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Contract No. W-7405-eng-48

NEUTRON DEFICIENT ISOTOPES OF CERIUM AND LANTHANUM

J. B. Chubbuck and I. Perlman

Special Review of Declassified Reports
Authorized by USDOE JK Bratton
Unclassified TWX P182206Z May 79

REPORT PROPERLY DECLASSIFIED

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Carbide & Carbon Chemicals Corp. (Y-12 Area)	25-28
Columbia University (Dunning)	29
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Hanford Directed Operations	34-38
Iowa State College	39
Los Alamos	40-42
Monsanto Chemical Company, Dayton	43-44
National Bureau of Standards	45-46
Naval Radiological Defense Laboratory	47
NEPA	48
New York Directed Operations	49-50
Oak Ridge National Laboratory	51-58
Patent Advisor, Washington	59
Technical Information Division, ORDO	60-74
UCLA Medical Research Laboratory (Warren)	75
University of California Radiation Laboratory	76-80
University of Rochester	81-82
Chicago Directed Operations	83
Declassification Procedure	
Declassification Officer	84-87
Publications Officer	88
Patent Department	89-90
E. O. Lawrence	91
Area Manager	92
Information Division	93
Total	93

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Neutron Deficient Isotopes of Cerium and Lanthanum

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Abstract

This is a description of some bombardments performed with the 60-inch and 184-inch cyclotrons at Berkeley. These bombardments resulted in the production of the following isotopes: 19.5 hour La^{135} which decays by orbital electron capture and emits gamma radiation of 0.76 Mev energy; 2.1 hour La^{136} which decays by positron emission, the positron having 0.84 Mev energy; La^{137} which has a half-life greater than 400 years; 16 hour Ce^{135} which decays by positron emission; 36 hour Ce^{137} which decays by orbital electron capture emitting conversion electrons of 0.18 Mev energy and gamma radiation of 0.28 and 0.75 Mev energies; and 140 day Ce^{139} which decays by orbital electron capture emitting conversion electrons of 0.15 Mev energy and gamma radiation of 0.18 and 1.8 Mev energies.

Neutron Deficient Isotopes of Cerium and Lanthanum

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Fast particle fission of bismuth in this laboratory has produced neutron deficient isotopes in the region of cerium[1]. The studies described herein were undertaken partly to identify some of these.

On the neutron deficient side of stability, two radioactive isotopes of lanthanum assigned to La^{137} [2,3], and La^{138} [4] have been reported but more recent evidence[5] shows La^{138} to be stable and present in nature to the extent of 0.089 percent. Evidence is presented below for assigning the reported radioactive properties of La^{137} to La^{135} and those of La^{138} to La^{136}.

To prepare the lanthanum activities cesium in the form of $CsNO_3$ was irradiated with 30 Mev helium ions in the 60-inch cyclotron. The lanthanum fraction was separated and the decay curve resolved into two components of 2.1 hours and 19.5 hours half-lives. Both of these activities, therefore, must belong to isotopes of lanthanum of mass number 136 or lower.

A low-resolution beta-ray spectrometer showed a positron of 0.82 Mev, decaying with the 2 hour half-life, the energy estimated from the visual end-point of the spectrometer curve. No negative particles were detected. A Feather analysis of a beryllium absorption curve, taken soon after the bombardment, gave a range in beryllium of 310 mg/cm^2, corresponding to an energy of 0.84 Mev.

A beryllium absorption curve was taken about twenty-four hours

after the bombardment, when the 2.1 hour activity had decayed out. This curve showed no particle radiation, but a 5.2 Kev L x-ray component could be resolved from the harder electromagnetic radiation. The positron activity determined earlier therefore belongs entirely to the 2.1 hour activity. Earlier absorption curves taken with aluminum showed the presence of a 34 Kev x-ray and a 0.76 Mev gamma ray in low intensity was determined by lead absorption. All of the electromagnetic radiation noted soon after bombardment could be attributed to the 19.5 hour activity that was present, thus the 2.1 hour activity probably has no electromagnetic radiation. In the 19.5 hour activity x-rays were more abundant than gamma rays by a factor of about 50 showing that most of the electron capture decay goes directly to the ground state.

