Title

The Isotopes of Americium

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Publication Date

1950-04-01

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

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K. Street, Jr., A. Ghiorso, and G. T. Seaborg

April 11, 1950

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THE ISOTOPES OF AMERICIUM

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April 11, 1950

ABSTRACT

Three new americium activities ($Am^{238?}$, Am^{243}, and $Am^{244?}$, the latter two formed by n,γ reactions) are described and some additional information is given on previously reported americium isotopes.

THE ISOTOPES OF AMERICIUM

K. Street, Jr., A. Ghiorso, and G. T. Seaborg
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University of California, Berkeley, California
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Intermittent investigation of the isotopes of americium during the past two years has resulted in the production of three new americium activities and has also yielded some additional information about previously[1] reported activities. Since the work on americium is still in progress, this letter will give only a brief report of the new results obtained and a detailed description of the experiments will be deferred until a later date.

$Am^{238?}$.-- Bombardment of Pu^{239} with 50-Mev deuterons in the 184-inch cyclotron results in the production of a new americium activity of *ca*. 1.2 hours half-life in addition to the previously reported 12- and 50-hour activities.[1] Differential counting with beryllium and lead absorbers indicate that the decay is accompanied by the emission of conversion electrons and x-rays. The same activity is produced in good yield with 17-Mev deuterons in the 60-inch cyclotron, thus its mass number is probably greater than 237, since there is good evidence[2,3] that even with the heavy elements the yield of the (d,4n) reaction is very small at 17 Mev. In view of its half-life, radiation characteristics, and method of formation, this activity is probably an orbital electron capturing isotope and is best assigned to Am^{238}.

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[1] G. T. Seaborg, R. A. James, and L. O. Morgan, National Nuclear Energy Series, Plutonium Project Record, Vol. 14B, "The Transuranium Elements: Research Papers," Paper 22.2 (McGraw-Hill Book Co., Inc., New York, 1949).

[2] R. A. James, A. E. Florin, H. H. Hopkins, Jr., and A. Ghiorso, *ibid*., Paper No. 22.8.

[3] L. B. Magnusson, S. G. Thompson, and G. T. Seaborg, Phys. Rev. (May 15, 1950 issue).

Am^{239}.-- The 12-hour orbital electron capturing Am^{239} has been previously reported to decay by alpha-particle emission of unknown energy to the extent of ca. 0.1 percent.[1] A redetermination of the alpha branching ratio yielded the better value ca. 0.01 percent. The energy of the alpha-particle has been determined by means of a multi-channel pulse analyzer to be 5.77 ± 0.05 Mev.

Am^{240}.-- The 50-hour electron capturing americium activity was tentatively assigned[1] to Am^{240}. This assignment has been confirmed. The 50-hour activity is produced in good yield from the bombardment of Pu^{239} with 10-Mev deuterons and is not observed in the bombardment of Pu^{239} with 9-Mev protons (60-inch cyclotron) in which Am^{239} is produced in good yield. Since the yield of the (d,3n) reaction is low at 10 Mev and since (p,n) should be the principle reaction producing americium with 9-Mev protons, the 50-hour activity is best assigned to Am^{240}. No alpha-particles associated with the 50-hour americium have been observed. This is consistent with its assignment to Am^{240} since the systematics of alpha-radioactivity[4] predict for this odd-odd nucleus a partial half-life for alpha-decay of some 10^3 years.

Am^{241}.-- The production of this isotope in milligram amounts by the neutron irradiation of plutonium[5] makes it possible to study the higher mass isotopes of americium produced by (n,γ) reactions and the results of such experiments are reported in the following paragraphs. Recent specific activity measurements by B. B. Cunningham, S. G. Thompson, and H. R. Lohr[6] give a somewhat shorter

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[4] I. Perlman, A. Ghiorso, and G. T. Seaborg, Phys. Rev. 77, 26 (1950).

[5] A. Ghiorso, R. A. James, L. O. Morgan, and G. T. Seaborg, Phys. Rev., in press.

[6] B. B. Cunningham, S. G. Thompson, and H. R. Lohr, unpublished work.

half-life for Am^{241} than that previously reported.[7] The new half-life is 475 years.

