The Decay of Cs^{136}†

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The radiations from Cs^{136} have been investigated with beta spectrometers, scintillation spectrometers, and a proportional counter spectrometer. Beta-particle groups of 341-kev and 657-kev energy were found, together with gamma-ray groups of energy 67.2, 153, 162, 265, 335, 822, 1041, 1245, 1410, 2350, and 2490 kev. A decay scheme is proposed on the basis of gamma-ray intensities and gamma-gamma coincidences.

THE nuclide Cs^{136} was discovered by Glendenin[1] in slow-neutron fission. Subsequent experiments by Finkle, Engelkemeir, and Sugarman[2] characterized the radiations by absorption techniques. Glendenin[3] was later able to assign this cesium isotope to mass 136 from the (n,α) reaction on La^{139}, and obtained a half-life of 13.7 days. Absorption experiments yielded a value of 0.35 Mev for the beta-particle energy, and 1.1 Mev for the gamma radiation.

Since Cs^{136} is a shielded nuclide, it is of special interest in the study of the fission process. Rather complex mixtures of cesium isotopes result from high-energy fission of uranium, and so a detailed study of the radiations from Cs^{136} was undertaken in the hope that some characteristic radiation would be discovered which could be used to unambiguously assign yields to Cs^{136} formed in high-energy fission.

For the present experiments carrier-free cesium fractions were obtained from uranium targets irradiated with 190-Mev deuterons in the 184-inch cyclotron of the University of California Radiation Laboratory. Early measurements of the radiations from such fractions showed that although Cs^{136} was the most prominent activity, the presence of other nuclides made the data rather questionable. Consequently, an intense source of the carrier-free, fission product cesium was deposited on the filament of a time-of-flight mass separator,[4] and the mass-136 fraction was collected. All measurements described below were performed on the mass-separated Cs^{136} sample.

The decay of a small portion of the mass-separated sample was followed with an end-window Geiger counter, and after six half-lives no deviation from a half-life of 12.9 days has been observed.

The radiations from Cs^{136} were studied on several instruments. A ring-focused, long magnetic lens beta spectrometer[5] was used to examine the electron spectrum in the energy range 100 to 2000 kev. For the energies below 200 kev a 25-cm radius, double-focusing beta spectrometer was employed. Gamma-ray energies were measured on sodium iodide scintillation spectrometers having a resolution for the Cs^{137} gamma ray of 7.5 to 9.0 percent full width at half-maximum, depending upon the application. Recording of the data was accomplished either by an automatically swept single-channel pulse-height analyzer, or a 50-channel analyzer for low counting rates. The low-energy electromagnetic radiation was also studied on a xenon-filled proportional counter, connected to the 50-channel analyzer.

Fermi analysis of the beta-particle spectrum shows the energies and intensities of the beta-particle transitions to be 341±2 kev (92.6 percent) and 657±3 kev (7.4 percent). From the Moszkowski nomographs,[6] log*ft* for the low-energy transition is 6.0, while that of the higher-energy beta group is 8.0.

Internal conversion lines from six gamma-rays were observed on the lens spectrometer, with the results shown in Table I. The K/L ratio for the 67.2-kev

TABLE I. Gamma-radiation from Cs^{136}.

Gamma ray	γ-ray energy, kev: Scintillation spectrometer	Proportional counter spectrometer	Beta spectrometer	K/L Beta spectrometer
γ_1	67±2	67.2±0.5		3.5
γ_2	160±2 (unresolved γ_2 and γ_3)		153±1	5.9
γ_3			162±1	1.0
γ_4	265±3			
γ_5	334±3		335±2	5.2
γ_6	820±8		822±2	3.0
γ_7	1040±10		1041±5	
γ_8	1245±13		1245±6	
γ_9	1410±28			
γ_{10}	2350±45[a]			
γ_{11}	2490±50[a]			

[a] Gamma-ray energies calculated from pair peaks.

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transition was determined on the double-focusing spectrometer.

Photoelectric peaks from eight gamma rays were identified on the scintillation spectrometers. Two additional peaks have been interpreted as pair production peaks from the two highest-energy gamma rays. The gamma-ray energies are also shown in Table I.

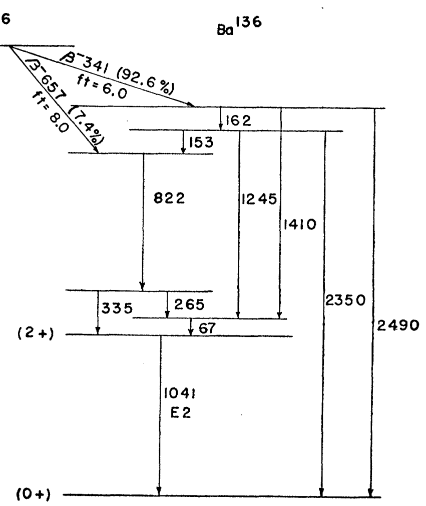

FIG. 1. Proposed decay scheme for Cs^{136}. Energy values are in kev.

No radiation was seen on the proportional counter besides the 67.2-kev transition, its xenon escape peak, and the K and L x-rays.

The decay scheme of Fig. 1 is proposed on the basis of gamma-ray intensities and gamma-gamma coincidence spectroscopy. The K-shell internal conversion coefficient for the 1.041-Mev gamma ray indicates an $E2$ transition, which leads to the assignment of a spin of two and even parity to the first excited state, as would be expected for an even-even nucleus.[7] A 1.041-Mev first excited state is consistent with other even-even nuclides in the region of mass 136. Work is continuing on the assignment of spins and parities to the other levels of Ba^{136}.

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Note added in proof.—Recent coincidence measurements show the 153-kev gamma ray to be in cascade with the 1245- and 162-kev gamma rays. This reverses the order of the 153–162 kev cascade from that shown in Fig. 1. The 153-kev transition is a crossover for a 65–88 kev cascade not shown in Fig. 1.

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Yield of Alpha Particles from Photonuclear Reactions at 23-Mev Bremsstrahlung

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The yield of alpha particles from (γ,α) reactions and other photoreactions involving alpha-particle emission from 9 elements up to atomic number 58 is given. Much of the data used have been previously published but further information has been obtained on the reactions in carbon, oxygen, and bromine. Original measurements have been made for the (γ,α) reactions in vanadium and silver. The yield is a maximum in the region of copper and drops rapidly with increasing atomic number. There is evidence that at high atomic numbers, reactions involving the emission of another particle as well as the alpha particle predominate over just single alpha-particle emission.

INTRODUCTION

THE study of the yield of neutrons and of protons from nuclei excited by photon absorption has received considerable attention. Sufficient data are now available for a preliminary examination of the dependence of alpha-particle yield on atomic number. The following is a report on the yield of alpha particles from the (γ,α) reaction produced by the bombardment of several medium weight nuclei with 23-Mev bremsstrahlung.

Figure 1 shows the (γ,α) yield points for betatron radiation having a maximum energy of 23 Mev. Some of the points shown are taken from previously described work, and some have been determined recently in this laboratory. A brief discussion of each point follows:

1. $C^{12}(\gamma,\alpha)Be^8$

This reaction has been examined by several workers,[1–4] some using bremsstrahlung and some using

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