As indicated in Table 1, the 2.1 hour activity was formed in about 1/100 the yield of the 19.5 hour activity. With the energy of helium ions employed, the $(\alpha, 2n)$ reaction is more prolific than the (α, n) reaction[6]. The order of the decay energies is also compatible with the assignment of the 2.1 hour period to La^{136} and the 19.5 hour period to La^{135}.

The radioactive isotope of cerium decaying by K-electron capture and assigned to mass number 137 is discussed below. The lanthanum daughter of this isotope was not definitely observed and a minimum half-life could be set at 400 years based on x-ray counting rates.

Cerium activities were produced by bombarding La_2O_3 with 20 Mev deuterons in the 60-inch cyclotron. A sample of the chemically separated cerium resolved into two components, 140 day Ce^{139} and a 36 hour activity assigned below to Ce^{137}. Pool and Krisberg[7] have recently reported work with Ce^{139} in which they found conversion

electrons and gamma-radiation of 0.184 and 0.8 Mev respectively. In the present study, the conversion electrons were confirmed, the low energy gamma ray was determined as 0.18 Mev but a value of 1.8 Mev was found for the hard component. The conversion electrons were determined as 0.15 Mev both with the beta-ray spectrometer and by absorption in beryllium.

In another bombardment of La_2O_3, 40 Mev deuterons from the 184-inch cyclotron were employed. This bombardment produced the 36 hour activity in far greater yield compared to the 140 day activity than did the 20 Mev deuteron bombardment. These two cerium activities are therefore probably not isomers and the most likely assignment for the 36 hour activity is Ce^{137}.

A sample of the 36 hour activity showed a well-defined conversion electron peak, with an energy of about 0.23 Mev. There was no positron activity with this isotope. A beryllium absorption curve indicated a range of about 45 mg/cm^2, corresponding to an energy of about 0.22 Mev. An aluminum absorption curve showed the presence of 34 Kev x-rays while gamma rays of 0.28 and 0.75 Mev were measured with lead absorbers.

A third bombardment of La_2O_3 was made, this time with 60 Mev deuterons in an attempt to prepare the parent of La^{135} by the d,6n reaction. The 36 hour Ce^{137} activity was formed in such high yield that the Ce^{135} activity was completely masked in the gross decay curve but a sample of the cerium activity placed on the beta-ray spectrometer showed positron activity. Because of the great background from scattered radiation the positron energy could only be estimated as 0.4 Mev. Integration of the area under the positron peaks of successive beta-ray spectrometer curves taken for two days

indicated a half-life of about 16 hours. It was impossible to determine any other characteristics of this isotope. The activity is assigned to Ce^{135} because it had not appeared in bombardments at lower energies and 19.5 hour La^{135} could be shown to grow into the cerium fraction at a rate corresponding to a half-life for its parent of about 16 hours.

The cooperation of Dr. J. G. Hamilton, Mr. D. C. Sewell, Mr. J. T. Vale, Mr. T. Putnam, Mr. B. Rossi and other members of the 60-inch and 184-inch cyclotron groups is gratefully acknowledged. This research was sponsored by the Atomic Energy Commission under Contract No. W-7405-eng-48 with the Radiation Laboratory, University of California, Berkeley, California.

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TABLE 1

Isotope	Type of Radiation	Half-life	Energy of Radiation in Mev		Produced by	Cross section $\times 10^{24}$ cm^2
			Particle	Electro-magnetic		
La^{136}	β^+	2.1 hrs.	0.84	None	$Cs^{133}(\alpha,n)$	0.0003*
La^{135}	K, γ	19.5 hrs.	None	0.76	$Cs^{133}(\alpha,2n)$	0.03*
La^{137}		> 400 yrs.			decay of Ce^{137}	
Ce^{139}	K, γ, e^-	140 days	0.15	0.18 1.8	$La^{139}(d,2n)$	0.09**
Ce^{137}	K, γ, e^-	36 hrs.	0.18	0.28 0.75	$La^{139}(d,4n)$	0.06† 0.002** 0.04††
Ce^{135}	β^+	16 hrs.			$La^{139}(d,6n)$	

* Bombardment energy 30 Mev α.
** Bombardment energy 20 Mev deuterons.
† Bombardment energy 40 Mev deuterons.
†† Bombardment with 40 Mev deuterons

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