Title
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Authors
Eskola, P.
Eskola, K.
Nurmia, M.
et al.

Publication Date
1972-10-24

Submitted to Physica Fennica

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P. Eskola, K. Eskola,
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October 24, 1972

Prepared for the U. S. Atomic Energy Commission
under Contract W-7405-ENG-48

No 48

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P. Eskola*, K. Eskola*,
M. Nurmia, and A. Ghiorso

1972

ISBN 951-45-0065-2

Lawrence Berkeley Laboratory, University of
California, Berkeley, California 94720

This report is intended for
publication in a periodical

October 24, 1972

*Present address: Department of Physics,
University of Helsinki,
00170 Helsinki 17, Finland

†Work performed under the auspices of the
U.S. Atomic Energy Commission

Abstract

Two isotopes of einsteinium, ^{243}Es and ^{244}Es, were studied by means of α-particle spectroscopy. The isotopes were produced by bombarding a ^{233}U target with ^{15}N ions accelerated by the Berkeley HILAC. The half-lives and the α-particle energies of the two nuclides were observed to be:

^{243}Es	21 ± 2 sec	7.89 ± 0.02 MeV
^{244}Es	37 ± 4 sec	7.57 ± 0.02 MeV

The mass assignments are based on excitation function measurements and in the case of ^{244}Es on the genetic link to its EC daughter ^{244}Cf. Estimates for the EC branching of ^{243}Es and ^{244}Es are given.

I Introduction

This work on neutron deficient einsteinium isotopes is closely related to the study of mendelevium isotopes with mass numbers 248 through 252.[1] Decay properties of ^{245}Es, ^{246}Es and ^{247}Es and their production by (HI,αxn)-reactions were briefly discussed in that study.

The lightest Es isotope reported before the present work is ^{245}Es. In 1961 Ghiorso et al.[2] produced this 7.65-MeV, 75-sec α activity by bombarding a target containing ^{240}Pu with ^{10}B ions accelerated by the Berkeley heavy-ion linear accelerator (HILAC). Their results were confirmed in 1967 by Mikheev et al.[3] who reported ^{245}Es to be a 7.70 ± 0.03-MeV, 1.33 ± 0.15-min α emitter with an electron-capture (EC) branching of 83^{+4}_{-3} %.

We have produced two new isotopes of einsteinium, ^{243}Es and ^{244}Es, by bombarding a ^{233}U target with ^{15}N ions accelerated by the Berkeley HILAC. The isotopes were observed and studied by means of α-particle spectroscopy. The mass assignments have been based on excitation-function measurements and in the case of ^{244}Es on the genetic link to its EC daughter ^{244}Cf.

II Experimental

The experimental techniques and apparatus used in this work were the same as those described in Refs. 1 and 4. The recoil atoms knocked out of the target by energetic ^{15}N ions were stopped in rapidly flowing He gas, which transferred the atoms onto the rim of a vertically mounted wheel. After an appropriate collection period the deposited recoil atoms were placed by a rotation of the wheel to face a series of Si-Au surface-barrier detectors to measure α-particle spectra of the recoils. There were seven detector stations arranged equidistantly at 45° intervals around the wheel. Each station had four detectors: two movable ones which alternately faced the wheel, and two stationary ones which in turn faced the one movable detector shuttled into off-wheel position. This configuration of detectors allowed a physical separation of genetically related α activities and their detection with high efficiency. A schematic representation of the arrangement of the 28 detectors around the vertical wheel and in each station is given in Ref.4.

Signals from the detectors were amplified by modular units developed in our laboratory, processed by a PDP-9 computer and stored on IBM tape. Each wheel-stepping interval and shuttle period were independently divided into four time subgroups of equal length.

