Kinetic Energies of Fragments from Seven Fission Reactions at Low Excitation Energies*

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This work describes a double-energy experiment performed with solid-state detectors on the thermal-neutron-induced fission of ^{233}U, ^{235}U, and ^{239}Pu; fast-neutron-induced fission of ^{231}Pa, ^{237}Np, and ^{238}U; and spontaneous fission of ^{252}Cf. Spectra of the fragment masses and energies were obtained. Average total kinetic energies and mean fragment masses for the fast-neutron-induced reactions are as follows: ^{231}Pa, 166.8±2 MeV, 92.2 and 139.8 amu; ^{237}Np, 174.0±2 MeV, 98.0 and 140.0 amu; and ^{238}U, 170.1±2 MeV, 98.5 and 140.5 amu. The results are compared with recent time-of-flight and radiochemical data, where available. Average total kinetic-energy correlations with $Z^2/A^{1/3}$ are shown.

I. INTRODUCTION

WITH the development of solid-state particle detectors of large area and good energy resolution and with recently developed energy-calibration techniques[1,2] it has become possible to perform measurements of fission-fragment energies with large solid angles and with energy resolution which approaches that of the time-of-flight method. This paper presents the results of a series of double-energy measurements performed with solid-state detectors on thermal-neutron-induced fission of ^{233}U, ^{235}U, and ^{239}Pu; fast-neutron-induced fission of ^{231}Pa, ^{237}Np, and ^{238}U; and spontaneous fission of ^{252}Cf. Preliminary results from ^{238}U have been reported elsewhere.[3]

There have been several recent measurements made on fission induced by thermal neutrons,[4–9] by charged particles,[10,11] and on spontaneous fission[6,12–14] but almost none for cases where the fission barrier is slightly greater than the neutron binding energy, as for example ^{231}Pa, ^{237}Np, and ^{238}U. For ^{238}U there have been radiochemical measurements of mass yields[15,16] and the ionization-chamber measurements of Wahl[17] with the corrections for ionization defect given by Leachman.[18] Since there is very little experimental data for this type of fissioning species and since double-energy measurements allow the determination of mass yields as well as fragment energies, it appeared worthwhile to undertake a series of measurements on the three nuclides ^{231}Pa, ^{237}Np, and ^{238}U. During the course of these measurements it became apparent that a series of measurements on the thermal-neutron-induced fission of ^{233}U, ^{235}U, and ^{239}Pu, and on the spontaneous fission of ^{252}Cf would be desirable, both to determine calibration uncertainties and to allow the investigation of systematic effects in mass yields and fragment energies.

II. EXPERIMENTAL METHOD AND EQUIPMENT

The experimental arrangement consisted of two silicon, surface-barrier detectors facing opposite sides of a thin fissile foil. This foil was positioned in the center of a neutron beam from the Omega West Reactor. The beam viewed the core of the reactor at a 45° angle through a 3 in. beryllium reflector, and was estimated to contain a flux of about 10^8 fission spectrum neutrons/cm^2 sec and an approximately equal flux of thermal neutrons. The detectors and four target foils were contained in a double-walled stainless-steel vacuum chamber. The foil mount was designed so that any one of four target foils could be positioned in the beam. During the experiment, the detectors were cooled by the circulation of water between the double walls of the vacuum chamber.

The fissile targets used were all deposited on 0.1 mg/cm^2 nickel foil which was supported by electroformed nickel mesh of 93% transparency. Except for the

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[1] H. W. Schmitt, W. M. Gibson, J. H. Neiler, F. J. Walter, and T. D. Thomas, in *Proceedings of the International Atomic Energy Agency Conference on the Physics and Chemistry of Fission, Salzburg, Austria* (International Atomic Energy Agency, Vienna, 1965), Vol. I, p. 531.
[2] H. W. Schmitt, W. E. Kiker, and C. W. Williams, Phys. Rev. **137**, B837 (1965).
[3] M. J. Bennett, thesis, The University of New Mexico, 1963 (unpublished).
[4] W. M. Gibson, T. D. Thomas, and G. L. Miller, Phys. Rev. Letters **7**, 65 (1961).
[5] J. C. D. Milton and J. S. Fraser, Can. J. Phys. **40**, 1626 (1962).
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[7] H. W. Schmitt, J. H. Neiler, and F. J. Walter, Phys. Rev. **141**, 1146 (1966).
[8] V. F. Apalin *et al.*, Nucl. Phys. **71**, 553 (1965).
[9] J. H. Neiler, F. J. Walter, and H. W. Schmitt, Phys. Rev. **149**, 894 (1966).
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[11] V. E. Viola and T. Sikkeland, University of California, Lawrence Radiation Laboratory Report No. UCRL-10284 (unpublished).
[12] S. L. Whetstone, Jr., Phys. Rev. **131**, 1232 (1963).
[13] J. S. Fraser, J. C. D. Milton, H. R. Bowman, and S. G. Thompson, Can. J. Phys. **41**, 2080 (1963).
[14] R. Brandt, S. G. Thompson, R. C. Gattis, and L. Phillips, University of California, Lawrence Radiation Laboratory Report No. UCRL-10506 (unpublished).
[15] S. Katcoff, Nucleonics **16**, 78 (1958).
[16] K. A. Petrzhak *et al.*, in *Soviet Progress in Neutron Physics*, edited by P. A. Krupchitskii (Consultants Bureau Enterprises, Inc., New York, 1963), p. 159.
[17] J. S. Wahl, Phys. Rev. **95**, 126 (1954).
[18] R. B. Leachman, Phys. Rev. **101**, 1005 (1956).

