states shown in Fig. 9 are bound: in Mg^{26}, the lowest binding energy is that of an α particle ($E_b=10.62$ Mev); in Al^{26}, that of a proton ($E_b=6.30$ Mev); in Si^{26}, the lowest binding energy is that of a proton also ($E_b=5.51$ Mev).

Si^{26} is undoubtedly a positron emitter, presumably primarily to the $T=1$, $J=0^+$ state of Al^{26} at 0.228 Mev. The ground state of Si^{26} is 0^+ (even-even nucleus) and the $0^+ \rightarrow 5^+$, $\Delta T=1$, transition to the ground state of Al^{26} would be highly forbidden. The maximum energy of the positrons involved in the $0^+ \rightarrow 0^+(\Delta T=0)$ decay would be 3.80 Mev. Assuming a log ft value of ~ 3, typical[13] of such transitions, the lifetime of the ground state of Si^{26} should be of the order of magnitude of 1 sec. Thus, Tyrén and Tove[2] probably did indeed observe the decay of Si^{26}.

[13] J. B. Gerhart, Phys. Rev. **109**, 897 (1958).

There is very little experimental information on the angular distributions of neutrons emitted in (He^3,n) reactions with the exception of the work presented in this paper, the investigation of $C^{12}(He^3,n)O^{14}$ by Bromley *et al.*[9] and that of $B^{10}(He^3,n)N^{12}$ by Ajzenberg-Selove *et al.*[14] There is considerably more information on (He^3,p) distributions which also involve two-nucleon transfer. A satisfactory means of theoretically analyzing (He^3,n) distributions is not available at this time.[5]

ACKNOWLEDGMENT

We are much indebted to Professor Aaron Lemonick and to Dr. R. O. Bondelid for their help in the exposure of the plates.

[14] F. Ajzenberg-Selove, M. L. Bullock, and E. Almqvist, Phys. Rev. **108**, 1284 (1957).

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Spontaneous Fission Yields of Cf^{252}†

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A radiochemical investigation has been made of the fission yield curve for the spontaneous fission of Cf^{252}. One source of 1×10^6, another of 2×10^7, and a third of 7×10^7 fissions per minute were used to obtain the data. Thirty-six radioactive nuclides between mass numbers 77 and 166 were separated, identified, and their fission yields calculated. Upper limits were set for nine other nuclides. The fission yield curve has maxima of 6.05% at masses 107 and 141, with a "full width at $\frac{1}{10}$ maximum" of each peak of approximately 27 mass units. There is a very narrow "trough" with a minimum value of $\leqq 8\times10^{-3}$% at mass number 124. In addition, while the curve as a whole is symmetrical about mass 124, each peak is not symmetrical about its own maximum, being significantly spread toward the most asymmetric fission modes. A small fine-structure peak was observed at mass 113. No evidence was seen of activities that could be ascribed to ternary fission events, upper limits of 10^{-4}% fission yield being set for individual nuclides between mass numbers 28 and 72.

INTRODUCTION

SEVERAL investigators[1,2] have reported radiochemical fission yields for the products of the spontaneous fission of Cf^{252}. Due to the scarcity of Cf^{252} at the time those experiments were performed, however, the investigations were limited to the most easily measured peak elements. When a source of approximately 1×10^6 fissions per minute became available several years ago,[3] it was decided that a more thorough investigation of the Cf^{252} spontaneous-fission yield curve would be profitable. After several experiments with this source it became apparent that nuclides with fission yields below 0.1% could not be determined with the desired accuracy. Subsequent availability of sources of approximately 2×10^7 and 7×10^7 fissions per minute made measurement of the entire fission yield curve feasible.

PROCEDURE

In order to eliminate the problem of handling fairly large amounts of alpha and neutron activity in solution and, more importantly, to prevent loss of the extremely valuable Cf^{252} in chemical manipulations, a recoil technique was used to collect the fission fragments. A schematic diagram of the experimental arrangement is shown in Fig. 1. An essentially weightless source was prepared by electroplating purified Cf^{252} in a small area on a 0.001-inch thick platinum disk which was subsequently flamed at red heat. Fission fragments were collected on 0.001-inch aluminum foils which were suspended $\frac{1}{8}$ inch above the Cf^{252} source by means of a brass ring. Range studies indicated that with this

† This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] L. E. Glendenin and E. P. Steinberg, J. Inorg. Nuclear Chem. **1**, 45 (1955).
[2] J. G. Cuninghame, J. Inorg. Nuclear Chem. **6**, 181 (1948).
[3] The author wishes to express his sincere appreciation to Dr. Stanley Thompson and the Heavy Elements Group in Berkeley or preparing the Cf^{252} used in these experiments.