III Results

The α-particle spectra displayed in Fig.1 resulted from bombardments of the ^{233}U target with 77-82-MeV ^{15}N ions and were recorded by the movable detectors when facing the wheel ("parent" spectra). The energies of the α-particle groups were determined using the SAMPO computer program.[5] The 6.773-MeV peak of ^{213}Fr and the 7.210-MeV peak of ^{244}Cf served as calibration standards.

The α-particle group at 7.89 MeV has been assigned to ^{243}Es and that at 7.57 MeV to ^{244}Es. The 7.73-MeV group belongs to ^{245}Es, but it is masked by the 7.69-MeV ^{214}Po. Both ^{214}Po and ^{215}At are present in the spectra as members of decay chains originating from activities produced by many-nucleon transfer reactions from ^{233}U. The strong peak at 7.21 MeV belongs to ^{244}Cf which is mainly an electron capture product of ^{244}Es. The origin of other activities is either a small lead impurity in the target (^{211}Po, ^{213}Fr), or they were accumulated on the wheel and on the detectors during earlier unrelated experiments (^{242}Cm, ^{253}Es).

In corresponding "daughter" spectra i.e. in the spectra recorded by the same detectors when in off-wheel position combined with spectra from the stationary detectors facing them, the 7.21-MeV ^{244}Cf was the only distinct daughter activity originating from bombardments of ^{233}U with ^{15}N. This is understandable because the EC daughters of ^{243}Es and ^{245}Es decay predominantly by EC themselves and the α-decay daughters, the unknown ^{239}Bk, ^{240}Bk and ^{241}Bk, are expected to decay mainly by EC.[6] On the right hand side of Fig.2 black circles mark the decay of the ^{244}Cf peak in the daughter spectra combined from several experiments. A least-squares analysis of the data gave a half-life value of 37 ± 4 sec and this is our best value for the half-life of ^{244}Es. By quadrants of the 12-min shuttle period the ^{244}Cf counts were distributed as 250, 207, 180, and 187 giving a half-life of 20 ± 11 min for ^{244}Cf. This value is in agreement with the reported value of 19.4 ± 0.6 min.[7] Open circles mark the decay of the 7.57-MeV α-activity in corresponding parent spectra, but due to large statistical errors the half-life value is rather inaccurate. The left half of Fig.2 shows the decay curve for the 7.89-MeV α activity in the parent spectra. An analysis of the data gave the value 21 ± 2 sec for the half-life of ^{243}Es. The error limits in all half-life values of this study were set equal to twice the standard deviation of the fit.

Further evidence for the suggested mass assignments of Es isotopes was obtained from the measured excitation functions. The curves in Fig.3a are for activities in the parent spectra and the curve in Fig.3b is for the 7.21-MeV activity in the daughter spectra. The latter curve has been corrected with geometry and time factors to make it comparable with the curves above. However, the correction due to the transfer efficiency ϵ_r discussed in the next paragraph has not been included. The fact that in Fig.3a the excitation curves labeled ^{245}Es, ^{244}Es and ^{243}Es reach their maxima at 73, 78 and 86 MeV, respectively, is consistent with the activities being produced by 3n, 4n and 5n reactions[8]. In Figs. 3a and 3b the excitation curves for ^{244}Cf have their maxima at 78 MeV which gives additional support for a parent-daughter relationship between the 7.57-MeV and 7.21-MeV activities.

In order to get estimates for the EC branchings of ^{244}Es and ^{243}Es, it was necessary to know the transfer efficiency ϵ_r of the EC daughter atoms onto the detectors relative to that of the α-decay recoils. This quantity was not determined in the course of these experiments, but assuming the value of ϵ_r to be 0.5 ± 0.2 or as measured[9] for the EC of ^{213}Ra the EC branching value of 96^{+2}_{-3} % for ^{244}Es was derived. It was difficult to extract the amount of 7.05-MeV ^{243}Cf[7] in the daughter spectra because of its low α-decay branching and the interfering 7.127-MeV ^{218}Rn. We are able to give only an upper limit of 70 % for the EC branching of ^{243}Es.

