Decay of Fm^{253}†

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The decay scheme of Fm^{253} has been investigated by α-particle, γ-ray, and electron spectroscopy. Eleven α groups were observed with energies and intensities 7.092(1.3%), 7.032(6.7%), 6.952(42.7%), 6.910(9.8%), $\sim$6.876($\sim$0.9%), 6.855(8.4%), 6.682(23.2%), 6.659(2.4%), 6.639(2.6%); 6.550(1.5%), and $\sim$6.496 MeV ($\sim$0.3%). Two γ rays of energy 144.8 and 271.8 keV were identified and their multipolarities determined as $M2$ and $E2$, respectively. The excited state at 144.8 keV has been assigned as $\frac{5}{2}+$ (622↑) and the half-life of this level was measured to be 45 μsec. The level at 416.6 keV is identified as the $\frac{1}{2}+$ (620↑) state. The energy levels of Cf^{249} and the α transition probabilities to them seem to be in agreement with the current theories.

I. INTRODUCTION

THE nuclide Fm^{253} was first produced and identified by Friedman *et al.*[1] by the nuclear reaction

$$Cf^{252}+He^4 \rightarrow Fm^{253}+3n,$$

and a half-life of greater than 10 days was reported. The identity of this isotope was confirmed by Amiel,[2] who reported a more accurate value of 4.5 ± 1.0 days for the half-life and a α-to-electron-capture branching ratio of $\sim$10.5%, the main α-particle group having an energy of 6.94 ± 0.04 MeV. On the basis of a later measurement a half-life of 3 ± 1 days was reported by Ghiorso.[3]

The early work was hampered by the small quantity of Cf^{252} target material available and by the large amounts of Fm^{255} and Fm^{252} which are produced simultaneously in the irradiation. The latter fermium isotopes mask the higher-energy α groups of Fm^{253}. Using the much larger amounts of Cf^{252}, now available, a relatively large amount of Fm^{253} was synthesized and the α, γ, and electron spectra investigated with high-resolution instruments. It was also possible to investigate the high-energy α spectrum of Fm^{253} after the interfering Fm^{255} and Fm^{252} had disappeared through decay. The present work led to the formulation of a decay scheme for Fm^{253}.

II. SOURCE PREPARATION

Approximately 100 μg of Cf^{252} (containing $\sim$5% Cf^{250}) were irradiated with 40-MeV α particles in the 60-in. Argonne cyclotron, at a beam intensity of 5 μA for a period of 32 h. The californium target was separated from fission products using conventional ion-exchange techniques, and the fermium was separated from einsteinium and californium using several successive cation resin columns with α-hydroxy isobutyrate[4] as the eluant. The chemical separations were done in a shielded cell because of the neutron hazard from the spontaneous fission of Cf^{252}. The fermium was finally purified from inorganic impurities by a cation resin column using hydrochloric acid as eluant.[5] The pure fermium was dissolved in 1 M HNO_3 containing 5% tetraethylene glycol as a spreading agent, transferred to a platinum disc and ignited. This gave a thin source for α spectra measurements. The source for α to L x-rays coincidences, γ-ray and electron measurements was prepared in the same manner using a thin quartz disc as the support.

Two irradiations of Cf^{252} were necessary to produce sufficient Fm^{253} for all the measurements required to deduce the decay scheme. The decay of the Fm^{253} radiations was followed for almost a month with frequent repurifications. All the assigned transitions were confirmed by the characteristic decay rate of Fm^{253}.

III. EXPERIMENTAL DATA

A. α Spectra

The α-particle spectra (singles and in coincidence with γ-rays) were measured with a 6-mm diam Au-Si surface-barrier detector, cooled[6] to $-30°$C. The α-singles spectrum of the fermium fraction, purified immediately after the bombardment, is shown in Fig. 1. It should be noted that the high-energy α groups of Fm^{253} are masked by the Fm^{255} and Fm^{252} α peaks whereas the α groups below 6.682 MeV will soon be obscured by the Es^{253} α peaks which grow in from the electron-capture decay of Fm^{253} during the measurement. The sample was allowed to decay for approximately 10 days so that Fm^{252} (half-life[1] = 22.7 h) and Fm^{255} (half-life[7] = 20.07 h) would decay to a very low level and the fermium was then purified from Es^{253} and Cf^{248}. The α-singles spectrum of the purified sample

† Based on work performed under the auspices of the U. S. Atomic Energy Commission.

[1] A. M. Friedman, J. E. Gindler, R. F. Barnes, R. Sjoblom, and P. R. Fields, Phys. Rev. **102**, 585 (1956).
[2] S. Amiel, Phys. Rev. **105**, 1412 (1957).
[3] A. Ghiorso, cited in E. K. Hyde, I. Perlman, and G. T. Seaborg, *The Nuclear Properties of the Heavy Elements* (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1964), Vol. II, p. 968.
[4] G. R. Choppin, B. G. Harvey, and S. G. Thompson, J. Inorg. Nucl. Chem. **2**, 66 (1956).
[5] L. Phillips and R. Gatti, unpublished data referred to in U. S. At. Energy Comm. NAS-NS 3031, 1960, p. 13 (unpublished).
[6] D. W. Engelkemeir, Nucl. Instr. Methods **48**, 335 (1967).
[7] F. Asaro, S. Bjørnholm, and I. Perlman, Phys. Rev. **133**, B291 (1964).

