New data on the alpha decay of Cf^{249}

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A precision magnetic α-particle spectrograph with $\pi\sqrt{2}$ double focusing was used to investigate the α-particle spectrum of Cf^{249} in the energy range of 5750-5150 keV. We observed 23 alpha transitions to Cm^{245} levels lying in the excitation energy range 0.5—1.0 MeV. The γ rays were examined with a Ge(Li) detector with a volume of about 5 cm^3. Analysis of the experimental data has resulted in a more complete energy level scheme for Cm^{245}. In particular, the rotational $^7/_2^-[743]$ and $^7/_2^+[613]$ bands associated with the 645 and 722 keV levels were observed. The possible existence of the rotational $^3/_2^+[622]$ band at an excitation energy of about 900 keV is noted.

1. INTRODUCTION

In a previously published paper[1] we reported data on the alpha decay of Cf^{249} to low-lying Cm^{245} levels up to excitation energies of about 500 keV. We have continued our studies of the fine structure of alpha decay of this isotope with a view to obtaining information on the energy states of Cm^{245} in the excitation energy range 0.5—1.0 MeV. Measurements on the γ rays accompanying the decay of Cf^{249} have enabled us to obtain additional information on the excited-state parameters and have facilitated the interpretation of the experimental data.

2. SOURCES AND APPARATUS

Studies of the alpha decay of Cf^{249} ($T_{1/2\alpha} \approx 360$ years) were carried out with the aid of a precision α-particle spectrograph with $\pi\sqrt{2}$ double focusing.[2] The Cf^{249} specimen was separated radiochemically from isotopically pure Bk^{249} ($T_{1/2\beta} \approx 314$ days) maintained for the period of a year. The source for the α-particle measurements was prepared by evaporation in vacuum. The source size was 3×60 mm and the surface density of the radioactive layer was 0.27 $\mu g/cm^2$. The substrate for the source was an Al_2O_3 film, approximately 0.05 μ thick. The energy standard was taken to be the energy of the α_{645} group of Cf^{249}, known to be 5559.3 ± 1.5 keV.[1,3] The individual energies of the α groups in the investigated part of the spectrum were determined to better than 2—3 keV.

Measurements of the γ-ray spectra were carried out with a Ge(Li) detector with a volume of ~5 cm^3. The energy calibration of the spectrometer and measurements of the γ-ray detection efficiency were performed using special reference spectrometric gamma sources and other emitters with well-known values of the energy and γ-ray yields. The energy resolution was 3—4 keV in the soft region and 6—8 keV at about 1 MeV. The uncertainty in the measured γ-ray line energies in the spectrum was not more than 2—5 keV; the relative intensities of weak γ lines were determined to about 30—40%.

3. EXPERIMENTAL RESULTS

Figure 1 shows spectrograms due to Cf^{249} at α-particle energies between ~5750 and ~5150 keV. The ordinates show the number of α particles (N_α) per millimeter of the length of the photographic plate and the abscissa axis gives the α-particle energy E_α in keV. Low-intensity α lines are shown magnified. Each line is indicated by the letter α_i, where i represents the corresponding level energy of the daughter nucleus Cm^{245}.

Table I shows the results of an analysis of the spectrograms, i.e., the energies of the individual α groups, their relative intensities in percent, the level energies of the daughter nucleus, and the hindrance factors HF.

The γ-ray transition energies and the corresponding relative intensities are given in Table II. It is import-