IV Discussion

The experimental results obtained in this study are summarized in Table I. The observed α-particle energies of ^{243}Es and ^{244}Es were already included in Fig.10 of our paper on Md isotopes.[1] In the figure the α-decay energies of the heaviest elements were plotted as a function of the neutron number N. The observed α-decay energies of the two new Es isotopes are in agreement with the values expected on the basis of such a systematics. A small dip in the measured α-decay energy is evident for ^{244}Es, as is the case for other $N = 145$ nuclei such as ^{241}Cm, ^{243}Cf and ^{245}Fm.

The α-decay hindrance factors were calculated using spin-independent $(l = 0)$ equations of Preston.[10] The radius parameter R was chosen to be 9.40 fm. For the α-decay branchings of ^{243}Es and ^{244}Es the values > 30 % and 4 %, respectively, were used. The observed α-transitions appear essentially unhindered and thus leave the last odd particle(s) in the same Nilsson orbital(s) in the daughter as in the parent.

We would like to express our appreciation of the help given by the personnel at the HILAC in all the phases of this work.

References

1. P.Eskola, Phys.Rev. C7, 280 (1973).

2. A.Ghiorso, T.Sikkeland, A.E.Larsh, and R.M.Latimer, unpublished results, 1961; quoted by E.K.Hyde, I.Perlman, and G.T.Seaborg, The Properties of the Heavy Elements, Vol. II (Prentice-Hall, Inc., Englewood Cliffs, N.J., 1964), p.945.

3. V.L.Mikheev, V.I.Ilyushchenko, and M.B.Miller, Yarern. Fiz.5, 49 (1967) [transl.: Soviet J.Nucl.Phys. 5, 35 (1967)].

4. K.Eskola, P.Eskola, M.Nurmia, and A.Ghiorso, Phys.Rev C4, 632 (1971).

5. J.T.Routti and S.G.Prussin, Nucl.Instr.Methods 72, 125 (1969).

6. K.A.Keller, H.Münzel, Nucl.Phys. A148, 615 (1970); K.A.Keller, H.Münzel, Kernforschungszentrum, Karlsruhe (West Germany) Report No. KFK-1059 (1969).

7. T.Sikkeland, A.Ghiorso, J.Maly, M.Nurmia, Phys.Letters 24B, 333 (1967).

8. T.Sikkeland and D.F.Lebeck, unpublished.

9. A.Ghiorso, K.Eskola, P.Eskola and M.Nurmia, Phys.Rev. C7, 2032 (1973).

10. M.A.Preston, Phys.Rev. 71, 865 (1946).

Table I. Summary of experimental results.

	Half-life (sec)	α-particle energy (MeV)	$\frac{EC}{\alpha + EC}$ (%)	α-decay hindrance factor
^{243}Es	21 ± 2	7.89 ± 0.02	< 70	< 6
^{244}Es	37 ± 4	7.57 ± 0.02	96^{+2}_{-3}	6