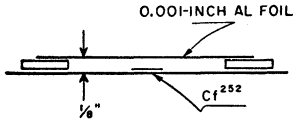

FIG. 1. Schematic diagram of the experimental arrangement for collecting fission fragments.

arrangement fewer than 0.1% of the Mo^{99} fission fragments had sufficient energy to pass through the 0.001-inch aluminum collecting foils.

During a run, the fission fragments were collected for a length of time which was dependent on the half-lives of interest. The aluminum catcher foil was then dissolved and the activities separated by more or less well-known radiochemical methods.[4] The activity of Mo^{99} was measured from each collection and was used as a monitor of the total number of fissions. The assumption implicit in this technique is that the collecting efficiency for all fission fragments was the same.

The usual method for measuring the fission yield of a nuclide involves counting the purified sample in a certain geometry and then making corrections for counter geometry, backscattering of radiation from the sample mount, and scattering of radiation from the sample itself in order to get the disintegration rate of the sample. Since these corrections are very difficult to measure accurately and even more difficult to reproduce under normal conditions, a somewhat different approach was used in these experiments.

The activities of the Cf^{252} fission products were measured on either an end-window methane-flow proportional beta counter or a NaI(Tl) γ counter, in any of several shelf positions. Each of these "standard geometries" had previously been calibrated by separating the same activity from a sample of U^{235} which had been irradiated with thermal neutrons. With Mo^{99} being taken out of each sample, a so-called "R factor" may easily be obtained, i.e.:

$$R_x=\frac{(C_x/C_{Mo^{99}}) \text{ for } Cf^{252}}{(C_x/C_{Mo^{99}}) \text{ for } U^{235}, \text{ thermal neutrons}}=\frac{(Y_x/Y_{99}) \text{ for } Cf^{252}}{(Y_x/Y_{99}) \text{ for } U^{235}, \text{ thermal neutrons}}, \quad (1)$$

where C_x is the counting rate (corrected for chemical yield and decay during bombardment) of nuclide x in its standard geometry at the end of bombardment, $C_{Mo^{99}}$ is the corresponding value for Mo^{99}, and Y is the fission yield. No corrections for geometry and scattering are needed in this calculation provided that the counting geometry, the chemical form and weight of the sample, and the sample-mounting arrangement remain the same in both the Cf^{252} and U^{235} samples. Of these, only the weight correction in samples that are beta-counted presents a problem since the geometry, sample compound, and sample-mount factors are easily reproduced and the variation of counting rate with sample weight in the γ counters is very small. In the beta-counted samples every effort was made to obtain samples of approximately the same weight for both the U^{235} and Cf^{252} bombardments. When the counting rate as a function of sample weight had been found to change significantly, a calibration curve was measured and all samples corrected to a standard weight. Thus the R factors should be an accurate measure of the ratios of the fission yields involved.

Multiplication of R_x by the fission yield of x from U^{235} fissioned by thermal neutrons[5] gives a "pseudo fission yield," which is, in effect, the fission yield of x relative to Mo^{99} in the spontaneous fission of Cf^{252}. If an accurate measurement is made of the fission yield of Mo^{99} in Cf^{252}, the "pseudo fission yields" may then be normalized to get the actual fission yields.

A check on the accuracy of this method may be made by drawing a smooth curve through the fission yield points. Integration under the curve should give a value of 200%, with a degree of reliability that is dependent on the number of points measured.

A direct measurement of the fission yield of Mo^{99} was made in the following manner: A solution containing a known amount of Cf^{252} and a small amount of molybdenum carrier in $6M$ HCl was passed through a Dowex A-1 anion column. Additional molybdenum carrier was added to the eluate and the Mo^{99} allowed to come to equilibrium. The molybdenum was then separated from Cf^{252} on a second anion column, purified, and counted in a known geometry.

In the current experiments several nuclides that are not seen in the thermal-neutron fission of U^{235} were separated. Fission yields for these species were calculated by conventional methods (i.e., with corrections being made for counting geometry and scattering).

