DISCOVERY OF A 7.6-HOUR HIGH-SPIN ISOMER OF EINSTEINIUM-256*

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Abstract

A 7.6-hour, beta-emitting isomer of ^{256}Es has been produced via the (t,p) reaction by bombarding ^{254g}Es with 16-MeV tritons. No evidence for an alpha branch has been found. A number of gamma rays have been observed, on the basis of which a partial decay scheme is proposed. It is concluded that the isomer has spin 7 or 8.

A. Introduction

In previous triton bombardments of ^{257}Fm at Los Alamos, a spontaneous fission activity which appeared to have a half-life of 8 to 12 hours was found in the chemically separated Es fraction. It was postulated that this activity was the result of 2.6-hour ^{256}Fm (91.9% SF, 8.1% alpha) which had grown into the Es fraction from a hitherto undiscovered, high-spin isomer of ^{256}Es formed by the (t,α) reaction on ^{257}Fm. [A 22-minute, beta-decaying isomer of ^{256}Es, believed to have a spin of 1, has been previously reported by Hulet et al. [1].] In order to verify this postulate, we have irradiated ^{254g}Es ($T_{1/2}$ = 276 days) with 16-MeV tritons at the LASL Tandem Van de Graaff accelerator in order to prepare ^{256m}Es by the (t,p) reaction. Since much more ^{254g}Es than ^{257}Fm was available it was hoped that stronger ^{256m}Es sources could be made in this manner.

B. Experimental Results and Interpretation

The target, consisting of 2.4 x 10^{14} atoms of ^{254g}Es deposited on an area of 0.038 cm^2 on 0.0013-cm beryllium foil, was bombarded with 16-MeV tritons and the recoil products were caught on a series of 30 μg/cm^2 carbon foils, which were rotated in front of the target.

Following several irradiation periods varying from a few hours to 12 hours in length, the carbon catcher foils were removed and chemically processed using alpha-hydroxy-isobutyrate elutions from cation exchange resin columns to prepare pure Fm and Es fractions. The decay of the spontaneous fission and alpha activities of these fractions was followed. In a separation performed 5 hours after the end of irradiation to allow the 22-minute ^{256g}Es to decay, the Es fraction still showed spontaneous fission activity which grew in with a 2.6-hour half-life (^{256}Fm) and decayed with a 7.6-hour half-life. Alpha spectra of this Es fraction showed the growth of the 6.93-MeV alpha group of ^{256}Fm, confirming the presence of a 7.6-hour beta-decaying isomer of ^{256}Es. In further confirmation, Z=100 K and L x rays were observed which decayed with an apparent half-life of 7.6 hours. No evidence has been found for an alpha branch of the 7.6-hour activity, nor of Z=99 L x rays (which would be indicative of an isomeric decay branch).

A 10-minute irradiation was performed and the spontaneous fission decay of the carbon catcher foil was observed immediately without chemical processing in order to see the growth of ^{256}Fm(SF) from both the 22-minute and 7.6-hour isomers of ^{256}Es. The resulting growth and decay curve (Fig. 1) could indeed be resolved into 22-minute, 2.6-hour, and 7.6-hour components, and from these data the relative production rates for the ^{256}Es isomers were determined. Relative production rates for the (t,n), (t,2n), (t,3n), (t,t′), (t,pn), and (t,α) reactions have also been determined from analysis of the α spectra and fission data from the appropriate fractions (cf. Table I). Values for recoil efficiency, chemical yield, and integrated current would be required to convert these data to absolute cross sections.

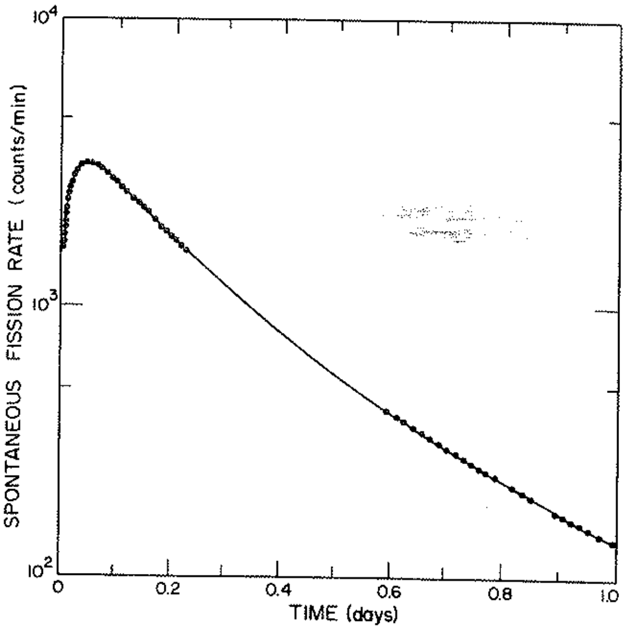

Fig. 1. Spontaneous-fission rate observed as a function of time following a 10-min bombardment of ^{254g}Es with 16-MeV tritons. Counting of the carbon recoil collector foil was begun 8.2 min after end of bombardment.