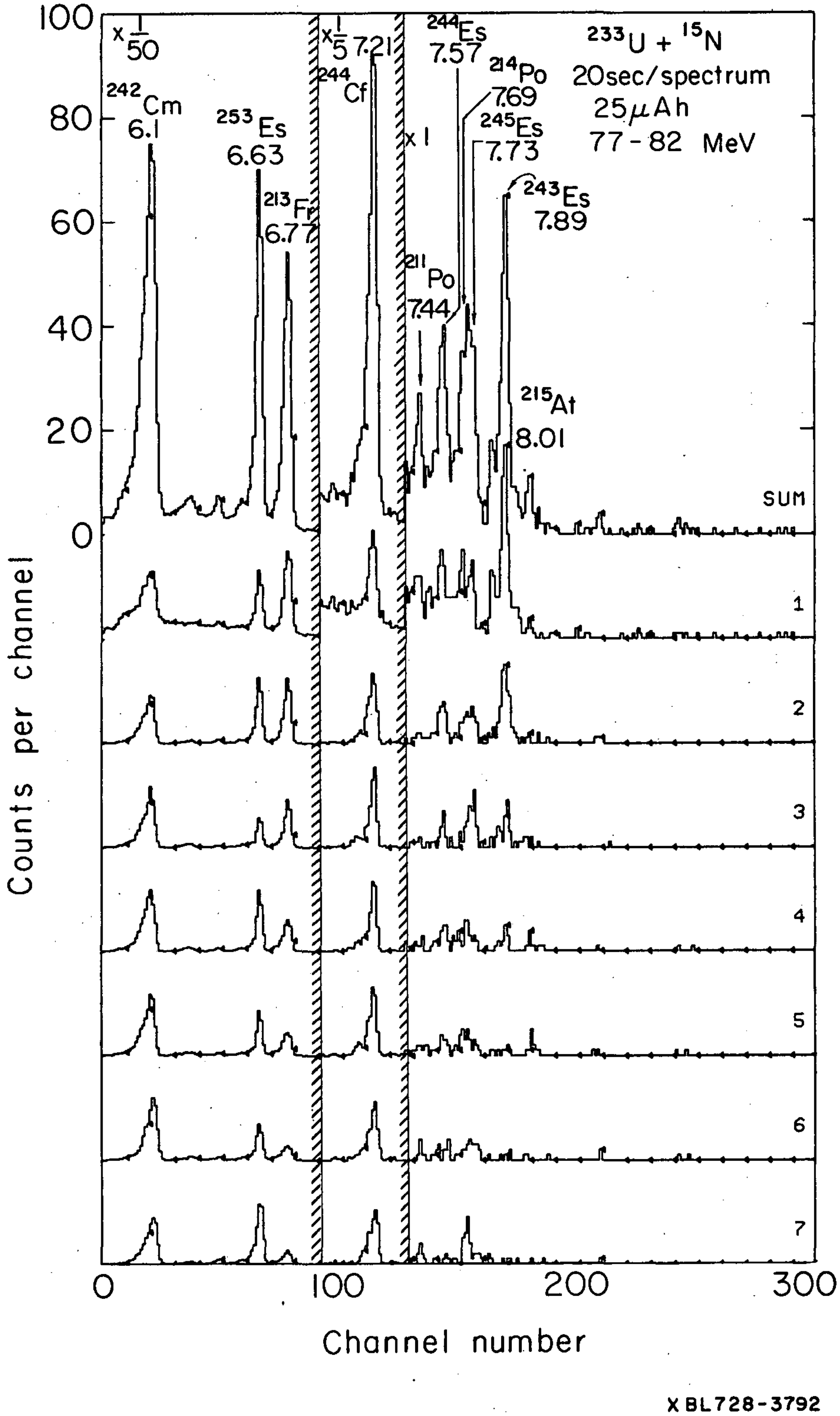

Fig. 1. A series of α-particle spectra produced by bombardments of ^{233}U with ^{15}N ions. The individual spectra show the total of counts recorded at each of the seven stations by the two movable detectors when facing the wheel. The sum of the seven spectra is plotted topmost.