^{252}Cf target, which was prepared by autodeposition,[19] all of the foils were prepared by vacuum evaporation of the tetrafluoride compound.[20] The foil thicknesses were as follows: ^{231}Pa, 70 μg/cm^2; ^{233}U, 40 μg/cm^2; ^{235}U, 0.5 μg/cm^2; ^{237}Np, 90 μg/cm^2; ^{238}U, 80 μg/cm^2; and ^{239}Pu, 0.5 μg/cm^2. The vacuum-evaporated fissile deposits were 1 cm in diameter. The active region of the ^{252}Cf source was approximately 2 mm in diameter. The strength of the ^{252}Cf source was approximately 5000 fissions per minute.

The detectors were masked with beveled collimators, whose sharp edges were rounded to a radius of approximately 1/20 mm, to prevent fragments from being detected near the edge of the sensitive region. The detectors used were all 4.5 cm^2 in area and were positioned approximately 4 cm from the target and outside of the neutron beam, which was 2.5 cm in diameter. The pulses from the detectors were amplified and fed to a coincidence circuit and also to the inputs of a two-parameter pulse-height analyzer which was gated by the output of the coincidence circuit. The pulse heights associated with each event were recorded on punched paper tape. After the runs, the pulse heights were transcribed onto magnetic tape which was used as the data input to the digital computer used for data analysis.

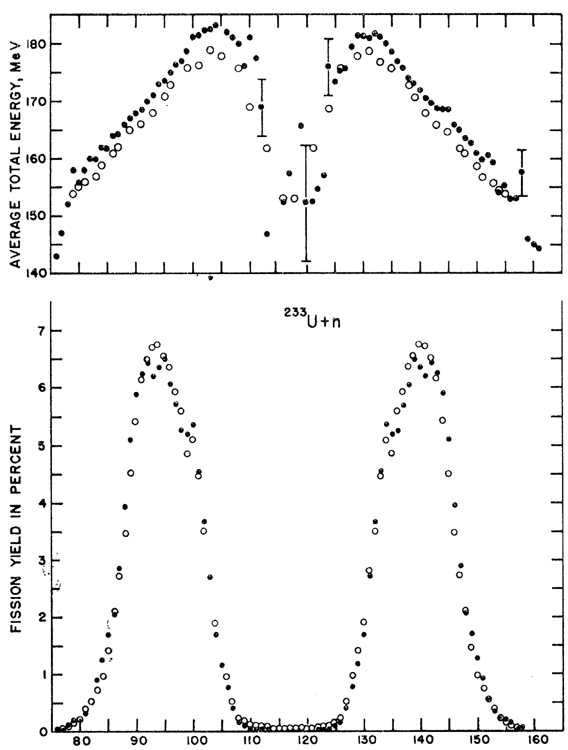

FIG. 1. Mass yields and total kinetic energies for thermal-neutron-induced fission of ^{233}U. The open circles are the present data, solid points the time-of-flight results from one side of the apparatus of Ref. 24. Typical statistical errors are shown for the time-of-flight total kinetic energy for regions of low mass yield. The statistical errors on the present data are generally 1.5 MeV. Neither of the sets of data has been corrected for energy loss in the fissile deposits.

The data presented were taken over a period of two years with two different electronic systems and with a variety of detectors. Nonetheless, comparison of the ^{235}U runs which were taken at least weekly throughout the duration of the experiment indicates that there was no appreciable difference in the analyzed data from the various experimental systems.

During each run a mercury-relay pulse generator was used to obtain a check on gain stability and noise levels. The output of this pulser, which operated at 65 pulses per second, was periodically connected to the inputs of the preamplifier by a timer-controlled coaxial relay.

III. ENERGY CALIBRATION AND DATA ANALYSIS

During the ^{238}U runs a daily energy calibration was made with a ^{235}U target. This calibration procedure was also used to give a check on the stability and reproducibility of the system. During the ^{231}Pa and ^{237}Np runs an improved electronic system was used and a weekly calibration with ^{235}U was found adequate. The ^{233}U, ^{239}Pu, and the ^{252}Cf data were obtained in short runs which were alternated with ^{235}U runs. The pulse generator was connected for 1 min intervals each hour or half-hour during all of the runs.