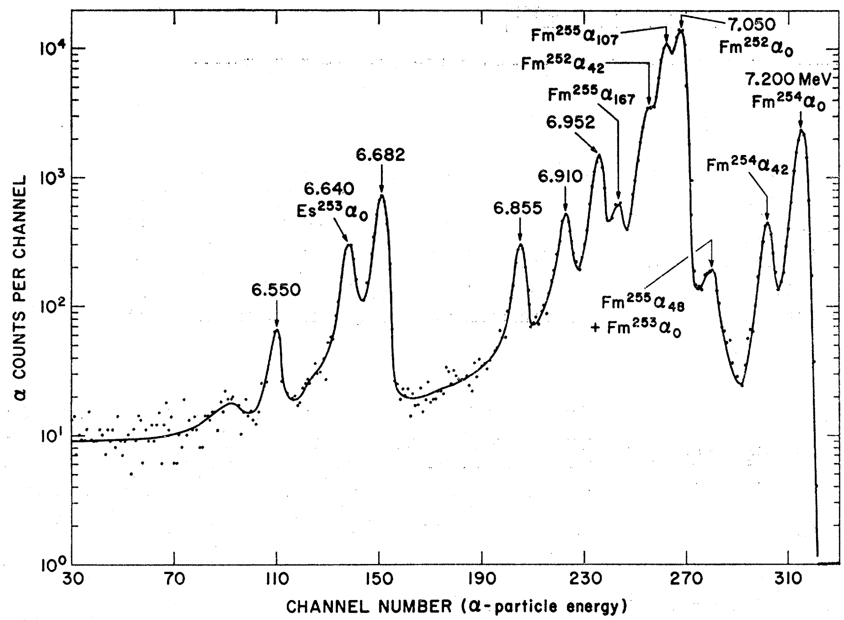

FIG. 1. Fm^{253} α-particle spectrum, taken immediately after chemical purification, with a cooled surface-barrier detector.

is shown in Fig. 2. The ground-state α transition is clearly established, as is the 7.032-MeV α group.

The γ-ray spectrum, measured in coincidence with all Fm^{253} α particles, using a 3×3-in. NaI(Tl) detector revealed the presence of a strong (274±5)-keV γ ray (0.22±0.03 photons/Fm^{253} α decay) and K x rays (~0.02 photons per Fm^{253} α decay). The α-γ coincidence experiment showed that the 274-keV γ ray was in coincidence with the 6.682-MeV α group. In order to identify the rotational members of the level populated by the 6.682-MeV α group, the α spectrum was measured in coincidence with the 274-keV photopeak and the results are shown in Fig. 3. The spectra shown in Figs. 1 and 3 were run at the same energy scale, and for comparison are placed together.

The α-particle energies were measured with respect to the Es^{253} α_0 group, which was taken as 6.640 MeV.[8] The energies listed in Table I and shown in Figs. 1, 2, and 3 were the best values obtained from several

TABLE I. α groups of Fm^{253}.

α-particle energy (MeV)	Excited-state energy (keV)	Intensity (%)	Hindrance factor
7.092±0.004	0	1.3±0.2	3.5×10^3
7.032±0.004	61	6.7±0.4	3.8×10^2
6.952±0.003	142	42.7±1.1	27
6.910±0.004	185	9.8±0.5	77
~6.876	~219	~0.9	6.2×10^2
6.855±0.003	241	8.4±0.5	52
6.682±0.003	417	23.2±0.9	3.3
6.659±0.004	440	2.4±0.4	25
6.639±0.004	460	2.6±0.5	19
6.550±0.005	551	1.5±0.4	13
~6.496	~606	~0.3	35

[8] A. H. Wapstra, Nucl. Phys. **57**, 48 (1964).

measurements. In Fig. 1 the Fm^{252} α_0 and Fm^{254} α_0 energies are those measured in the present experiments. The intensities of the 6.659- and 6.639-MeV groups were obtained from the α-γ coincidence measurements assuming that the relative abundances of the 6.682-, 6.659-, and 6.639-MeV α groups in Fig. 3 were the same as in α-singles spectrum. This assumption is justified by the fact that the 440- and 460-keV levels deexcite to the 416.6-keV state which in turn depopulates to the 144.8-keV level. The α-decay hindrance factors, listed in Table I, were calculated from Preston's[9] equations.

B. γ-Ray Spectra

The γ-rays and conversion electrons associated with the Fm^{253} decay were measured simultaneously. The sample was placed in an evacuated chamber for counting the conversion electrons. The γ rays after passing through the source backing (0.014-in. quartz disk) and a 0.01-in. beryllium plate were detected with a 2.2 cm²×0.5 cm deep Ge(Li) detector. The γ-ray spectrum of the fermium fraction, purified immediately after the bombardment, is shown in Fig. 4. The γ rays associated with the α decay of Fm^{255} (58.6 and 81.2 keV[10]) were distinguished by their faster decay rate ($t_{1/2}$=20.07 h). The broad peak near the 81.2-keV photopeak is caused by the back-scattering of the Es K x rays (K_α and K_β both). The decay of the Fm^{253} γ spectrum was followed for about a week in order to get a good value of the half-life. The energies and intensities of the einsteinium K x rays and Fm^{253} γ rays are listed in Table II.

