Submitted to Physical Review Letters

UCRL-19953
Preprint

c.2

THE ALPHA DECAY OF ^{240}Am

D. J. Gorman and F. Asaro

RECEIVED
LAWRENCE
RADIATION LABORATORY

SEP 23 1970

LIBRARY AND
DOCUMENTS SECTION

August 1970

AEC Contract No. W-7405-eng-48

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

UCRL-19953
c.2

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

34

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

THE ALPHA DECAY OF ^{240}Am*

D. J. Gorman† and F. Asaro

Lawrence Radiation Laboratory
University of California
Berkeley, California 94720

August 1970

Abstract:

Alpha decay has been observed in the odd-odd nucleus ^{240}Am. Three alpha groups were observed with energies of 5.378±.001, 5.337±.002, and 5.286±.003 MeV. The branching ratio for these three alpha groups was determined to be 1.9×10^{-4}%. The ground state of the ^{240}Am is composed of 5/2 - [523] proton and 1/2 + [631] neutron quasiparticle states with resultant spin and K of 3, and odd parity. The favored alpha decay proceeds to a rotational band in ^{236}Np based on the same state.

During the course of experiments on the alpha decay of ^{239}Am [1] we observed for the first time alpha decay in the odd-odd nucleus ^{240}Am. The americium was initially prepared by bombarding 200-300 mg of ^{239}Pu fluoride with 18 MeV deuterons in the 88-inch cyclotron at the Lawrence Radiation Laboratory, Berkeley. The plutonium used contained significant amounts of ^{241}Pu which decays to ^{241}Am with a 13.2 year half-life.[2] As a result, the only initial evidence of alpha particles from ^{240}Am was a broadening of the 5.389 MeV alpha peak of ^{241}Am.[1]

To confirm that this broadening was indeed due to alpha particles from ^{240}Am we undertook to prepare a sample containing much less ^{241}Am. Plutonium

was obtained containing 99.973% ^{239}Pu and with only 0.0001% ^{241}Pu. The plutonium was purified by adsorption on an AG-1 anion column in 10M HCl.[3] After elution with 10M HCl to remove any americium present, the plutonium was eluted with 10M HCl - 0.1M HI,[3] and converted to the fluoride by addition of HF.

Approximately 200 mg of the dried fluoride was irradiated with 18 MeV deuterons for a total of 421 microamp hours. The irradiated sample was dissolved in concentrated HCl and H_3BO_3. The plutonium was adsorbed on an AG-1 anion column in 10M HCl.[3] Lanthanum carrier was added to the effluent, and the americium was purified by taking it through a $La(OH)_3$ - LaF_3 cycle.[4] The americium was separated from the lanthanum on an AG-50 cation column with 20% ethanol-saturated HCl solution.[4] After further purification on another anion column (to remove traces of plutonium remaining) and a cleanup column[5] the sample was vaporized onto platinum.

The alpha spectrum was observed over a period of several days with a 6 mm Au-Si surface barrier detector with a resolution (full-width at half-maximum) of 20 keV, and recorded in a 400 channel pulse height analyzer. The resultant spectrum is shown in Fig. 1.

The decay of the two larger ^{240}Am peaks was followed, and they were found to decay with a half-life of approximately 51 hours. The ^{240}Pu was observed to grow in with a half-life of 51 hours indicating it is produced from the electron capture decay of ^{240}Am. The ^{238}Pu present is thought to come from the electron capture decay of 1.9 h - ^{238}Am. The chemistry required about 5-6 hours from the end of the bombardment to the final separation of the plutonium. Sufficient ^{238}Am could remain after this time to produce the ^{238}Pu observed.

The energies and abundances of the ^{240}Am alpha groups are given in Table I.

The gamma spectrum of ^{240}Am exhibits K X-rays and two strong gamma rays with energies of 888.8 and 987.5 keV [6] coming from the electron capture decay. Assuming that all electron captures give rise to one of these gamma rays[6,7,8] the branching ratio for the three observed alpha groups of ^{240}Am is 1.9×10^{-4}%.