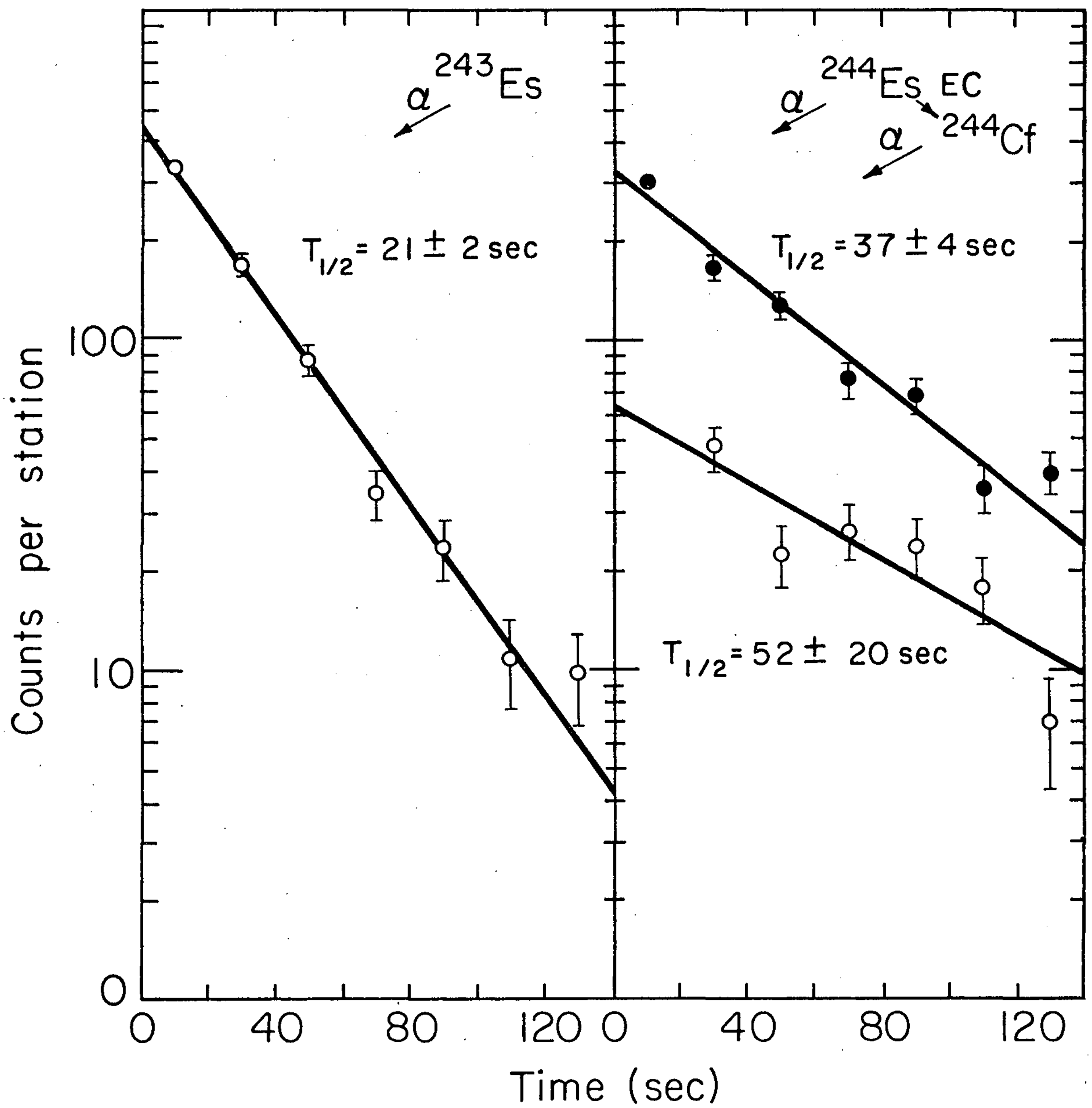

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Fig. 2. Decay curves for α decay of ^{243}Es and ^{244}Es in "parent" spectra and of ^{244}Cf in "daughter" spectra. Open circles denote the parent α activity, black circles the daughter α activity. The error bars indicate an uncertainty of one standard deviation.