<u>Am^{242}</u>.-- In addition to the 16-hour Am^{242m}, a long-lived Am^{242} produced by the (n,γ) reaction on Am^{241} has been reported;[1] alpha-decay of this isotope was demonstrated by separating the Np^{238} daughter and 0.5-Mev beta-particles in the americium fraction were also ascribed to Am^{242}. The fact that the observed beta-particles do belong to Am^{242} has now been demonstrated by observing the growth of Cm^{242} (half-life 162 days) in the purified, pile neutron-bombarded americium in an amount corresponding to the number of beta-particles observed. Mass spectrographic analysis of this americium shows Am^{242} to be present to the extent of <u>ca</u>. 0.5 percent. This analysis together with the results from the above Cm^{242} growth experiment and the yield from a Np^{238} extraction allow both the alpha- and beta-decay half-lives of Am^{242} to be estimated. The partial half-life obtained for beta-particle emission is roughly 10^2 years and that for alpha-particle emission is <u>ca</u>. 10^4 years. The (n,γ) cross section for the formation of Am^{242} is very roughly 10^{-22} cm^2 but this may be off by a factor of several due to the many uncertainties involved, especially the neutron flux.

<u>Am^{243}</u>.-- Neptunium separations from the americium fraction of an irradiation of Am^{241} with pile neutrons show the presence of equilibrium amounts of both Np^{238} and Np^{239}. The presence of Np^{239} proves the existence of the new isotope Am^{243} which is produced by two successive neutron capture processes in Am^{241} and decays by alpha-particle emission to Np^{239}. Mass spectrographic analysis of the americium of this bombardment showed Am^{243} present to the extent of <u>ca</u>. 0.5 percent. This together with the yield of Np^{239} determined in the chemical

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[7] B. B. Cunningham, National Nuclear Energy Series, Plutonium Project Record, Vol. 14B, "The Transuranium Elements: Research Papers," Paper No. 19.2 (McGraw-Hill Book Co., Inc., New York, 1949).

extraction experiments gives a partial half-life for alpha-particle emission for Am^{243} of roughly 10^4 years. Alpha-particle pulse analysis of americium from another irradiation (containing approximately 10 percent Am^{243}) showed the alpha-particle energy to be 5.21 ± 0.03 Mev. This energy and half-life indicate that alpha-emission in this odd-even nucleus is not prohibited,[4] but like the case of the analogous nucleus Am^{241}, the measured alpha-particle energy may not represent the ground state transition. If one takes 5.84 Mev[8] for the alpha-particle energy of the ground state transition of Cm^{243} and closes a decay cycle using the measured alpha-particle energy of Am^{243} and 0.7 Mev for the beta-decay disintegration energy[9] of Np^{239}, one finds that Am^{243} could be unstable with respect to beta-decay by _ca._ 0.05 Mev. However, due to the uncertainties in the above energies (especially Np^{239}) it is entirely possible that Am^{243} is beta-stable; the alpha-particle energy of Cm^{243} is also very uncertain and it is not known whether it corresponds to the ground state transition. In order to test this point curium was separated from an aged sample containing Am^{243} and no detectable Cm^{243} was found; this experiment places a lower limit of about 10^3 years on the partial half-life of Am^{243} for negative beta-emission. The cross section for the reaction $Am^{242}(n,\gamma)Am^{243}$ seems to be large, of the order of some 4×10^{-21} cm^2, a value which is subject to large error because of the uncertainty in the neutron flux.

_Am^{244}?_.— Irradiation of americium containing approximately 10 percent of the isotope Am^{243} with thermal neutrons in the uranium-heavy water pile at the Argonne National Laboratory produced a new americium activity of _ca._ 25-min. half-life at a yield corresponding to a cross section of roughly $1/2 \times 10^{-22}$ cm^2.

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[8] K. Street, Jr., S. G. Thompson, and A. Ghiorso (to be published).

[9] G. T. Seaborg and I. Perlman, Revs. Mod. Phys. _20_, 585 (1948).

This activity is probably due to the beta-emitting isotope Am^{244}, formed by an (n,γ) reaction.

We would like to thank Dr. R. A. James and Dr. S. G. Thompson for their assistance in many of the experiments, and Mr. F. L. Reynolds for the mass spectrographic analysis of the americium samples. It is a pleasure to thank T. M. Putnam, Jr., G. B. Rossi, J. T. Vale, and the crews of the 60-inch and 184-inch cyclotrons for their cooperation in the bombardments with these machines, and also W. H. Zinn and the operating group of the Argonne Laboratory pile for their cooperation and help in neutron irradiation experiments.

This work was performed under the auspices of the United States Atomic Energy Commission.

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