[9] M. A. Preston, Phys. Rev. **71**, 865 (1947).
[10] I. Ahmad, Ph.D. thesis, Lawrence Radiation Laboratory Report No. UCRL-16888, 1966 (unpublished).

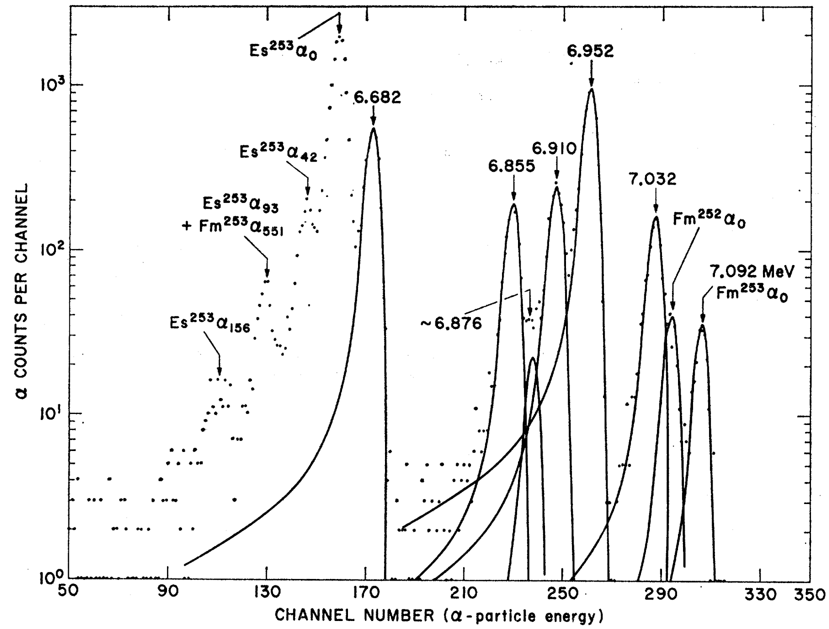

FIG. 2. Fm^{253} α-particle spectrum, measured after the decay of Fm^{252} and Fm^{255}.

C. Conversion-Electron Spectra

The conversion electrons of Fm^{253} were measured with a 0.8 $cm^2\times0.2$ cm deep Si(Li) detector, cooled to -30°C. In order to avoid the effects of overshoot pulses caused by the α particles, a double delay line pulse shaping was employed. The electron-singles spectrum was taken to determine the multipolarities of the prominent transitions. The spectrum in the 50- to 400-keV energy region is shown in Fig. 5. The low-energy (below 50 keV) electron lines could not be identified because of high background. The efficiency (including geometry) of the detector was determined with a standard Hg^{203} source. The strength of the source was obtained by counting the 279.2-keV photons with the 2.2 $cm^2\times0.5$ cm deep Ge(Li) detector, whose efficiency was calibrated with γ-ray standards. The electron intensities and conversion coefficients measured in our work are given in Table III. The intensity of the $(M+N+\cdots)$ line of 144.8-keV transition was obtained by subtracting the contribution of the K line of the 271.8-keV transition. The multipolarities of the transitions were determined by comparing the experimental K and L conversion coefficients with the theoretical values of Sliv and Band.[11] The theoretical values of M conversion coefficients were obtained from the calculations of Rose,[12] to which corrections[13] were applied for screening effect.

The electron–K-x-ray coincidence experiment was carried out to differentiate the transitions following the electron-capture decay of Fm^{253}. Any transition (unless delayed) associated with the K-electron capture will have its K, L, and $(M+N+\cdots)$ lines present in a spectrum measured in coincidence with K x rays. No

TABLE II. Electromagnetic radiations of Fm^{253}.

Energy (keV)	Relative intensity	Remark
112.2±0.4 (Es $K\alpha_2$)	53±5	Es K x rays associated with E.C. decay; total=173
117.9±0.4 (Es $K\alpha_1$)	73±7	
132.6±0.5 (Es $K\beta_1'$)	35±4	
136.6±0.5 (Es $K\beta_2'$)	12±2	
144.8±0.4	0.75±0.08	γ rays associated with α decay of Fm^{253}
271.8±0.4	10 (norm)[a]	
405 ±2	~0.3	

[a] The absolute intensity of this γ ray has been found to be (0.22±0.03) photon per Fm^{253} α decay.

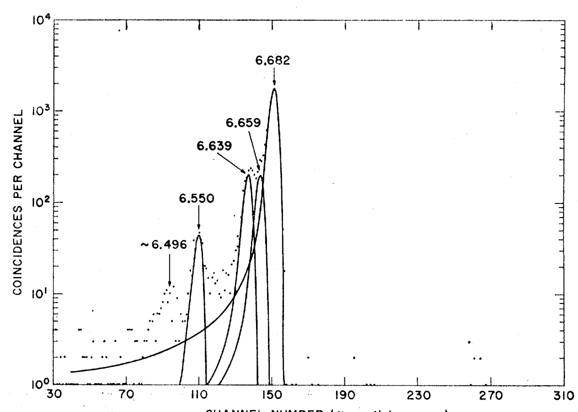

FIG. 3. Fm^{253} α-particle spectrum, taken in coincidence with 271.8-keV photopeak. Resolving time of the instrument was 50 nsec.

[11] L. A. Sliv and I. M. Band, in *Alpha, Beta, and Gamma-ray Spectroscopy*, edited by K. Siegbahn (North-Holland Publishing Company, Amsterdam, 1965), Vol. 2, p. 1639.