During data analysis a random number between $+\frac{1}{2}$ and $-\frac{1}{2}$ was added to each pulse height to smooth the effects of finite channel widths. Also, the pulse heights were normalized so as to keep the position of the pulser line constant. This last correction was quite small, usually less than 1% per week.

Because of the large cross sections for thermal-neutron-induced fission, and because there were roughly equal fluxes of fast and thermal neutrons in the beam, essentially all of the fissions recorded for the ^{233}U, ^{235}U, and ^{239}Pu targets were induced by thermal neutrons. The ^{252}Cf source was not used when the beam was open. During the ^{231}Pa and ^{237}Np runs a boron absorber was put in the beam to eliminate contributions from possible thermal-neutron-fissioning impurities in the targets. This absorber caused a reduction of 200:1 in gross fission rate for a ^{239}Pu foil.

The energy calibration procedure used is due to Schmitt and his co-workers[1] and is based on their values for the thermal-neutron-induced fission of ^{235}U. The procedure requires the mass of each fragment. These masses were estimated from a linear, mass-independent calibration which required that the observed mean values of the ^{235}U pulse-height distributions coincide with the average energies obtained by time-of-flight. Mass and momentum conservation were

[19] The ^{252}Cf foil was prepared by S. G. Thompson, Lawrence Radiation Laboratory, Berkeley, California.

[20] The foils were prepared by J. R. Povelites. The method is described by L. D. F. Allen, Los Alamos Scientific Laboratory Report No. LA-2769, 1962 (unpublished).

TABLE I. Average values and root mean square widths σ of the total-kinetic-energy, single-fragment-energy, and mass distributions. The full width at half-maximum $w(m)$ of the mass distributions and the number of recorded events are included. Uncertainties shown for the present experiment are estimated probable errors.

	^{231}Pa+n Present expt.	^{233}U+n Present expt.	^{233}U+n Previous work[a]	^{235}U+n Present expt.	^{235}U+n Previous work[b]	^{237}Np+n Present expt.	^{238}U+n Present expt.	^{238}U+n Previous work	^{239}Pu+n Present expt.	^{239}Pu+n Previous work[e]	^{252}Cf+n Present expt.	^{252}Cf+n Previous work[f]
$\langle E_K\rangle$ (MeV)	166.8±2.0	171.2±2.0	173.1	172.0±2.0	171.9±1.4	174.0±2.0	170.1±2.0	168[c]	179.3±2.0	177.7±1.8	184.3±2.0	185.7
$\sigma(E_K)$ (MeV)	10.35	10.84	11.0	11.68		12.34	12.47		12.09		12.07	11.3
$\langle E_L\rangle$ (MeV)	100.3±1.5	101.7±1.5	103.1	101.7±1.5	101.56	102.1±1.5	99.7±1.5	89[d]	104.0±1.5	103.2±1.0	105.1±1.5	105.71
$\sigma(E_L)$ (MeV)	5.56	5.54	5.5	5.74		6.17	6.24		5.93		6.48	5.86
$\langle E_H\rangle$ (MeV)	66.5±1.5	69.5±1.5	70.0	70.3±1.5	70.34	71.9±1.5	70.4±1.5	60[d]	75.3±1.5	74.5±0.8	79.3±1.5	80.01
$\sigma(E_H)$ (MeV)	7.03	7.40	7.5	7.90		8.42	8.53		8.36		8.85	8.53
$\langle M_L\rangle$ (amu)	92.2±1.0	94.8±1.0	94.5	96.2±1.0	96.57	98.0±1.0	98.5±1.0		100.6±1.0	100.34	108.2±1.0	108.39
$\langle m_H\rangle$ (amu)	139.8±1.0	139.3±1.0	139.5	139.8±1.0	139.43	140.0±1.0	140.5±1.0		139.4±1.0	139.66	143.8±1.0	143.61
$\sigma(m)$ (amu)	5.77	5.69	5.6	5.75	5.36	6.43	6.73		6.11	6.01	7.33	6.77
$w(m)$ (amu)	13.4	14.4		15.1		15.7	16.1		14.7		16.7	
No. events	129 000	21 500		145 000		134 000	45 000		21 600		8 600	

[a] See Ref. 24. [b] See Ref. 7. [c] See Ref. 18. [d] See Ref. 17. [e] See Ref. 9. [f] See Ref. 12.

applied to the resulting provisional energies, yielding a provisional mass for each fragment. These provisional masses were then used in the Schmitt energy calibration.