RESULTS AND DISCUSSION

Experimental values for the spontaneous fission yields of Cf^{252} are listed in Table I. Errors listed are the average deviations of multiple determinations and are a measure of the reproducibility of the numbers. Those yields that are listed as upper limits represent samples in which the counting rate (usually less than two counts per minute above a ten-count-per-minute background) was too low for positive identification of the half-life.

The Mo^{99} value of $(2.57\pm0.03)\%$ is the average of

[4] Aside from the fact that space does not permit it, the major features of most of the chemical separations involved have been reported often enough in the literature so that their inclusion here would be redundant. A reasonable sampling of general radiochemical techniques may be obtained by consulting: W. W. Meinke, University of California Radiation Laboratory Report UCRL-432, 1949 (unpublished); Los Alamos Report LA-1566, 1953 (unpublished); University of California Radiation Laboratory Report UCRL-4377, 1954 (unpublished). For detailed information on the exact procedures used in these experiments, the author may be consulted.

[5] Values for the U^{235} thermal-neutron fission yields were obtained from a report compiled by J. O. Blomeke, Oak Ridge National Laboratory Report ORNL-1783, 1955 (unpublished).

TABLE I. Spontaneous fission yields of Cf^{252}.

Nuclide	No. of determinations	Fission yield % Present work	Correction for fract. chain yield	Glendenin and Steinberg[a]	Cuninghame[b]
Mg^{28}	1	$\leqq 7.1\times10^{-5}$			
K^{43}	2	$\leqq\leqq 1.1\times10^{-4}$			
Ni^{66}	2	$\leqq\leqq 6.8\times10^{-5}$			
Zn^{72}	2	$\leqq\leqq 6.2\times10^{-5}$			
As^{77}	2	$\leqq\leqq 8.8\times10^{-5}$			
As^{78}	3	$(1.97\pm0.18^{c})\times10^{-3}$			
Br^{83}	3	$(2.14\pm0.93)\times10^{-2}$			
Sr^{89}	2	0.32 ± 0.01			
Y^{91}	2	0.59 ± 0.06			
Y^{93}	3	0.83 ± 0.03	0		
Zr^{95}	1	1.37	0		
Zr^{97}	3	1.54 ± 0.15	0.01		2.1 ± 0.3
Mo^{99}	3	2.57 ± 0.03	0	2.2 ± 0.5	3.0 ± 0.45
Mo^{101}					4.1 ± 0.8
Rh^{105}	4	5.99 ± 0.21	0		
Ru^{105}				9.2 ± 1.4	
Pd^{109}	5	5.69 ± 0.59	0	6.8 ± 1.3	
Ag^{111}	4	5.19 ± 0.29	0	4.5 ± 0.9	
Pd^{112}	5	3.65 ± 0.18	0.10	4.5 ± 0.9	
Ag^{113}	4	4.23 ± 0.38	0.01	4.2 ± 0.8	
Cd^{115}	4	2.28 ± 0.13	0	2.8 ± 0.5	
In^{117}				$\leqq 1.0$	
Sn^{121}	3	0.142 ± 0.008	0		
Sn^{125}	2	$(9.3\pm0.4)\times10^{-3}$	0.02		
Sb^{127}	3	0.130 ± 0.008	0.001		
Sb^{129}	3	0.615 ± 0.017	0.052		
I^{131}	3	1.27 ± 0.18	0		
Te^{132}	2	1.75 ± 0.03	0.09	2.8 ± 0.4	
I^{133}	3	2.77 ± 0.20	0.01	4.8 ± 0.7	
I^{134}				4.2 ± 0.6	
I^{135}				4.0 ± 0.6	
Xe^{135}	3	4.33 ± 0.08	0		
Cs^{136}	1	3.5×10^{-2}	(independent yield)		
Cs^{137}	1	4.40	0		
Cs^{138}	1	4.94	0.01	6.3 ± 0.9	
Ba^{139}	2	5.73 ± 0.16	0	6.2 ± 0.9	
Ba^{140}	7	6.32 ± 0.54	0.11		
Ce^{141}	2	5.9 ± 0.3	0		
Ce^{143}	3	5.94 ± 0.35	0	7.8 ± 1.5	
Pr^{143}					7.4 ± 1.5
Nd^{147}	6	4.69 ± 0.08	0		4.0 ± 0.8
Pm^{149}	1	2.65	0		
Pm^{151}	1	2.18	0		
Sm^{153}	6	1.41 ± 0.03	0		1.3 ± 0.3
Eu^{156}	3	$(7.03\pm0.08)\times10^{-1}$	0		
Tb^{161}	1	1.5×10^{-1}			
Dy^{166}	3	$(1.80\pm0.16)\times10^{-2}$			
Er^{169}	3	$(1.72\pm0.41)\times10^{-3}$			
Tm^{172}	3	$\leqq 4.4\times10^{-4}$			
Tm^{174}	3	$\leqq\leqq 4.0\times10^{-4}$			
Yb^{175}	2	$\leqq\leqq 2.3\times10^{-4}$			
Lu^{177}	1	$\leqq\leqq 9.6\times10^{-5}$			