[12] M. E. Rose, *Internal Conversion Coefficients* (North-Holland Publishing Company, Amsterdam, 1959).

[13] Y. Y. Chu and M. L. Perlman, Phys. Rev. **135**, B319 (1964).

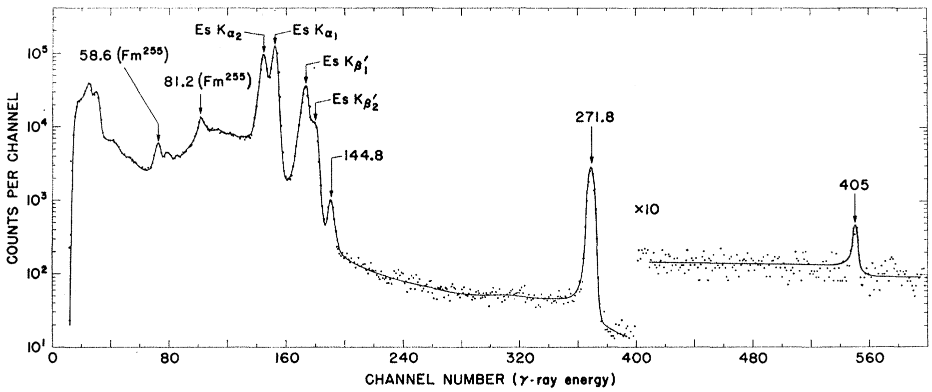

FIG. 4. Fm^{253} γ-ray spectrum, taken with a 2.2 $cm^2\times0.5$ cm Ge(Li) detector.

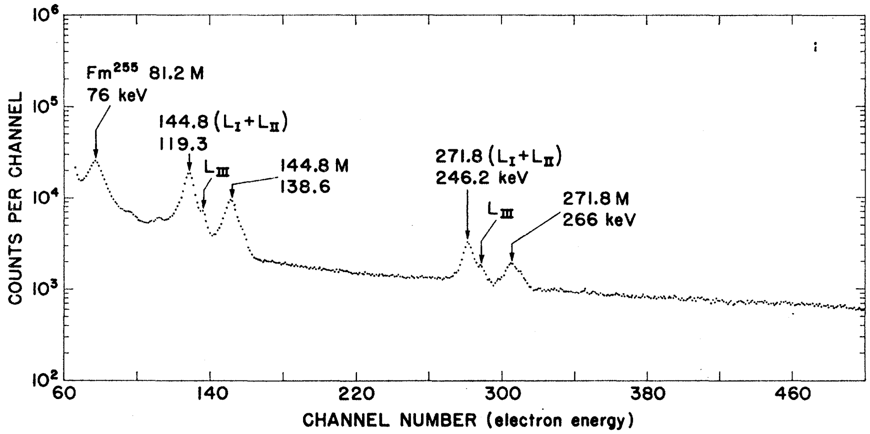

FIG. 5. Fm^{253} conversion-electron spectrum, measured with a cooled Si(Li) detector.

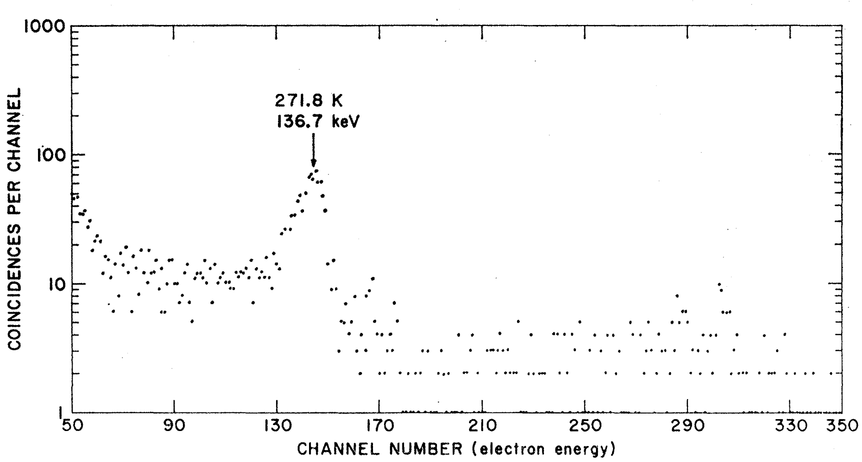

FIG. 6. Fm^{253} conversion-electron spectrum, taken in coincidence with Es K x rays. Resolving time of the instrument was 100 nsec.

such lines are observed in Fig. 6. The only line present in the spectrum is the K-conversion line of the 271.8-keV transition.

An approximate value of K-conversion coefficient of the 144.8-keV γ ray was obtained by a delayed γ-α coincidence experiment. The output of the time-to-height converter[14] (see Sec. E) was used as a gate for the γ rays. This gave the K x-ray to L x-ray intensities ratio. Making corrections for the fluorescent yields of the K and L x rays, the K-conversion coefficient was found to be ~20.

D. Half-Life and α Branching Ratio

The half-life of Fm^{253} was measured by following the decay of the 271.8-keV photopeak, detected with a Ge(Li) detector. The source was placed at a fixed

[14] This time-to-height converter was built in this laboratory by W. C. Bentley.

TABLE III. Conversion electrons of Fm^{253}.