Values obtained from a calibration procedure of this type are final or post-neutron-emission energies. Initial energies were obtained by correcting for neutron emission. If it is assumed that the neutrons are emitted isotropically from the fragments, the average correction for the energy of a fragment of initial mass m which emits ν neutrons can be obtained from the equation $E_f=E_i(1-\nu/m)$, where E_f and E_i are the final and initial fragment energies, respectively. These corrections were performed using the provisional masses mentioned above and a linear approximation to the "universal neutron curve" given by Terrell.[21] In the region near symmetry not covered by this linear approximation it was assumed that ν decreased linearly from 3.04 at mass 120 to 0 at mass 126. It is believed that the values for ν obtained in this way are accurate to within ±1

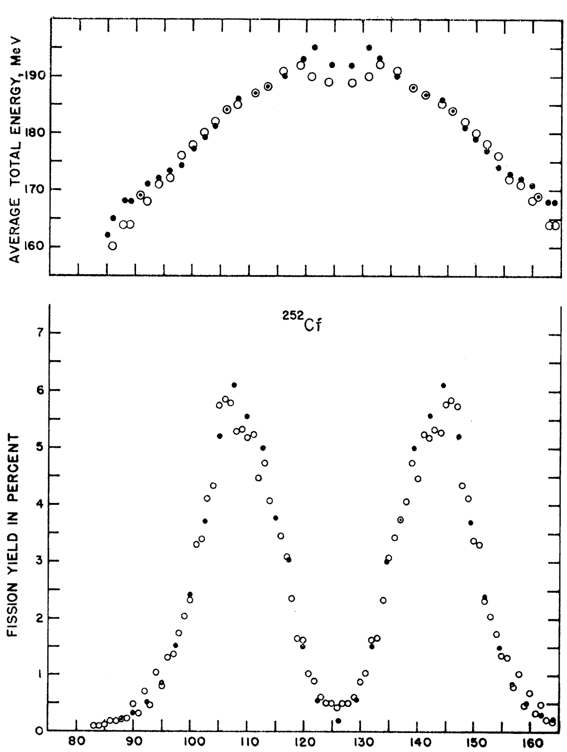

FIG. 2. Mass yields and total kinetic energies for spontaneous fission of ^{252}Cf. The open circles are the present data, solid points are from the time-of-flight results of Whetstone (Ref. 12). Statistical errors on the total kinetic energies for the present data are approximately 2.5 MeV.

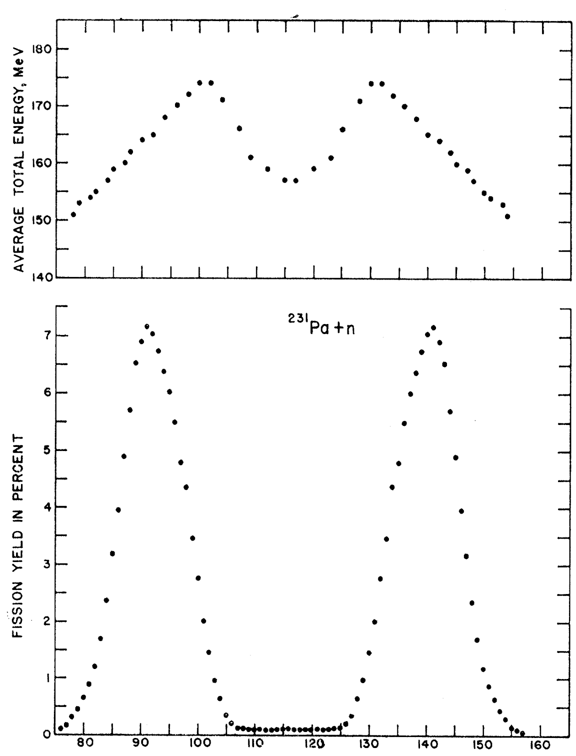

FIG. 3. Mass yields and total kinetic energies for fast-neutron-induced fission of ^{231}Pa. Statistical errors on the total kinetic energies are approximately 1 MeV. The data have not been corrected for energy loss in the fissile deposit.

[21] J. Terrell, Phys. Rev. **127**, 880 (1962).

