify the energy of the alpha peaks in relation to the principal peak, the intensity of which is given in Column III (I_o). The letters S and L , respectively, denote the small and large detectors used.

The structure seen in the figures did not, in every case, provide a basis determining the energy; the energy has been given only in the cases when the individual peaks were measurable. Peak A occurs distinctly in all series. Only in series 1,3 and 6 does peak B appear distinctly enough for its energy to be evaluated while in the other three series it can be distinguished. Peak C did not occur in series 1 because of poor statistics and in the last series was too broad for its energy to be determined. Finally, peak D occurs only in series with sufficient statistics. The weighted mean energies of peaks A , B , C and D are respectively lower than the main peak by 52,6, 101, 154, and 251 KeV. The intensities of the individual peaks lend themselves only to a rough estimation.

Discussion

The alpha decay of ^{245}Cf should exhibit a similarity to that of ^{243}Cm. If the ground state of ^{245}Cf was a 5/2+ [622] state, then, of course, the dominant transition would populate that state in ^{241}Cm, but account would also have to be taken of possible alpha decay to the neighbouring Nilsson states. In the Table III the experimental transition energies are compared with those of rotational bands built on the states 7/2 - [743], 1/2+[631], 5/2+[622], 7/2+[624] and 9/2-[734]. The rotational formula with maximal and minimal values of $\hbar^2/2J$ known from the experiment was used. Our data is difficult to interpret, assuming, that the 52.6 KeV energy corresponds to the spacing of the first two rotational members built on the one-particle 5/2+[622] state, which seems to be rather puzzling. As can be seen from the table, higher spins are needed to explain the difference, when known values of $\hbar^2/2J$ are taken into account. However the second and the fourth energy values from the experiment do correspond to the values of the 5/2 + [622] rotational members. It seems to be likely, that in alpha decay of ^{245}Cf two rotational bands at least are involved.

The authors are grateful to Professor G.N.Flerov for permanent interest and valuable discussion.

References

1. S.G.Thompson, K.Street, Jr.A.Ghiorso and G.T.Seaborg. Phys. Rev., 80, 790 (1950).
2. A.Chetham-Strode, Jr., G.R.Choppin and B.G.Harvey. Phys. Rev., 102, 747 (1956).
3. V.V.Volkov, L.I.Gusyeva, A.S.Pasyouk, N.I.Tarantin, K.V.Filippova. Zh. Eksp. Teor. Fiz., 36, 762 (1959).
4. F.S.Stephens, Jr., F.Asaro and I.Perlman. Phys. Rev., 113, 212 (1959).

5. F.Asaro, S.Bjornholm and I.Perlman. Phys. Rev., 133, B291 (1964).

Received by Publishing Department
on July 17, 1968.

Table I. Nilsson level scheme for isotopes with 145 and 147 neutrons.

Isotope	7/2-[743]	1/2+[631]	5/2+[622]	7/2+[624]	9/2-[734]
^{237}U	(475)	0	145		
^{239}Pu	392	0	286	512	
^{241}Cm		0			
^{239}U			(0)		
^{241}Pu			0	172	
^{243}Cm			0		
^{245}Cf					

Table II. Results of measurements of ^{245}Cf alpha sectra. I_0 -intensity of the principal peak. A, B, C and D – the energy of registered alpha peaks in relation to the principal peak. S and L denote the small and large detectors used.

Run	Series	I_0	A	B	C	D	Detect.
I	1	95	53	107			S
II	2	500	52		156		S
III	3	360	53	99	169		S
IV	4	2400	52		151	266	L
	5	1700	54		153	230	L
	6	1050	52	101			L

Table III. The transition energies between rotational members of the bands built on five Nilsson levels. Maximal and minimal values of $\hbar^2/2J$ have been used. In the case of 1/2 spin the decoupling parameters are presented.

Experiment	7/2-[743]		1/2+[631]			5/2+[622]		7/2+[624]		9/2-[734]	
	^{235}U ^{239}Pu	5,1 4,7	^{235}U ^{237}Pu ^{239}Pu	6,04 6,36 6,25	-0,28 -0,42 -0,58	^{237}U ^{239}Pu ^{245}Cm	6,42 6,37 6,30	^{241}Pu ^{245}Cm	6,45 6,20	^{245}Cm	5,09 4,87
52.6	42	46	9		13	43	45	56	58	53,5	56
101	94	102	57		53	101	103	124	129	117	122
154	155	168	73		85	70	173	205	213	190	198
251	226	245	161		185	252	257	298	309	273	285