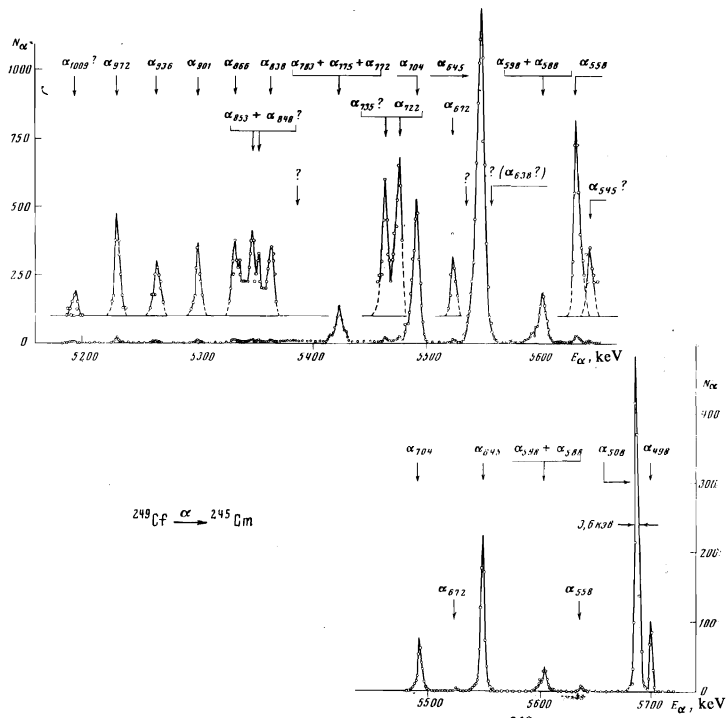

FIG. 1. A portion of the recorded spectrum of Cf^{249} (E_α is the α-particle energy and N_α is the number of α particles per millimeter of the photographic plate).

TABLE I. Values of E_α, I_α, E_l, and HF for $Cf^{249}\alpha \rightarrow Cm^{245}$

E_α, keV	I_α, %	E_l, keV	HF	E_α, keV	I_α, %	E_l, keV	HF
5704	$3\cdot10^{-2}$	498	$3\cdot10^3$	5433	$\sim7.7\cdot10^{-4}$	772	$3.4\cdot10^3$
5694	$2\cdot10^{-1}$	508	380	~5431	$\sim2.6\cdot10^{-3}$	~ 775	$\sim1\cdot10^3$
5658	$\sim10^{-4}$	545	$5\cdot10^5$	~5422	$\leqslant2.9\cdot10^{-4}$	~ 783	$\geqslant8\cdot10^3$
5645	$\sim1.5\cdot10^{-3}$	558	$2.8\cdot10^4$	~5370	$\sim1.3\cdot10^{-4}$	~ 838	$\sim8.3\cdot10^3$
5616	$6.9\cdot10^{-3}$	588	$4.2\cdot10^3$	~5359	$\sim10^{-4}$	~ 848	—
5604	$1\cdot10^{-3}$	598	$2.5\cdot10^4$	~5355		~ 853	—
~5566	—	~638	—	~5341	$\sim4\cdot10^{-4}$	~ 866	$\sim2\cdot10^3$
5559	$5.2\cdot10^{-2}$	645	270	~5307	$\leqslant1.3\cdot10^{-4}$	~ 901	$\geqslant3.6\cdot10^3$
5532	$2.1\cdot10^{-4}$	672	$4.6\cdot10^4$	~5273	$\leqslant1.2\cdot10^{-4}$	~ 936	$\geqslant2.5\cdot10^3$
5501	$1.8\cdot10^{-2}$	704	370	~5238	$\leqslant2\cdot10^{-4}$	~ 972	$\geqslant900$
5483	$3.2\cdot10^{-4}$	722	$1.6\cdot10^4$	~5201	$\leqslant5\cdot10^{-5}$	~1009	$\geqslant2\cdot10^3$
5471	$2\cdot10^{-4}$	735	$2\cdot10^4$				

TABLE II. γ radiation accompanying the decay of Cf^{249}

E_γ, keV	I_γ, %	E_γ, keV	I_γ, %	E_γ, keV	I_γ, %	E_γ, keV	I_γ, %
43?	~0.05	243	0.28	356	0.08	720	0.16
53	0.2	253	2.1	388	75.9	~740	0.01
66	0.035	267	0.7	650	~0.01	~760	0.02
76	0.24	296	0.1	670	~0.001	~770	~0.03
84	0.26	322	0.06	680	0.005	~990	~0.0007
92	0.42	333	16.7	700	0.007		

ant to note that our experimental data are in satisfactory agreement with the results reported elsewhere[4-6] in the γ transition energy range up to 400 keV. Most of the γ rays with $E_\gamma > 400$ keV were detected for the first time. To determine the γ-ray yield per alpha decay we assumed that the relative α transition intensity to the 387 keV level was 84%,[1] and the relative intensity of the γ-ray transition which relaxed this level was 76%. The multipolarity of the latter level was taken to be E1. According to our estimates, the γ-ray yield was approximately 90 γ-ray photons per 100 alpha decays, which was in good agreement with the results reported in[4].