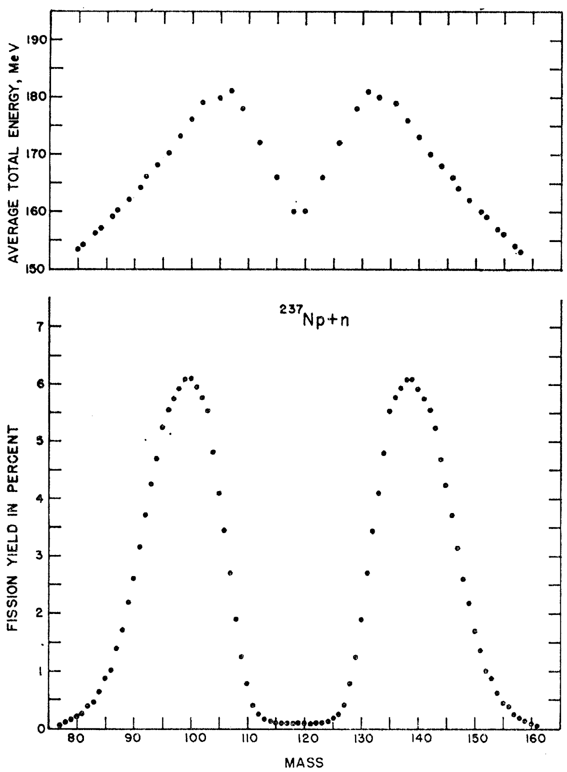

FIG. 4. Mass yields and total kinetic energies for fast-neutron-induced fission of ^{237}Np. Statistical errors on the total kinetic energies are approximately 1 MeV. The data have not been corrected for energy loss in the fissile deposit.

neutron, corresponding to an uncertainty of 1% in fragment energy. Comparison with experimental data on the variation of ν with mass[8,22] indicates that the accuracy is generally $\pm\frac{1}{2}$ neutron. The same calibration procedure and neutron correction method were used for all of the data presented here.

From the initial fragment energies and from conservation of mass number and momentum, the initial mass of each fragment was calculated. Mass and energy spectra were compiled and the events sorted according to mass ratio. Averages and root-mean-square widths were computed for all of the energy and mass spectra. It should be noted that this data analysis procedure requires the mass yields and total kinetic energies as a function of mass to be symmetric about one-half the mass of the fissioning nucleus.

To allow estimation of the consistency of the calibration procedure a ^{235}U run and the ^{252}Cf run were also analyzed with a calibration based on ^{252}Cf.[1] The results obtained by the use of the two calibrations differ by 1.5% in total kinetic energy and 0.4% in light-fragment mass. These differences are attributed to the uncertainties in the determination of the calibration constants for the ^{252}Cf run, which contained only 8600 events.

The measured total kinetic energies were corrected for energy loss in the source foil according to the data of Northrup and Brolley.[23] Corrections to the average total kinetic energy were: for ^{233}U, 0.75 MeV; for ^{231}Pa, 1.29 MeV; for ^{237}Np, 1.66 MeV; and for ^{238}U, 1.48 MeV. Corrections for the ^{235}U and ^{239}Pu targets were negligible.

IV. RESULTS AND DISCUSSION

The results of these measurements are summarized in Table I. The errors shown in the table are estimated

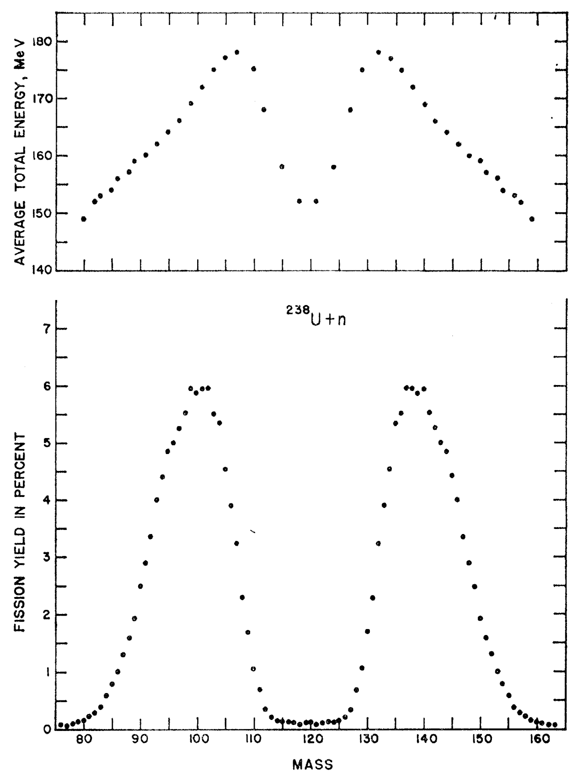

FIG. 5. Mass yields and total kinetic energies for fast-neutron-induced fission of ^{238}U. Statistical errors on the total kinetic energies are approximately 1.5 MeV. The data have not been corrected for energy loss in the fissile deposit.

from a comparison of the present data with the time-of-flight data of Whetstone[12] for ^{252}Cf and preliminary results of Stein and Britt[24] for ^{233}U. These errors do not include any contribution from possible errors in the data upon which the calibrations are based, or in the time-of-flight data. None of the data have been corrected for dispersions. The energies shown in the table have been corrected for energy losses in the sources used.

Figures 1 and 2 show the mass yields and total kinetic energies for the ^{233}U and ^{252}Cf data, respectively. For comparison, the time-of-flight data are also shown. It is

[22] H. R. Bowman, J. C. D. Milton, S. G. Thompson, and W. J. Swiatecki, Phys. Rev. **126**, 2120 (1962); **129**, 2133 (1963).