[a] See reference 1. [b] See reference 2. [c] Average deviation of multiple determinations.

three direct measurements of the Mo^{99} fission yield. The remaining fission yields were obtained by multiplying the "pseudo fission yields" by (2.57/6.14), or 0.4186.

In Fig. 2 major contributors to the fission yield curve are plotted versus mass number, while all of the fission yield data are plotted in Fig. 3. The yield curve represents what the author considers to be the best curve that can be drawn through the experimental points. Integration under the curve of Fig. 2 gives a value of 98.4%, which indicates that the data are at least consistent to $\pm2\%$. In addition, there is a sufficiently large number of points, so that the curve may drawn with a fairly high degree of reliability.

The fission yield curve of Fig. 3 has several very interesting features. Comparison with the yield curve for the thermal-neutron fission of U^{235} shows that the mass numbers of the maxima of the heavy-mass peaks of Cf^{252} and U^{235} nearly coincide, while that of the light-mass peak of Cf^{252} is approximately 13 mass units larger than that of the corresponding U^{235} peak.

While the maximum of the Cf^{252} heavy-mass peak

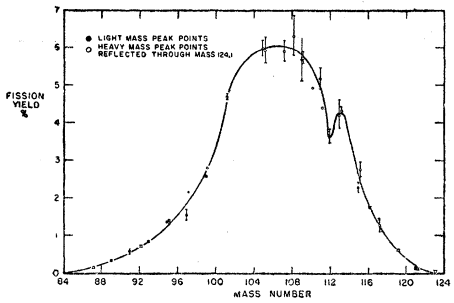

FIG. 2. Cf^{252} spontaneous fission yield as a function of mass number. ● Light-mass-peak points. o Heavy-mass-peak points reflected through mass 124.1.

appears at roughly the same mass number as that of U^{235}, the peak itself is significantly wider; the "full width at $\frac{1}{10}$ maximum" is approximately 6 mass units greater than that for U^{235}. Since this added width is all of the heavy-mass side of the peak, the more asymmetric types of fission would seem to be much more probable in the spontaneous fission of Cf^{252} than in the thermal-neutron fission of U^{235}.

The striking similarity between the Cf^{252} and U^{235} curves in the region of masses 125–140 emphasizes once again that the extra stability of nuclides in this region may be playing a most important part in the low-energy fission process. The fact that the light-mass side of the Cf^{252} heavy-mass peak is so similar to that for U^{235}, and that there is a concavity in the Cf^{252} curve in the region of mass 150, leads to the conjecture that perhaps the curve for the heavy-mass peak is actually a sum of two separate kinds of asymmetric fission.

If there are forces at work in the thermal-neutron fission of U^{235} that conspire to determine the position and the shape of the heavy-mass peak, one may hypothesize that these forces will operate to give a curve in the same position and of the same shape for Cf^{252}. To a fair approximation, the light-mass sides of the Cf^{252} and U^{235} peaks are parallel. If a line is drawn parallel to the heavy-mass side of the U^{235} peak and joining the Cf^{252} curve at the point where the concavity begins, the difference between this line and the measured Cf^{252} curve may be considered as a deviation from the "standard peak shape."

Treatment of the curves in this manner is shown in Fig. 4. The deviation from "standard peak shape" is a curve with a maximum at about mass 154 (mirror mass 94). While this sort of treatment is tenuous at best, it seems improbable that this value would be in error by more than a few mass units.