Electron energy (keV)	Conversion shell	Transition energy	Electron intensity[a]	Conversion coefficient Expt.	Conversion coefficient Theor.	Multi-polarity
119.3±0.5	L^{b}	144.8	16±2	20±3	21 (for $M2$)	
138.6±0.6	$M+N+\cdots$	144.8	6±1	7±1	∼6	$M2$
136.7±0.8	K^{c}	271.8	0.9±0.2	0.09±0.02	0.1 (for $E2$)	
246.2±0.5	L^{b}	271.8	2.0±0.2	0.20±0.02	0.2	$E2$
266 ±1	M	271.8	0.8±0.1	0.08±0.01	∼0.09	

[a] The electron intensities are normalized to the intensity of the 271.8-keV γ ray, which was taken as 10 (see Table II).
[b] The energies given for the L lines are those of the $(L_{I}+L_{II})$ lines.
[c] The energy and intensity of this line is obtained from the electron to K x-ray coincidence experiment.

geometry and counted for 1000 min intervals. The decay of the peak was followed for a week and the half-life, thus measured, is (72±3) h. The α-branching ratio of Fm^{253} was determined by observing the growth of the Es^{253} in a purified sample. It was found that (12±1)% of the total disintegrations occur by α decay.

E. Half-Life of the 144.8-keV Level

The absence of the 6.952-MeV peak in the α spectrum taken in coincidence with γ rays (including L x rays) indicates that the 144.8-keV level deexcites by a delayed transition. The half-life of this state would be expected to be greater than the coincidence resolving time (3 μsec) used in the experiment.

The half-life of the 144.8-keV level was measured with the apparatus shown in Fig. 7. The α pulses were passed through a single-channel analyzer to select the 6.85- to 6.97-MeV energy interval. The selected α pulses were used to trigger the sweep of a Tektronix 541 oscilloscope which generated a sawtooth pulse. The γ-ray pulses were fed to a single-channel analyzer which was gated by the californium L x rays. The sawtooth pulse from the oscilloscope was mixed with the output pulse of the single-channel analyzer in a time-to-height converter, so that the amplitude of the output pulse was proportional to the time delay between the arrivals of the α and γ pulses. The output pulse of the time-to-height converter was then analyzed with a 400-channel analyzer, and the resulting delay curve is shown in Fig. 8. The time scale was calibrated with an oscillator of known frequency. The performance of the system was checked by measuring the half-life of the 85.5-keV level of Es^{254}, which is known to be (213±8) μsec.[15] The present measurements gave the half-life of the 144.8-keV state as (45±5) μsec.

IV. DISCUSSION

A. Decay Scheme

In this section we will attempt to assign spin and parity to the observed levels and interpret them in terms of current theories. In the region of permanent nuclear deformation, the single-particle energy levels are best explained in terms of the Nilsson[16] model. The Nilsson diagram, in the region of interest, namely neutron No. 126 to 160, is shown in Fig. 9. Each level in the diagram is doubly degenerate and is characterized by a set of quantum numbers. These quantum numbers, besides the projection of the particle angular momentum on the nuclear symmetry axis, Ω, and parity π, are: N, the total oscillator quantum number, n_Z, the number of oscillator quanta along the symmetry axis, Λ, the component of the total orbital angular momentum along the symmetry axis, and Σ, the component of the intrinsic spin s on the nuclear symmetry axis which is limited to the values of $\pm\frac{1}{2}$ only. For relatively low-

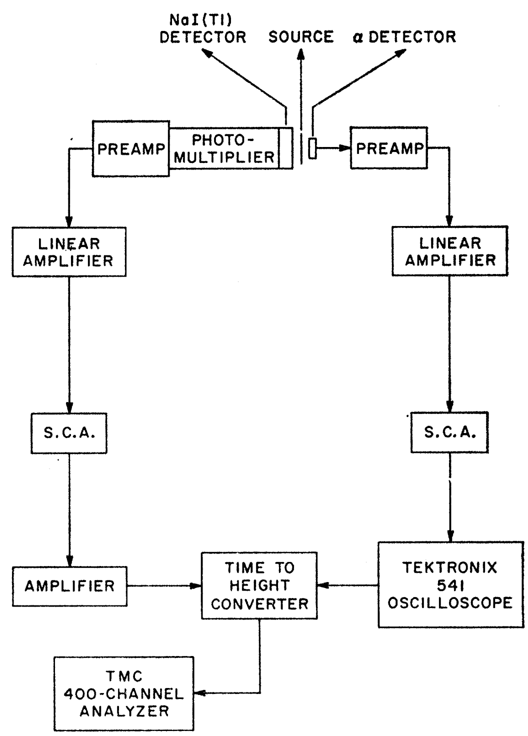

FIG. 7. Block diagram of the electronic circuit used to measure the half-life of the 144.8-keV state.

[15] W. C. McHarris, F. S. Stephens, F. Asaro, and I. Perlman, Phys. Rev. 144, 1031 (1966).

[16] S. G. Nilsson, Kgl. Danske Videnskab. Selskab, Mat. Fys. Medd. 29, No. 16 (1955).