[23] J. A. Northrup and J. E. Brolley, Phys. Rev. **92**, 1091(A) (1952).

[24] W. E. Stein and H. C. Britt (to be published).

evident from Fig. 1 that the total kinetic energies found in this experiment for ^{233}U are systematically low by slightly more than 2 MeV relative to the time-of-flight data. The total energies for ^{252}Cf are identical within the statistical uncertainties in the present data. The mass yields derived in this experiment agree to within a fraction of a mass unit with those obtained by time-of-flight.

Comparison of the mass yields near symmetry for ^{233}U, ^{235}U, ^{238}U, and ^{239}Pu observed in this experiment with radiochemical yields[15,16] indicates a considerable dispersion of events into the deep valley near symmetry. The mass yields in the valley found in this experiment are between 1.5 and 3 times those measured radiochemically. Thus, the present data may be quite unreliable in regions of low mass yield.

Details of the mass yields and the variation of the total kinetic energy with mass for the fast-neutron-induced fission of ^{231}Pa, ^{237}Np, and ^{238}U are shown in Figs. 3, 4, and 5, respectively. Figure 6 is a composite of mass distributions obtained in this study. The results of Neiler, Walter, and Schmitt[9] for $^{241}Pu+n$ are also included. These figures and the average fragment masses given in Table I show clearly the constancy of mass of the heavy-fragment group. With the exceptions of ^{252}Cf, the edge of the heavy-fragment yield near mass 132 is almost unchanged for all of the nuclei studied. This effect has been attributed to the closing of the 82 neutron and 50 proton shells in the heavy fragment.[25]

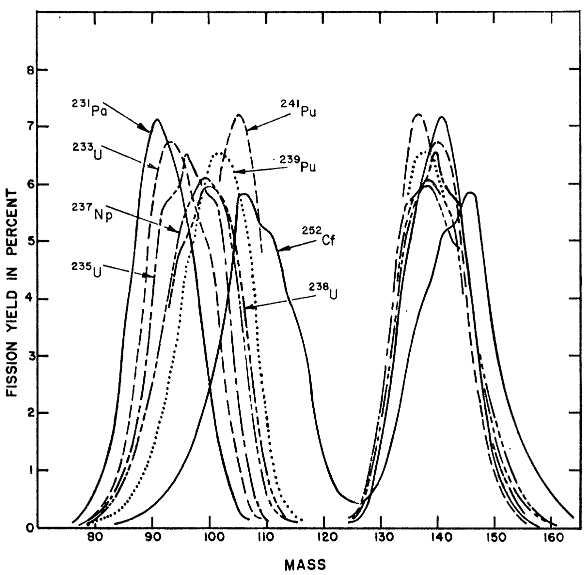

FIG. 6. Composite of mass distributions obtained in this experiment. The data for $^{241}Pu+n$ are from Neiler, Walter, and Schmitt (Ref. 9).

From a comparison of the mass distributions obtained in three-particle and binary fission of ^{235}U, Schmitt *et al.*[26] have suggested that the nucleon cluster containing 50 neutrons may remain intact and play an important role in determining the shape of the mass distribution for the more asymmetric modes. Fine structure has been observed[4,5] in the kinetic-energy spectra and the mass distributions of a number of fissioning nuclei. Thomas and Vandenbosch[27] conclude that these irregularities are correlated with structure in the semi-empirical mass surface for even-even products. At low excitation energy, peaks appear at about the same heavy-fragment mass numbers (135, 141, and 146) for the thermal-neutron-induced fission of ^{233}U, ^{235}U, and ^{239}Pu. This structure persists to higher fragment excitation with the appearance of peaks and shoulders on an otherwise smooth mass distribution. Similar peaks have been reported[12,13] for ^{252}Cf at heavy-fragment masses 140, 146, and 152. In all cases the periodicity of the structure is about 5 mass units.

The preference for particular masses is seen in the comparison shown in Fig. 6. Structure is observed in a number of the distributions with the most prominent peaks at heavy-fragment mass numbers 136, 141, and 146. With the exception of ^{252}Cf, the most probable