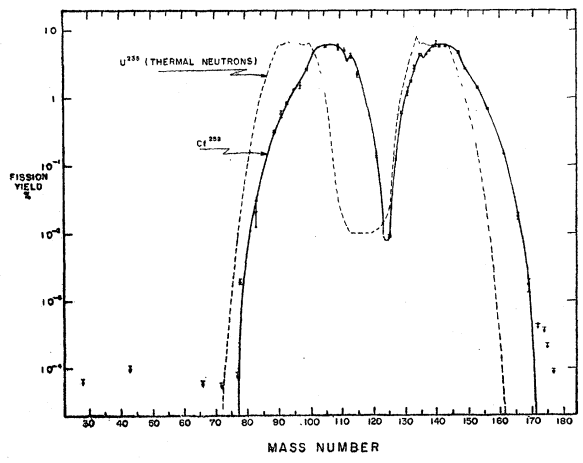

FIG. 3. Cf^{252} spontaneous fission yield as a function of mass number. All plotted points are measured, none reflected. The curve as drawn is symmetrical about mass 124.1. The yield curve for the fission of U^{235} with thermal neutrons is included for comparison.

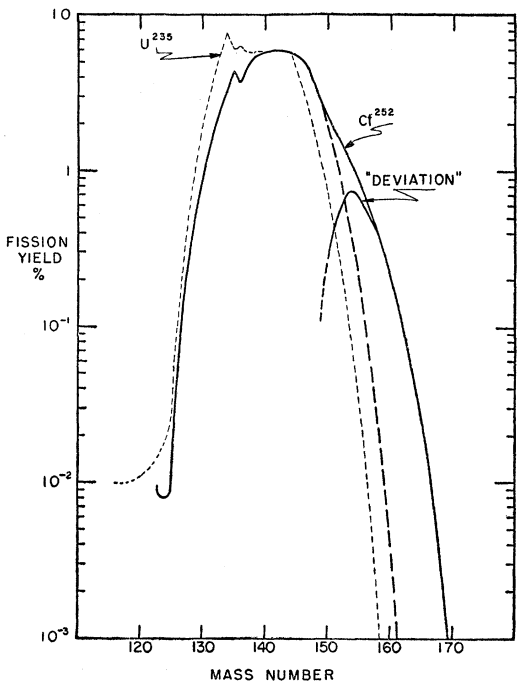

FIG. 4. Analysis of the "two-component fission peak."

No very strong argument can be made for the validity of this two-component-peak hypothesis except that the experimental peak shape suggests that it might be so. Mass 154 and 94 are not near any closed-shell configuration, and there is no known reason for assigning any special preference to these masses in the fission of Cf^{252}. It will be interesting to see whether calculations currently in progress in Berkeley on refinements of the liquid-drop model for fissioning nuclei will be able to shed any light on this matter.

The minimum fission yield in the trough between the two peaks has not been measured directly in these experiments. Since Sn^{125} lies within one mass unit of the minimum, the fission yield for mass 124 should be $\leqq 8\times10^{-3}\%$. The trough itself is much narrower than has been observed in any other type of fission, having

a "full width at 10 times minimum" of 5 mass units, as compared with a value of 18 mass units for U^{235}.

One feature of the curve that is somewhat uncertain is the fine structure at masses 113 and 135. During the course of the experiment, when it became apparent that there might be an irregularity in this region, special effort was made to obtain the most precise numbers for the fission yields of the masses in question. Thus it was necessary to take into account several factors which could easily have contributed a systematic error to the final yield values. One of the chief sources of this type of error is incomplete chemical exchange between the fission fragment and the carrier used in the radiochemistry. Another is the error inherent in resolving a multicomponent decay curve, especially where activities of similar half-lives are involved. A third source of error involves the difficulty in measuring the total chain yield when parent and daughter nuclides of approximately equal half-lives are present and the daughter is to be separated as the chain yield.

The elements separated in the fine-structure region are Pd, Ag, and I. To ensure exchange in the Pd samples the collector plates were dissolved in the presence of Pd carrier in HCl-HNO_3, and the Pd was reduced to the metal and redissolved in the same solution before any further chemistry was done. The Ag targets were dissolved in acid and made basic with NH_4OH as an exchange step, while the I targets were dissolved in NaOH and oxidized with NaOCl before the IO_3^- carrier was reduced to I^- in dilute HNO_3.