Using this branching ratio and the measured alpha intensities, the hindrance factors for the transitions were calculated.[9] These are listed in Table I. The small magnitude of the hindrance factors is indicative of favored alpha decay.[10] The states of the daughter nucleus populated by favored alpha decay have the same Nilsson quantum numbers, ($K\pi$ [$Nn_z\Lambda$]) as the parent state.

To determine the nature of the states populated in the favored alpha decay, the rotational constants and the energy difference between the ground and first excited states were calculated for the different combinations of Nilsson proton and neutron states available. The moments of inertia were calculated by subtraction of the even-even value (obtained from ^{234}U) from the sum of the odd proton (from ^{235}Np) and odd neutron (from ^{235}U) values.[13] The rotational constants for the proton states 5/2 + [642] and 5/2 - [523] in ^{235}Np were taken as 4.87±0.01 and 6.09±0.04 respectively.[1] The rotational constants used for the neutron states 1/2 + [631], 5/2 + [633], and 7/2 - [743] were 6.04, 6.014, and 5.133 respectively,[2] and the even-even value in ^{234}U was taken as 7.30.[2] The results of this caluclation are summarized in Table II which gives the calculated rotational constant $R = \hbar^2/2\mathfrak{J}$ and the ground to first excited state energy difference for the two possible resultant K values.

14. S. G. Nilsson, K. Dansk. Vid. Selsk. Mat. Fys. Medd. 29, No. 16 (1955).

15. C. J. Gallagher, Jr., and S. A. Moszkowski, Phys. Rev. 111, 1282 (1958).

Table I. ^{240}Am Alpha Groups

Alpha Particle Energy (MeV)†	Intensity (%)	Hindrance Factor
5.378±0.001	86.8±1.0	2.0
5.337±0.002	12.0±0.4	8.1
5.286±0.003	1.23±0.10	39

†Relative to ^{241}Am (5.486 MeV) and ^{240}Pu (5.168 MeV).

Table II. Rotational constants and transition energy to first excited state of rotational band for different proton and neutron configurations in ^{236}Np.

PROTON STATE	NEUTRON STATE		
	1/2 + [631]↓	5/2 + [633]↓	7/2 - [743]↑
	R = 4.275±0.009	R = 4.262±0.009	R = 3.800±0.008
5/2 + [642]↑	[a](3+) [b]34.20±0.07	(5+) 51.1±0.1	(1-) 15.20±0.03
	(2+) 25.65±0.05	(0+) 8.52±0.02	(6-) 53.2±0.1
	R = 5.187±0.034	R = 5.168±0.034	R = 4.504±0.030
5/2 - [523]↓	(2-) 31.1±0.2	(0-) 10.34±0.07	(6+) 63.1±0.4
	(3-) 41.5±0.3	(5-) 62.0±0.4	(1+) 18.0±0.1

R = the rotational constant $\hbar^2/2\mathcal{J}$ in keV.

(a) The K-value and parity of the resultant state.

(b) The energy difference between the ground state of the rotational band and the first excited state calculated from the simple rotational formula.

$$E_I = E_o + R\ I(I + 1)$$

Table III. Analysis of the Alpha Decay of ^{240}Am to Members of the Favored Rotational Band in ^{236}Np

FINAL STATES		RELATIVE ABUNDANCE UNCORRECTED FOR ENERGY †			ENERGY CORRECTION FACTOR $P_o(Z,E)$ ‡	SUMMATION NORMALIZED	EXPERIMENTAL ABUNDANCE
SPIN (K = 3)	RELATIVE ENERGY (keV)	L = 0	L = 2	L = 4	(%)	(%)	(%)
3	0	1.0	.2646	1.959×10^{-4}	56.3	88.1	86.8
4	41		.2857	9.797×10^{-4}	29.3	10.4	12.0
5	92		.08463	1.658×10^{-3}	14.4	1.54	1.23

Hindrance factors for L waves deduced from alpha decay of ^{238}Pu, ^{240}Pu, ^{240}Cm, and ^{242}Cm.