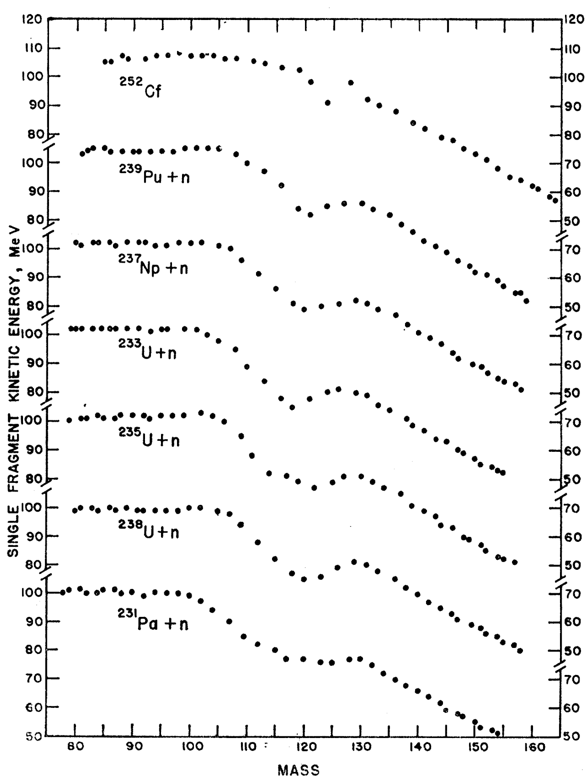

FIG. 7. Single fragment energies as a function of mass for all the fissioning species studied plotted in order of increasing $Z^2/A^{1/3}$. Statistical errors near the most probable masses are 1 to 2 MeV, ranging to 5 MeV for highly asymmetric fission of ^{252}Cf. The data have not been corrected for energy loss in the fissile deposits.

[25] See, for example, I. Halpern, Ann. Rev. Nucl. Sci. **9**, 245 (1959).

[26] H. W. Schmitt, J. H. Neiler, F. J. Walter, and A. Chetham-Strode, Phys. Rev. Letters **9**, 427 (1962).

[27] T. D. Thomas and R. Vandenbosch, Phys. Rev. **133**, B976 (1964).

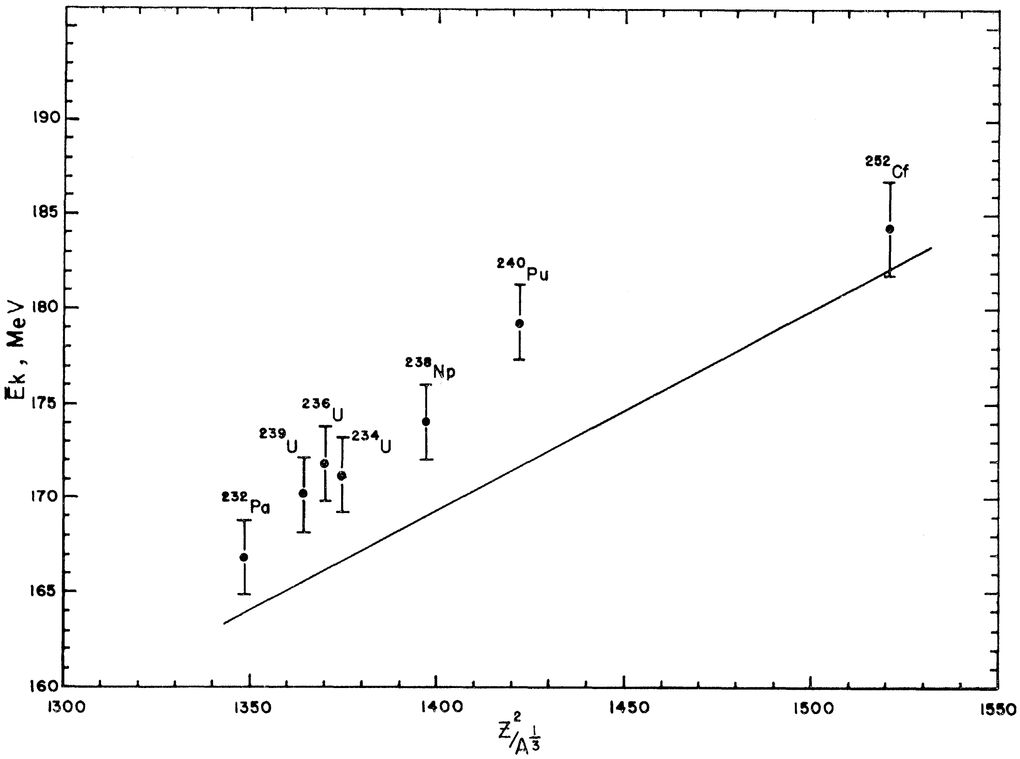

FIG. 8. Average total kinetic energies as a function of $Z^2/A^{1/3}$. The straight line is from Ref. 11. These data have been corrected for energy loss in the fissile deposits according to the results of Northrup and Brolley (Ref. 23).

heavy-fragment mass appears to decrease uniformly as the mass of the compound nucleus increases. Upon closer examination a similar effect is observed in previously published data.[7,9] In addition to this shift in most probable mass, the peak yields appear to decrease from a maximum of about 7% for $^{231}Pa+n$ to a minimum of approximately 6% for $^{238}U+n$. The peak yield then rises to approximately 7% with a further increase in the mass of the compound nucleus. The latter effect is most clearly seen in the light-fragment group where the various distributions are more separated. Conversely, the widths of the distributions appear to reach a maximum at intermediate masses of the compound nucleus. Since the rms widths are very sensitive to tailing effects and to asymmetries in the distributions, the measured full width at half-maximum w was chosen as a representative quantity and included in Table I. Within the accuracy of these data, w increases linearly with the mass of the compound nucleus between 232 and 239 amu.