To minimize errors in analysis of the decay curves, all counting data were placed on punched cards and processed through an IBM-650 calculator using a least-squares analysis. Length of collection time and time of separation were chosen to minimize Ag^{112} activity in the Ag^{113} samples and I^{135}-Xe^{135} activity in the I^{133} samples.

Preliminary measurements indicated that fission yields for the mass-135 chain that were obtained through measurement of I^{135} would probably not be very accurate. The decay curves had a minimum of five components, and resolution was very uncertain for the 6.7-hr I^{135} and its 9.2-hr Xe^{135} daughter. The final mass-135 chain yield was obtained by measuring the separated Xe^{135} activity.

For collection times greater than several hours, the mass-135 decay chain can be represented by

$$\underset{\substack{n_1\\R_1}}{I^{135}} \xrightarrow{\lambda_1} \underset{\substack{n_2\\R_2}}{Xe^{135}} \xrightarrow{\lambda_2} Cs^{135},$$

where λ_1 and λ_2 are the decay constants, and n_1 and n_2 the number of atoms of I^{135} and Xe^{135}, respectively. R_2 is the independent rate of formation of Xe^{135}, and R_1 is the rate of formation of I^{135} plus all of its precursors in the mass-135 chain.

Development of the growth and decay equation gives

$$n_2=e^{-\lambda_2 T}\left[\frac{R_1+R_2}{\lambda_2}(1-e^{-\lambda_2 t})\right]-\frac{R_1}{\lambda_2-\lambda_1}(e^{-\lambda_2 T})$$
$$\times(e^{-\lambda_1 t}-e^{-\lambda_2 t})+\frac{R_1}{\lambda_2-\lambda_1}(1-e^{-\lambda_1 t})(e^{-\lambda_1 T}-e^{-\lambda_2 T}) \quad (2)$$

for the number of atoms of Xe^{135} present at time T after the end of a bombardment of length t. If the length of bombardment and the time of the I-Xe separation are such that

$$e^{-\lambda_2 T}(e^{-\lambda_1 t}-e^{-\lambda_2 t})=(1-e^{-\lambda_1 t})(e^{-\lambda_1 T}-e^{-\lambda_2 T}), \quad (3)$$

then Eq. (2) reduces to

$$R_1+R_2=n_2\lambda_2 e^{\lambda_2 T}/(1-e^{-\lambda_1 t}). \quad (4)$$

The fission yield for the mass-135 chain in Table I represents the average of three runs in which the bombardment length varied by almost a factor of five (4.0 and 19.7 hr) and the corresponding I-Xe separation times varied by more than a factor of two (9.5 and 4.2 hr). The average deviation of the fission yields for these three runs is less than two percent.

This method of separating an element at a time that is dependent on the length of bombardment was also used on the 131 and 133 chains. No difference was found between yields calculated in this manner and those determined by more conventional means.

The palladium fraction was separate in five different experiments, silver four, and iodine three, as shown in Table I. While it may be possible to draw a smooth curve without fine structure through the points in Fig. 2, it is necessary to ignore the Pd^{112} yield to do it. The author feels that the nuclides in question have been measured often enough, the experimental conditions have varied widely enough, and the average deviation is small enough so that the fission yield curve (including fine structure) drawn in Fig. 2 is the most precise one that can be drawn through these points.

If the curve is indeed an accurate representation of fact, then it is unfortunate that the fine structure should fall just where it does. The minimum is only one mass unit wide, and while the Pd^{112} can be measured without great difficulty, its mirror mass, 136, cannot be measured at all by radiochemical methods. Thus the existence of the fine-structure peak is dependent almost entirely on the value for the Pd^{112} yield.

It is possible that a low value for the Pd^{112} yield may be caused by fractional chain yield losses inherent in the radiochemical method. If a sufficiently large percentage of the primary fission fragments with mass 112 has atomic numbers greater than 46, then Pd^{112} will not be an accurate measure of the total chain yield. Unfortunately the author knows of no direct measurements of yield as a function of atomic

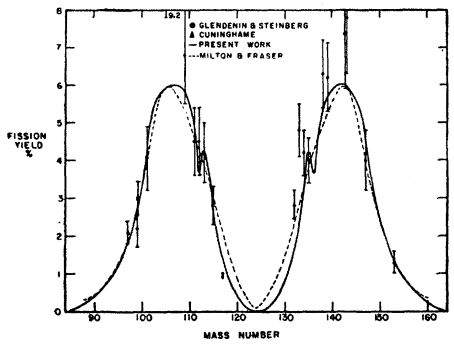

FIG. 5. Comparison of Cf^{252} spontaneous fission yield data.

number for a given mass in the spontaneous fission of Cf^{252}.

