Half-Lives and Alpha Energies of Cm^{248} and Cm^{246}

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The new isotope Cm^{248}, the daughter of Cf^{252}, has been separated from a sample of californium. Cm^{248} decays by the emission of a 5.054±0.015 Mev α particle with an alpha half-life of $(4.7\pm0.4)\times10^5$ years. The spontaneous fission half-life of Cm^{248} was found to be $(4.6\pm0.5)\times10^6$ years. Cm^{246} was also observed in the curium daughters isolated from the californium sample; the Cm^{246} decays by the emission of a 5.373 ±0.010 Mev α particle with a half-life of 6620±320 years.

CURIUM-248 would be expected to have a half-life in the order of 10^5 to 10^6 years based on alpha systematics.[1] Although it is known that Cm^{248} must be present in curium produced by the long neutron irradiation of plutonium in order that Bk^{249} and the heavier actinides can be formed,[2] neither alpha groups due to Cm^{248} nor a detectable Pu^{244} daughter can be found because of the long half-life and low abundance of Cm^{248}.

One way in which Cm^{248} can be formed in high abundance is from the alpha-decay of californium-252. Californium produced by neutron irradiation of Pu consists of Cf^{249}, Cf^{250}, Cf^{251}, and Cf^{252},[3] but most of the alpha activity is due to Cf^{252} since it has the shortest half-life and is found in high abundance; most of the remaining alpha activity is due to Cf^{250}. Thus the curium daughters will consist mainly of Cm^{248} and Cm^{246} with very small amounts of Cm^{247} and Cm^{245}.

We have isolated the curium daughters from a sample of 2.27×10^6 disintegrations/minute of californium prepared from plutonium irradiated in the Materials Testing Reactor. The californium was first separated from curium and other actinide elements by several Dowex 50 lactate ion-exchange column runs.[4] After standing for 169 days curium was again separated from the californium by several Dowex 50-α-hydroxyisobutyrate ion exchange column runs.[5] The curium from the second separation showed alpha particles of energy 5.05 and 5.37 Mev, as well as those due to Cm^{244} and Cm^{242} which had not been completely removed in the first separation. Additional ion-exchange column runs failed to separate the new alpha groups from the known curium isotopes, so the 5.05- and 5.37-Mev alpha emitters are also curium. The 5.37-Mev particles are due to Cm^{246}; particles of this energy have also been found in curium produced by the decay of Pu^{246}.[6] The 5.05-Mev particles are almost certainly due to Cm^{248}. On the basis of heavy-element systematics, Cm^{248} and Cm^{247} would be expected to have about this α-particle energy. However, the contribution from Cm^{247} will be negligible because of the low disintegration rate of Cf^{251} in our californium and the expected long half-life of Cm^{247}.

At the time of the curium milking, alpha pulse analysis of the californium showed 85.2% Cf^{252} and 14.8% Cf^{250} alpha particles. After correcting for the chemical yield, it was found that the ratio of the Cf^{250} disintegration rate to the Cm^{246} rate was $(2.03\pm0.09)\times10^4$ and the ratio of Cf^{252} rate to the Cm^{248} rate was $(1.36\pm0.10)\times10^6$. Using 2.2±0.2 yr for the half-life of Cf^{252},[3] and 9.3±0.9 yr for that of Cf^{250},[7] a half-life of 6620±320 yr was calculated for Cm^{246} and $(4.7\pm0.4)\times10^5$ yr for Cm^{248}. The alpha half-life of Cm^{246} can be compared with values of 4000±600 yr,[8] and 5000±500 yr[7] obtained by mass analyzing the plutonium daughters from curium of known isotopic composition, and a value[6] of 2300±500 yr obtained by determining the amount of curium produced from the decay of Pu^{246}.

The alpha energies of Cm^{246} and Cm^{248} were determined using the AECL gridded ionization chamber and 30-channel pulse height analyzer.[9] The curium was electroplated onto a polished platinum disk in order to obtain a thin uniform plate with a high yield. Alpha energies of 5.054±0.015 Mev for Cm^{248} and

TABLE I. Summary of the results of this investigation.

Nuclide	Alpha energy	Alpha half-life	Fission half-life
Cm^{246}	5.373±0.010 Mev	6.620±320 yr	
Cm^{248}	5.054±0.015 Mev	$(4.7\pm0.4)\times10^5$ yr	$(4.6\pm0.5)\times10^6$ yr

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5.373±0.010 Mev for Cm^{246} were obtained by using Po^{210} (5.301 Mev), Po^{214} (7.680 Mev), Po^{218} (5.998 Mev), Em^{222} (5.486 Mev), Cm^{242} (6.110 Mev), and Cm^{244} (5.798 Mev) as standards.