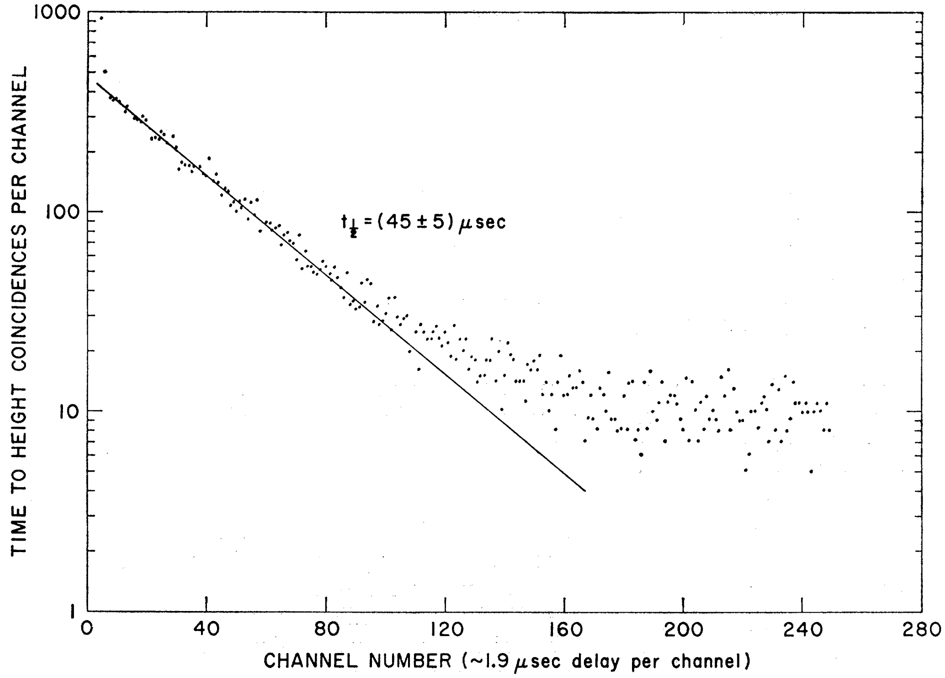

FIG. 8. The time-to-height coincidence delay curve for the 144.8-keV state.

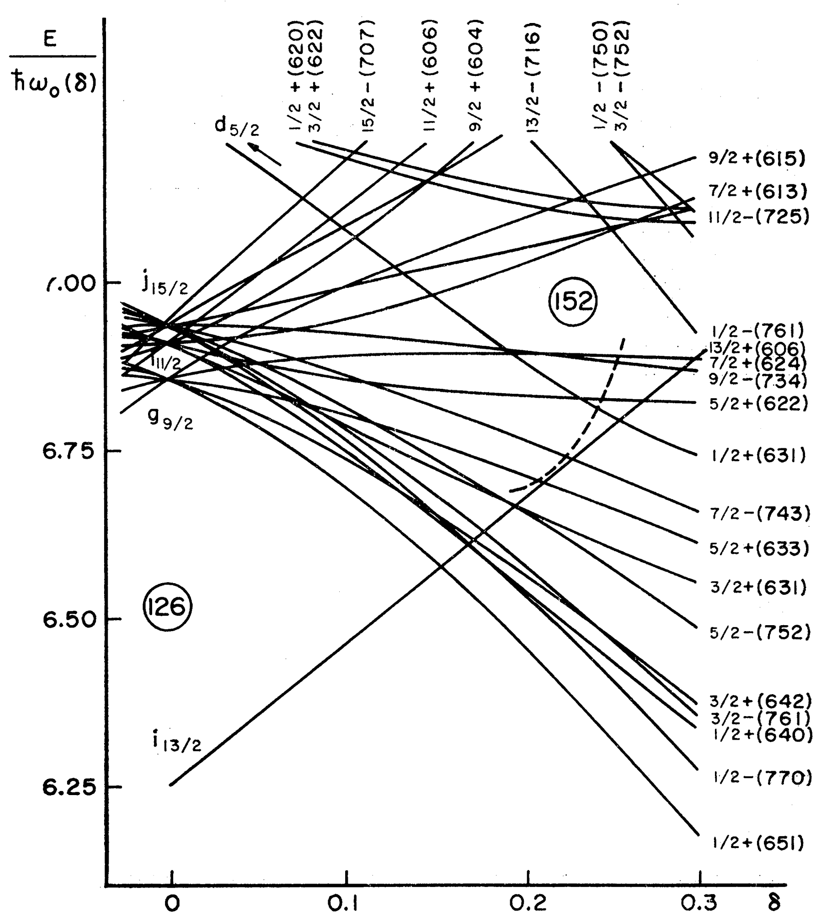

FIG. 9. Nilsson diagram for neutrons in the region $126 \leqslant N \leqslant 160$.

energy levels of the odd-mass nuclei, the component of the total nuclear angular momentum I on the symmetry axis, K, is equal to Ω. Also to each intrinsic state (single-particle state) is added a rotational band with spins $K, K+1, K+2, \cdots$. The excited state energy E_I of the rotational states with spin I is given by the equation[17]

$$E_I=E_0+(\hbar^2/2\mathscr{I})[I(I+1)+\delta_{K,1/2}a(-)^{I+\frac{1}{2}}(I+\tfrac{1}{2})]. \quad (1)$$

In the above equation E_0 is a constant and depends on the intrinsic state, $\mathscr{I}$ is the nuclear moment of inertia about an axis of rotation perpendicular to the symmetry axis, and a is a constant, called the decoupling parameter. The last term in the equation has nonzero value only for levels belonging to $K=\frac{1}{2}$ bands.