4. ENERGY LEVEL SCHEME FOR Cm^{245}

Analysis of the α-particle spectrograms in the α-particle energy range which we have investigated showed that there were 23 groups corresponding to transitions to the excited states of Cm^{245} lying at 500–1000 keV above the ground state. Most of these levels were established for the first time in the course of our study of the alpha decay of Cf^{249}. It would appear that they must be divided into three subgroups. The levels in the first subgroup may be interpreted as the higher members of known rotational bands.[1] The second subgroup contains levels which might be used to construct new bands, the appearance of which in the level scheme is expected on the basis of qualitative theoretical predictions (see, for example,[7]). Finally, the third subgroup contains levels which would require additional experimental data for their ambiguous interpretation.

In developing the level scheme for Cm^{245} we used γ-ray transition energies and quantum yields per alpha decay. Of the 23 recorded α transitions, the level scheme locates with adequate reliability about 15 transitions.

Figure 2 shows the energy level scheme for Cm^{245} constructed on the basis of published data[1] and the results reported here. It is clear from this figure that the level scheme provides for a number of rotational bands. Known bands based on the 252, 387, and 645 keV levels with initial parameters $5/2^+[622]$, $9/2^-[734]$, and $7/2^-[743]$, respectively, were augmented with the new levels belonging to the first subgroup. Thus, for example, in the favorable band, i.e., in the band having the same initial parameters as the ground state of the parent nucleus Cf^{249}, we established the levels with spins $15/2^-$, $17/2^-$, and $19/2^-$, known from previous work. The data reported in[1] were used as a basis for predicting the existence of the $7/2^-[743]$ band but this interpretation was based on only two levels (645 and 704 keV) and was not altogether reliable. However, the detection in the present research of the next members of the band (775 and 866 keV), and the presence of γ transitions relaxing its lower states, can be regarded as a confirmation of this interpretation.

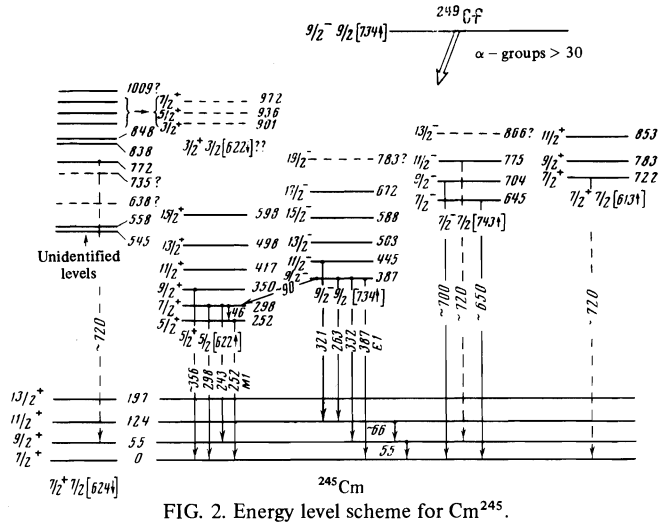

FIG. 2. Energy level scheme for Cm^{245}.

The levels in the second group can probably be used to construct at least three bands, two of which are shown in Fig. 2 ($7/2^+[613]$ and $5/2^+[622]$). The third band might be constructed from the levels at 772 and 838 keV. The quantum parameters proposed for it are $9/2^+[615]$. The corresponding values of the hindrance factors for the α transitions to these levels are HF = 3400 and 8800, and $\hbar^2/2J \approx 6.0$ keV. Naturally, the arrangement of the levels in the second subgroup into rotational bands is, to some extent, hypothetical.

The theoretical predictions of Gareev et al. in[7] for the Cm^{245} nucleus in the excitation energy range 0–1 MeV suggest that there are at least 12 rotational bands. However, the calculated energies of the initial states in these bands[7] do not agree with the energies of the states as interpreted in the present paper.

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