The spontaneous fission half-life of Cm^{248} was determined by fission-counting the curium sample after exhaustive separations from californium. When a correction of 3% was applied to allow for the spontaneous fission of Cm^{246} (assuming its half-life to be 3×10^7 yr),[10] a value of $(4.6\pm0.5)\times10^6$ yr was obtained. The results of this investigation are summarized in Table I.

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Decay of Neutron-Deficient Isotopes of Pd and Rh†

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Pd isotopes of masses 98, 99, and 101 were prepared by α-particle bombardment of ruthenium. The radiations of these isotopes and of their Rh daughters were investigated with a scintillation coincidence spectrometer. Rh^{98} decays with a half-life of 8.7±0.1 minutes by emission of 2.5±0.2 Mev positrons in coincidence with 650±10 kev γ rays. Its Pd^{98} parent was shown by successive daughter extractions to decay with a half-life of 17.5±0.5 minutes. Rh^{99} (4.7±0.1 hours) showed 0.74-Mev positrons (10%) in coincidence with 335±10 kev γ rays (70%). Other γ rays were observed at 615±15 kev (20%), 890±20 kev (weak line coincident with 335-kev γ), 1.26±0.03 Mev, and 1.41±0.04 Mev (weak). Pd^{99} (21.6±0.6 minutes) was identified by successive Rh daughter extractions. Its maximum positron energy is 2.0±0.1 Mev and the following γ rays were observed: 140, 275, 420, and 670 kev. The 140-kev γ ray is the most intense and the 420-kev peak represents two γ rays of about the same energy in cascade. Rh^{101} (4.7±0.2 days) decays by electron capture followed by emission of 312±10 kev γ rays. Pd^{101} (8.5±0.3 hours) emits 0.58 ±0.04 Mev positrons (4%) by decay to the ground state of Rh^{101}. The γ rays observed were at 288 kev (15%), 590 kev (15%), 720, 1190, and 1280 kev (last three less intense). The photopeak at 288 kev represents two coincident γ rays of about the same energy. Tentative spin and parity assignments were made for the ground states of the nuclides investigated. Mass assignments were confirmed by a study of the relative yields of the various radioactive isotopes as the bombarding α-particle energy and isotopic composition of the Ru target were varied.

INTRODUCTION

IN order to help identify the mass number of a long-lived Tc isotope,[1] assumed to be Tc^{98}, its γ-ray spectrum was compared with that of Rh^{98}. Since both of these nuclides decay to stable Ru^{98}, some of the γ rays might be identical from both. When this work was begun, a 9-min Rh^{98} had been reported[2] but its mass assignment also was uncertain and no information was given about any γ rays. Therefore a study of this isotope was undertaken and extended to include other Rh and Pd isotopes produced in the same bombardments. During the course of these measurements, a new paper appeared[3] in which additional data are presented on Rh^{98}, Rh^{97}, Pd^{98}, and Pd^{99}. Some of these data were confirmed and extended in the present investigation.

EXPERIMENTAL PROCEDURE

Small samples of $RuCl_3$ or of Ru metal powder were irradiated with α particles at a series of energies between 17 and 40 Mev. When necessary, the 40-Mev α particles from the cyclotron were degraded to the desired energy by the proper thickness of Al foil. Irradiation times varied between 5 and 30 minutes; the beam current was usually 0.5–1.0 μa.

Shortly after each irradiation the target was dissolved in diluted HCl,[4] Pd^{+2} carrier was added, and then Pd dimethylglyoxime was precipitated. This was dissolved in hot HNO_3, and then a few successive $Fe(OH)_3$ and AgCl scavenging precipitations were made. The Pd was precipitated again as the dimethylglyoxime. When an active Pd sample was desired for study this purification cycle was repeated. When an active Rh daughter activity was wanted, the second Pd precipitate was allowed to stand for an appropriate growth time. Then it was dissolved, Rh^{+3} carrier was added, and the Pd was removed by a series of precipitations with cupferron. Finally the Rh was precipitated as $K_3Rh(NO_2)_6$. In the last few experiments an ion exchange method was used for separating the Rh from the Pd parent. This will be described below in the section on Pd^{98}.

Decay of gross β rays and of gross γ rays was followed with end window proportional counters and with NaI(Tl) scintillation detectors, respectively. The β- and

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