The ground state of Cf^{249} is known as $\frac{9}{2}-$ (734↑) from a study of its α decay[10] to Cm^{245}. In the present experiments, the ground-state α transition of Fm^{253} has been identified as the 7.092-MeV group. The level 61 keV above the ground state is interpreted as the first rotational member of this band. This gives the value of the rotational constant $\hbar^2/2\mathscr{I}$ as (5.6 ± 0.3) keV.

The level at 144.8 keV has been observed to decay to the ground state and the multipolarity of the connecting transition has been found to be $M2$. Thus, the spin and parity of this state should be either $\frac{5}{2}+$ or $\frac{9}{2}+$. The levels at 188 and 244 keV appear to be the first and second rotational members of the 144.8-keV state, respectively. The energy spacings between these levels are consistent with a $K\pi=\frac{5}{2}+$ assignment. The only $\frac{5}{2}+$ Nilsson state in this energy region is the hole state $\frac{5}{2}+$ (622↑).

The half-life of the 144.8-keV state has been found to be 4.5×10^{-5} sec. The partial half-life of the 144.8-keV γ ray, after making correction for the conversion electrons, is calculated to be 2.6×10^{-3} sec. The single-particle half-life of a 144.8-keV $M2$ γ ray, calculated by Weiskoff's[18] formula, is 1.3×10^{-5} sec. Thus, the 144.8-keV transition shows a 200-fold retardation over the single-particle estimate, probably due to the violation of selection rules[19] in the asymptotic quantum numbers n_Z and Λ.

The level at 416.6 keV deexcites almost entirely to the 144.8-keV state by an $E2$ transition. The only possible values of spin and parity, consistent with the above observation are $\frac{1}{2}+$ and $\frac{9}{2}+$. The 6.682-MeV α group populating the 416.6-keV level has a low hindrance factor (HF=3.3) which indicates a favored[20] transition. Thus, the 416.6-keV state of Cf^{249} should have the same Nilsson quantum numbers as the ground

[17] A. Bohr and B. R. Mottelson, Kgl. Danske Videnskab. Selskab, Mat. Fys. Medd. **27**, No. 16 (1953).

[18] J. M. Blatt and V. F. Weisskopf, *Theoretical Nuclear Physics* (John Wiley & Sons, Inc., New York, 1952), p. 627.

[19] G. Alaga, Nucl. Phys. **4**, 625 (1957).

[20] A. Bohr, P. O. Fröman, and B. R. Mottelson, Kgl. Danske Videnskab. Selskab, Mat. Fys. Medd. **29**, No. 10 (1955); P. O. Fröman, Kgl. Danske Videnskab. Selskab, Mat. Fys. Skrifter **1**, No. 3 (1957).

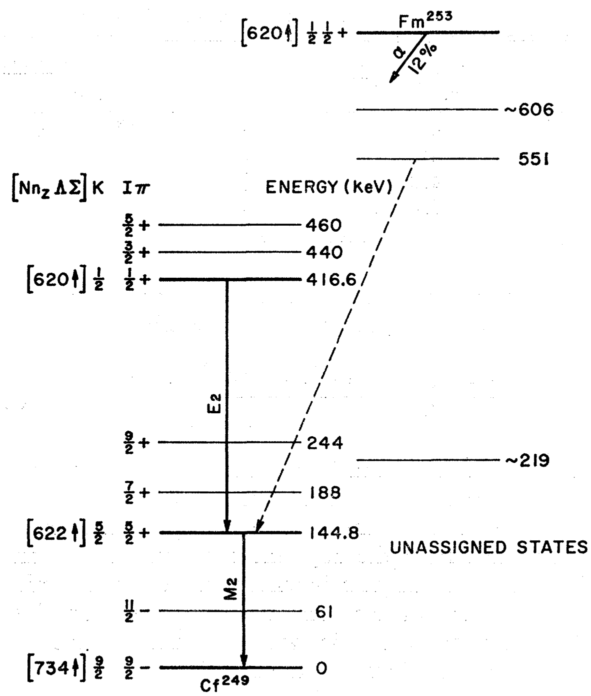

FIG. 10. Decay scheme of Fm^{253}.

state of Fm^{253}. The neutron number 153 in Cf^{251} occupies the $\frac{1}{2}+$ (620↑) state,[7] and as Fm^{253} is isotonic with Cf^{251}, it will be expected to have the same ground-state configuration. The energy spacings between the 416.6-, 440-, and 460-keV levels are consistent with the $K=\frac{1}{2}$ assignment and are comparable to those observed[7] in Cf^{251}. However, the spacings are not known accurately enough to calculate good values for the decoupling parameter and rotational constant.

The α groups populating the 551- and 606-keV levels have been found to be in coincidence with the 271.8-keV γ ray (Fig. 3). These α groups were also present in a spectrum measured in coincidence with 350- to 600-keV γ rays. Also a 405-keV γ ray was identified in the γ-ray spectrum taken with the Ge(Li) detector. These observations indicate that the 551-keV state deexcites to the 144.8-keV level and also to the 416.6-keV level. The possible spin and parity assignments are $\frac{1}{2}+$, $\frac{3}{2}\pm$, and $\frac{5}{2}+$. The only Nilsson orbitals available in this energy region (Fig. 9) are $\frac{1}{2}+$ (631↓) and $\frac{3}{2}+$ (622↓). With the limited information, it is not possible to make a definite assignment. However, it should be remarked that the α-decay hindrance factor to the 551-keV state is small and would not be expected for states[7,10] whose sign of Σ (projection of the intrinsic spin on the symmetry axis) was opposite to that of the ground state of the parent nucleus. For complete decay scheme, see Fig. 10.