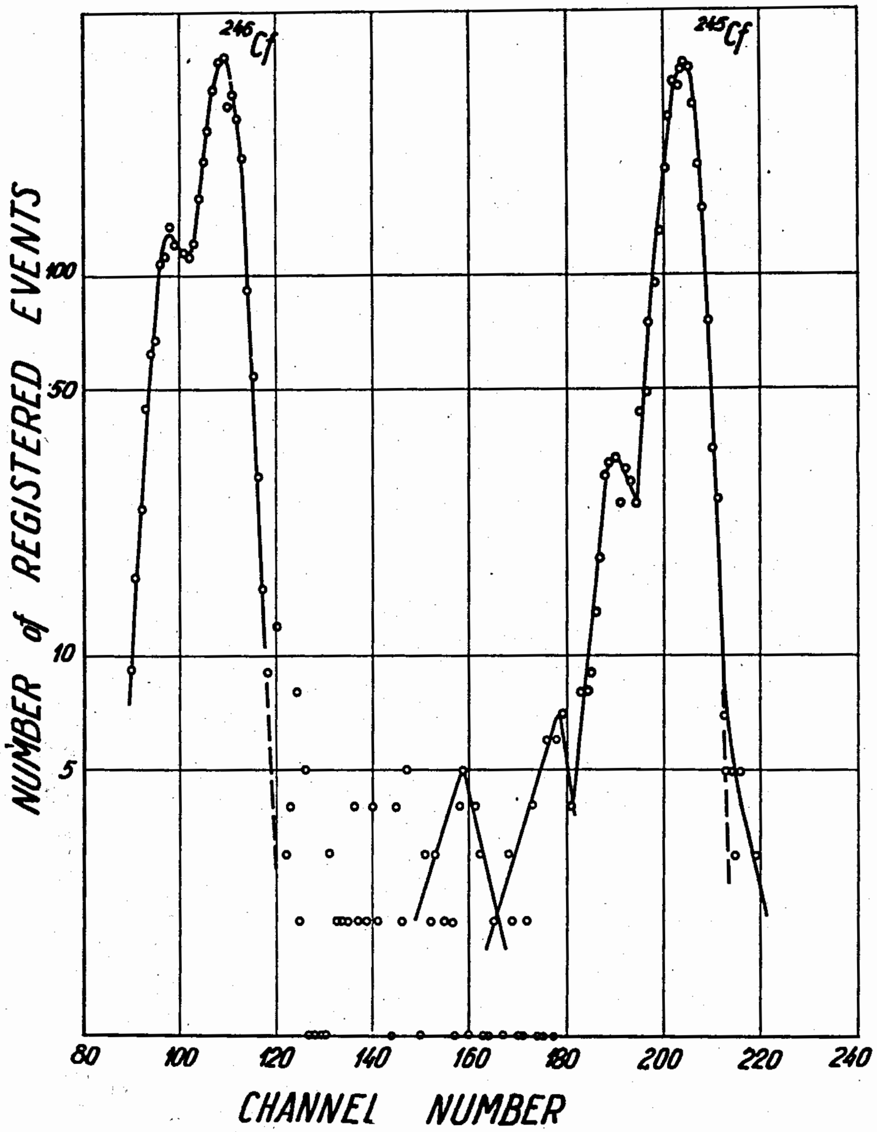

Fig.1 Alpha spectrum of Cf isotopes produced by the reaction $^{238}U(^{12}C, xn)$, , measured with the small detector. The beam energy 80 MeV.

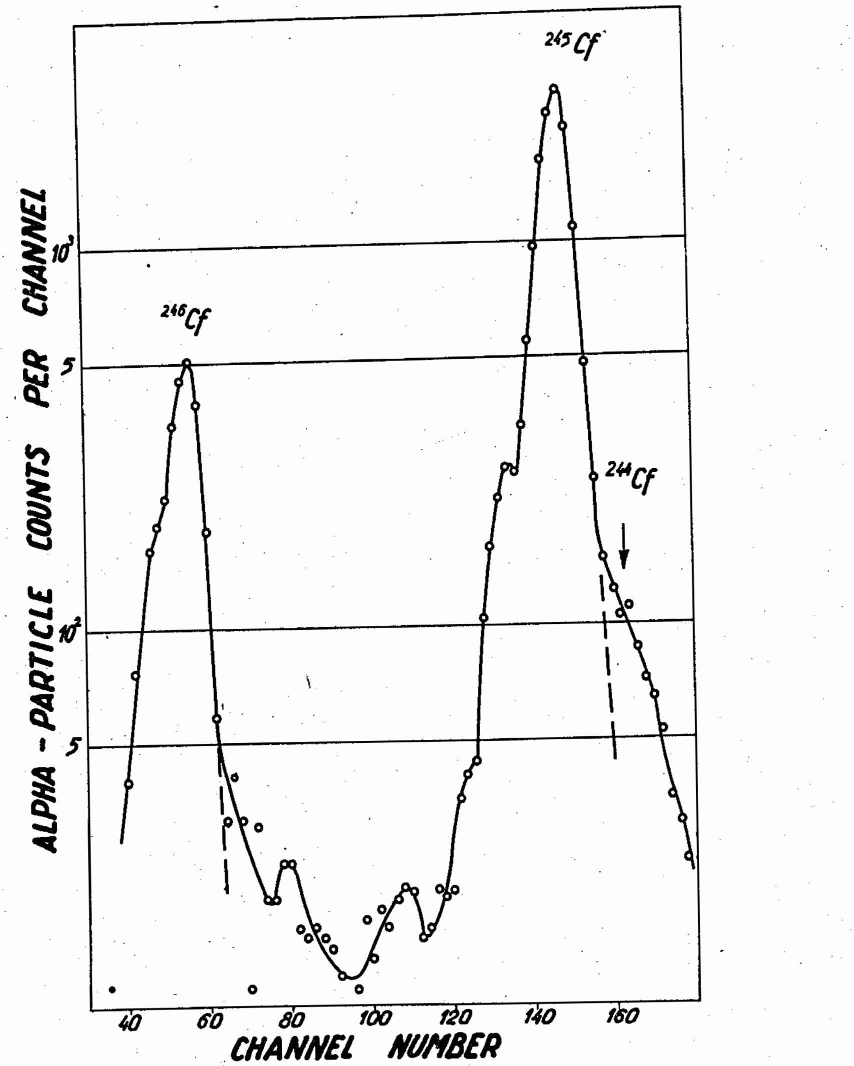

Fig.2 Alpha spectrum of Cf isotopes measured with large detector.