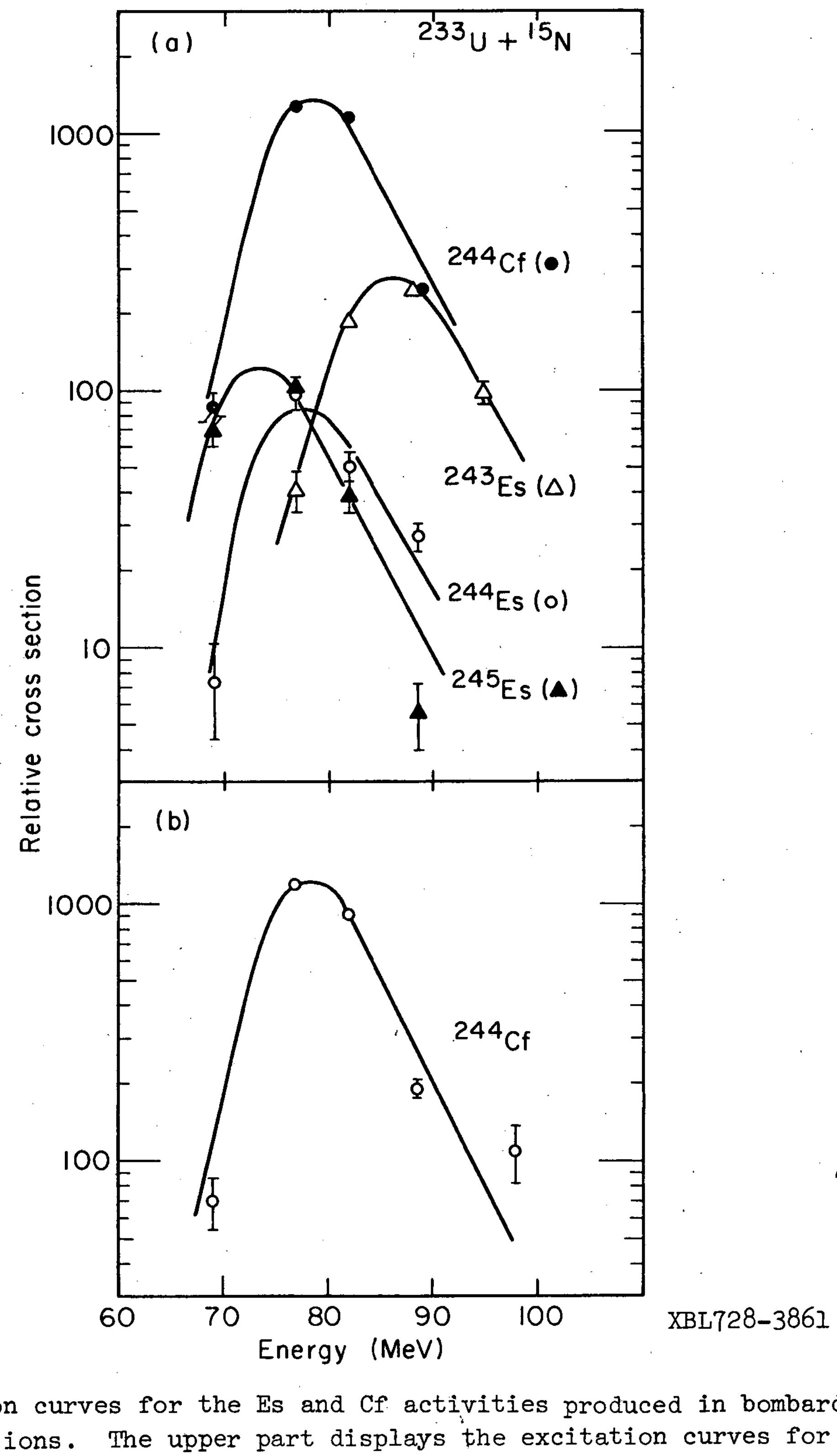

Fig. 3. Excitation curves for the Es and Cf activities produced in bombardments of ^{233}U with ^{15}N ions. The upper part displays the excitation curves for the activities in "parent" spectra and the curve in the lower part is for the ^{244}Cf activity in "daughter" spectra. The error bars indicate an uncertainty of one standard deviation; where no error bars are marked the uncertainty is close to the size of the point showing the experimental result.

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