TABLE I

Relative production rates for various reactions in the 16-MeV triton bombardment of ^{254}Es

Product	Reaction	Relative production rate
^{256}Es (22 min)	t,p	1.00
^{256m}Es (7.6 h)	t,p	0.63
^{253}Cf (17.6 d)	t,α	0.80
^{256}Fm (2.6 h)	t,n	0.064
^{255}Fm (20.1 h)	t,2n	0.78
^{254}Fm (3.2 h)	t,3n	0.37
^{255}Es (39.4 d)	t,pn	7.5
^{254m}Es (39 h)	t,t′	0.35

Samples of the Es fraction were also prepared for gamma-ray studies. Using a 60-cm^3 Ge(Li) detector with 1.8-keV resolution (FWHM at 1333 keV), we observed at least 25 gamma rays attributable, on the basis of decay rate, to the ^{256m}Es activity. The principal contaminants observed were 3.2-hour ^{250}Bk (the daughter of ^{254g}Es) and 39-hour ^{254m}Es. Gamma-gamma coincidence data were also obtained; however, because of the low source activity, only the strongest coincidences could be observed. The relatively strong 862.0-, 231.3-, and 172.6-keV transitions are definitely in cascade, and since one would expect the intraband transitions associated with the ground-state rotational band to be among the strongest low-energy transitions, we have tentatively assigned the 231.3- and 172.6-keV gamma rays as the $8^+ \rightarrow 6^+$ and $6^+ \rightarrow 4^+$ transitions, respectively (cf. Fig. 2). The energy and intensity of an observed 111.4-keV transition strongly suggests that it is the $4^+ \rightarrow 2^+$ transition. Based on these assignments, we calculate rotational-band parameter values of A = 8.04 keV and B = 3.1 eV, from which the 2^+ level energy is calculated to be 48.1 keV. This value agrees reasonably well with a theoretical value of 47.9 keV, which we obtained by extrapolating from the known 2^+ level energy (45.0 keV) of ^{254}Fm, using the calculated ground-state ε_2 deformation-parameter values of Möller, Nilsson, and Nix[2] and the approximation $(\hbar^2/2\mathfrak{J}) \propto \varepsilon_2^2$.

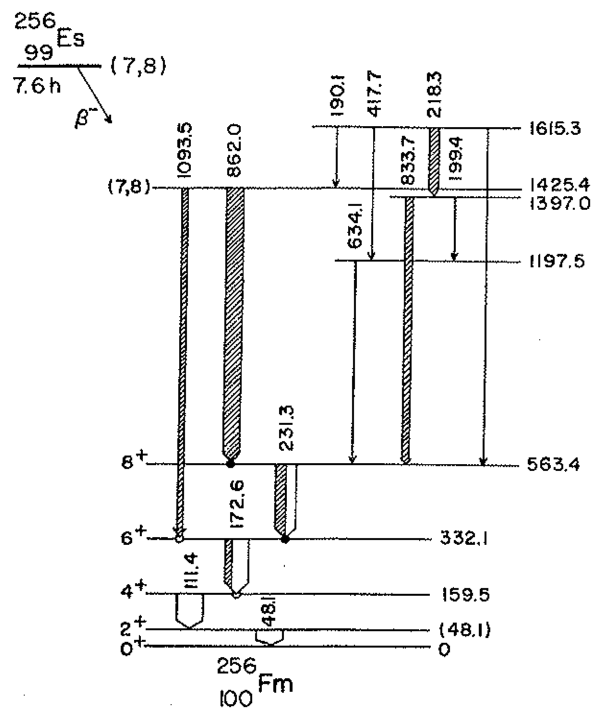

Fig. 2. Partial decay scheme of ^{256}Es(7.6 h).

Except for the 1425.4-keV level, all of the levels above 1 MeV in Fig. 2 are tentative, being based only on energy and intensity balance. The 1425.4-keV level probably has spin 7 or 8, based on its decay mode. The 7.6-hour parent state populates this level strongly, which, in conjunction with the Nilsson-model[2] orbitals available for Z≈99, N=157, leads us to believe that ^{256m}Es has a spin and parity of 7^+ or 8^+, although 9^- cannot be excluded. Intensity balance suggests that there is very little direct beta decay to the 8^+ level of the ground-state band.

Further studies will be undertaken as soon as a new ^{254g}Es target is available.

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References

1. E. K. Hulet (private communication).

2. P. Möller, S. G. Nilsson, and J. R. Nix, Nucl. Phys. A229 (1974).