B. α Transition Probabilities

The relative values of α-decay probability to various members of a favored band can be calculated semi-

TABLE IV. Calculated α intensities to the members of the favored band ($K=\frac{1}{2}$).

Energy of the state (keV)	$I\pi$	Calculated relative intensity (%) $L=0$	$L=2$	$L=4$	Σ	Experimental intensity
417	$\frac{1}{2}+$	23.2 (norm)			23.2	23.2
440	$\frac{3}{2}+$	$\cdots$	1.9	$\cdots$	1.9	2.4
460	$\frac{5}{2}+$	$\cdots$	2.2	$\cdots$	2.2	2.6
~510 (calc)	$\frac{7}{2}+$	$\cdots$	$\cdots$	~0.1	~0.1	not observed

empirically. The reduced transition probability P, to a certain state, is given by the equation[20]

$$P=\frac{P_E}{N}\sum_{L=0,2,4}\frac{|\langle I_iLK_i(K_f-K_i)|I_iLI_fK_f\rangle|^2}{(\mathrm{HF}_L)_{e-e}},\quad(2)$$

where P_E is the α-transition probability expected from simple barrier-penetration theory,[9] $(\mathrm{HF}_L)_{e-e}$ is the hindrance factor of the α wave of angular momentum L, obtained from the adjacent even-even nuclei, and the term in the angular bracket is the Clebsch-Gordan coefficient. N is a constant and its value is obtained empirically from the known α intensities, and the subscripts i and f refer to the initial and final states.

The hindrance factors for $L=0$, 2, and 4 α emission from Fm^{254} are known as 1, 3.8, and 26, respectively.[21] The hindrance factors for the $L=0$, and 2 α waves of Fm^{252} were calculated from the α energies and intensities measured in our experiments and are found to be 1 and 3.8. The α abundances, calculated with Eq. (2), and the values of $(\mathrm{HF}_L)_{e-e}$ for $L=0$, 2 and 4 α waves of 1, 3.8, and 26, respectively, are given in Table IV. The agreement between the experimental and calculated quantities is fairly good.

The relative α population to the rotational levels of an unfavored band can be calculated by the equation[20]

$$P=P_E\sum_L C_L|\langle I_iLK_i(K_f-K_i)|I_iLI_fK_f\rangle$$
$$+b_L(-)^{I_f+K_f}\langle I_iLK_i(-K_f-K_i)|I_iLI_f-K_f\rangle|^2,\quad(3)$$

where C_L and b_L are two adjustable parameters which are determined empirically from known α intensities. The second term in the equation is used only for transitions where $L\geqslant K_i+K_f$. For transitions where Σ does not change sign during the α decay, b_L has small value[7] (usually less than 1). The $I=\frac{5}{2}$ member of the $\frac{5}{2}+$ (622↑) band receives all the $L=2$ α wave and hence has a low hindrance factor. The α population of the $\frac{7}{2}$ and $\frac{9}{2}$ members can be reproduced by using a value of b_L of $+0.20$ for the $L=4$ α wave. The observed intensities of the $I=\frac{9}{2}$ and $I=\frac{11}{2}$ members of the $\frac{9}{2}-$ [734↑] band give a value of b_L for the $L=5$ wave of $+0.73$.

[21] H. V. Michel, Nucl. Data (to be published).

V. ELECTRON-CAPTURE DECAY OF Fm^{253}

No transition associated with the electron-capture decay of Fm^{253} has been identified in the present experiment. From the closed cycle, the energy available for the electron-capture decay is calculated to be 0.334 ± 0.008 MeV. The ground state[22] of Es^{253} is known as $\frac{7}{2}+$ (633↑) and that of Es^{251} as $\frac{3}{2}-$ (521↑).[23] The fact that the 97th proton occupies different orbitals in Es^{253} and Es^{251}, which differ little in deformation, suggests that the $\frac{7}{2}+$ (633↑) and $\frac{3}{2}-$ (521↑) states are very close in energy. The ground state of Fm^{253} has been assigned as $\frac{1}{2}+$ (620↑) on the basis of the present investigations. The electron-capture decay will thus be expected to populate the $\frac{3}{2}-$ (521↑) level of Es^{253} (first forbidden transition $\Delta I=+1$(yes)). Since no transition has been observed following the electron-capture decay one can safely assume that 100% of the electron capture goes to this state. This gives a value for log ft of 6.7, which is consistent with the values[19] obtained for other first-forbidden transitions in this region of nuclei.

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[22] F. Asaro, S. G. Thompson, F. S. Stephens, and I. Perlman, Lawrence Radiation Laboratory Report No. UCRL-9382, 1960 (unpublished); also presented in somewhat different form by I. Perlman, in *Proceedings of the International Conference on Nuclear Structure at Kingston, Ontario, 1960* (University of Toronto Press, Toronto, 1961), pp. 553–557.

[23] I. Ahmad, W. C. McHarris, and P. R. Fields (private communication).