Except for the aforementioned variation of w, there is little evidence in the present data to support the suggestion that the 50-neutron shell plays a fundamental role in the shape of the mass distribution. These data indicate that the low-mass side of the light-fragment peak moves toward lower mass in a more or less regular manner as the compound nuclear mass decreases from 236 to 232 amu.

Single fragment energies as a function of fragment mass are shown in Fig. 7. The figure is plotted in order of increasing $Z^2/A^{1/3}$. As has been observed previously,[5,9] light-fragment energies as a function of fragment mass are quite constant for all the nuclei studied. The average light-fragment energy increases slowly with increasing $Z^2/A^{1/3}$.

The average total kinetic energies are plotted in Fig. 8 as a function of $Z^2/A^{1/3}$. The straight line shown is due to Viola and Sikkeland[11] and comes from a least-squares fit to experimental data available in 1962. The points from the present experiment appear to fit a line of the same slope but shifted upward by 4.7 MeV, although there is a suggestion of somewhat greater slope. This energy shift is consistent with the recent increase in time-of-flight energies[28] relative to earlier results, upon which most of the measurements prior to 1964 were based.

The separation distances between charge centers have been calculated on the basis of a uniformly charged spheroid model, using Milton's values for the charge ratio.[29] The computations were performed both for the average total kinetic energy and for total kinetic energies near symmetry. The results agree with the earlier results of Britt, Wegner, and Gursky[10] for charged-particle fission. In particular, the values obtained near symmetry for thermal fission now agree with the values obtained for charged-particle and fast-neutron fission.

[28] See, for example, the discussion in Ref. 9.
[29] J. C. D. Milton, University of California, Lawrence Radiation Laboratory Report No. UCRL-9883 Rev., 1962 (unpublished).

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Emission of Long-Range Alpha Particles in the Spontaneous Fission of Cf^{252}†

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An experimental investigation of α-particle emission in the spontaneous fission of Cf^{252} is described. The measured angular distribution and energy distribution of the α particles are presented, as well as the mass-ratio distribution of the fission fragments and the single-fragment energy distribution in fission accompanied by long-range α particles (LRA fission). Also shown is the angular distribution of the α particles as a function of the α-particle energy, the total fission-fragment energy, and the mass ratio. The experimental results show the LRA-fission process to be very similar to binary fission until the moment of scission. The angular distribution of the α particles as a function of the mass ratio (corrected for α-particle recoil) confirms the earlier conclusion that the scission point moves towards the light fragment as the mass ratio increases. The experimental results provide evidence that the α particle is emitted very close to the scission point and within 10^{-21} sec of the moment of scission. The angular distribution data support the model which explains the variation of the number of neutrons emitted in binary fission as a function of fragment mass on the basis of a variation in the nuclear deformation of the fission fragments at scission.

I. INTRODUCTION

THE occasional emission of a high-energy α particle during the fission process was first observed by Alvarez.[1] Most of the early work on this process was done with the aid of photographic plates, and therefore it was generally called long-range alpha fission (LRA fission for short). Since it occurs only once in approximately 400 fission events (this number varies according to the fissioning nucleus and its excitation energy), the accurate measurement of LRA fission presented great experimental difficulties, and its relative rareness did not give much hope that it would greatly help in the understanding of the fission process in general.

Recently the research activity in the LRA-fission process has considerably increased. One of the reasons for this renewed activity is the advent of the solid-state detectors which can be used for the detection of both the fission fragments and the α particles with good energy and angular resolution. Another important reason for the renewed activity is the recent development of multidimensional pulse-height analyzers.

One of the most important facts to note about the emission of high-energy α particles in the fission process is the angular distribution, which is peaked in the direction perpendicular to the direction of the fission fragments.[2] This experimental fact leads one to believe that the α particle is emitted very close to the moment of scission when the two fragments separate. It is assumed that the α particle is emitted from the "neck" connecting the two fission fragments, most probably at the point at which the neck ruptures.[3] The sharply peaked angular distribution can then be explained by the effect of the electrostatic fields of the two fission fragments on the α particle. This rather accurate localization of the moment of its emission and the point at which it is emitted makes the α particle a possible tool for the study of the configuration of the nucleus at the moment of scission. Thus it may be said that one of the major reasons for our interest in LRA fission is the use of the α particles as a "probe" of the nuclear configuration at the moment of scission. The detailed examination of the α-particle distribution in LRA fission gives us direct information on the shape of the nucleus at scission. In principle the shape of the nucleus can be determined in considerable detail, provided that the

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