L = 0	1.0
L = 2	1.6
L = 4	232

†This is equal to the square of the Clebsch-Gordan coefficient for the transition divided by the hindrance factor.

‡Calculated according to Hyde,[12] p. 245.

FIGURE CAPTION

Fig. 1. ^{240}Am alpha spectrum--smoothed by computer.

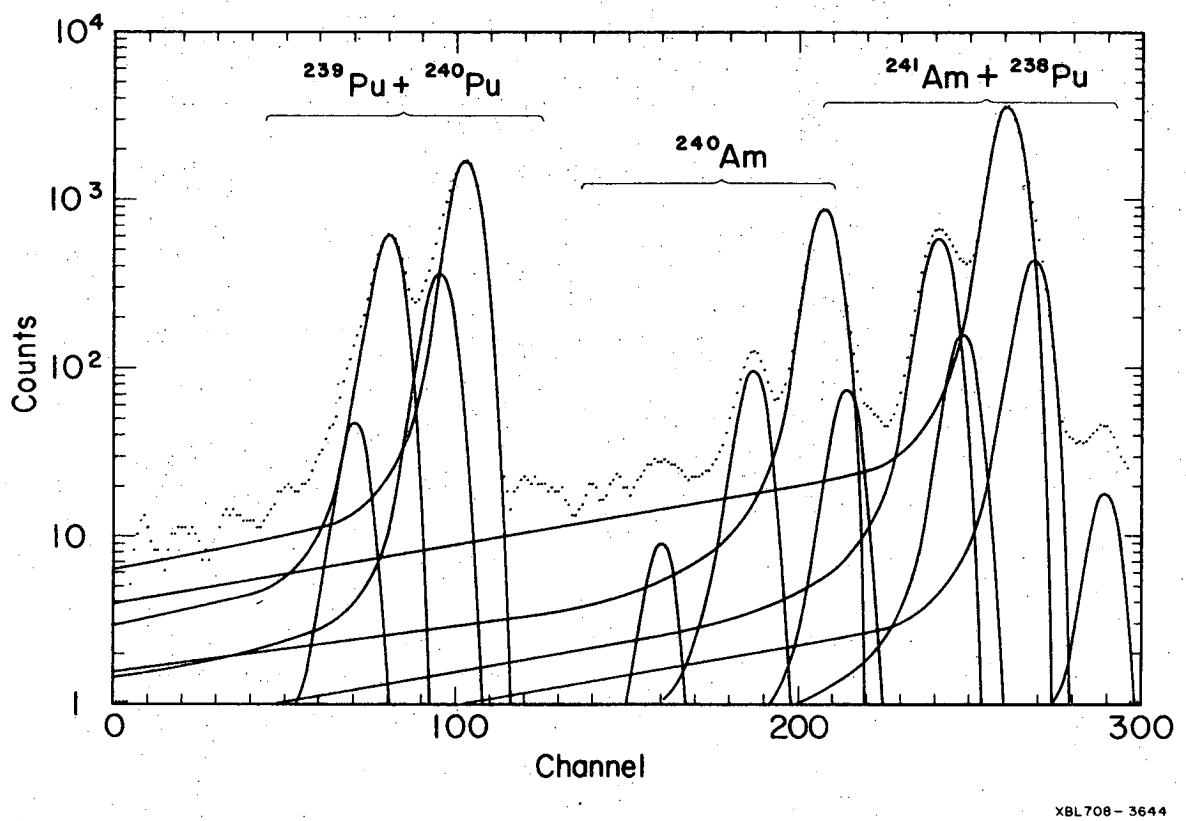
10^4
10^3
10^2
10
1
Counts
0
100
200
300
Channel
^{239}Pu + ^{240}Pu
^{240}Am
^{241}Am + ^{238}Pu
XBL708-3644

Fig. 1

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720