In order to get some feel for the size of the corrections involved, the "equal chain length" hypothesis of Glendenin, Coryell, and Edwards,[6] as modified by Nethaway,[7] has been used to calculate the corrections to the measured chain yield, and the data are included in Table I. Inspection shows that in almost all cases the correction is insignificant. Pd^{112} has the largest correction, but even the sum of the measured Pd^{112} yield and the fractional chain yield correction gives a total mass-112 chain yield value (3.75%) which is considerably less than the mass-113 yield (4.2%). If a smooth curve is to be drawn without fine structure, the mass-112 yield should be at least 4.5%. It may well be that the Gaussian curve that was used to calculate the correction is too narrow and that the correction should be larger, but the author feels that more conclusive evidence is needed as to exact size of the correction before too much reliance is placed in its accuracy.

As an aid to rationalization after the fact it may be noted that a primary-fission fragment having a mass of 135 and the same neutron-to-proton ratio as Cf^{252} would contain 82.5 neutrons. Thus the extra stability of the 82-neutron shell could conceivably be contributing to the fine structure in the heavy-mass peak and, in a complementary fashion, in the light-mass peak.

Comparison of the present data with previously reported yields does not help a great deal in this particular matter. The yields of Glendenin and Steinberg[1] and Cuninghame[2] are shown in Fig. 5 and listed in Table I. The Cuninghame data agree quite well with the curve, but none of the elements in the fine-structure region were reported. The Glendenin and Steinberg data show reasonable agreement in both the light- and heavy-mass peaks, but the limits of error are so large that no conclusive statement can be made as to the existence or nonexistence of a fine-structure peak. It should perhaps be emphasized that the Cf^{252} source with which Glendenin and Steinberg had to work was so small (several thousand fissions per minute) and the counting rates of their samples so low that the fact that there is as much agreement as there is between their yields and the present data is quite remarkable.

The curve of Milton and Fraser[8] in Fig. 5 was obtained by time-of-flight measurements on Cf^{252} fission fragments. While the general agreement with the present data is quite good, one cannot reasonably expect fine structure to be discernible by this technique.

During the course of the present experiments it was tentatively reported from Berkeley that Cf^{252} ternary fission tracks had been seen in nuclear emulsions. The first reports indicated a ternary-fission yield as high as 0.1%. In order to measure the radioactive products of these ternary-fission events several elements of atomic number less than that of arsenic were separated. In no case was any activity seen which could be attributed to nuclides formed in ternary fission, and upper limits of approximately 10^{-4}% fission yield are set for Mg^{28}, K^{43}, Ni^{66}, and Zn^{72}. While the elements separated were rather arbitrarily chosen because of their ease of purification, the nuclides should represent a fair sampling of the yields in this part of the periodic table. Thus it seems reasonable to assume that unless the ternary-fission peak is extremely narrow, or the ternary-fission products either stable or neutron deficient, that the ternary-fission events occur with less than 10^{-3}% fission yield.

ACKNOWLEDGMENTS

The author has no desire to leave the impression that he has done all the work reported in this paper. A total of seventy-eight Cf^{252} fission-fragment collection experiments was performed, many of which involved the coordinated and cooperative effort of a number of workers. Thus it is with the sincerest appreciation that the author acknowledges the aid of Dr. Peter Stevenson, Dr. Harry Hicks, Dr. Floyd Momyer, and Dr. Harris Levy; James Niday, Robert da Roza, James Armstrong, Llad Phillips, and Raymond Gatti; Mrs. Nancy Lee, and Mrs. Dolores Razavi in various phases of the work. In addition, the author wishes to thank Dr. Stanley Thompson for providing the Cf^{252} sources and for tolerating various trials and tribulations during the course of the experiments with commendable equanimity.

[6] L. E. Glendenin, C. D. Coryell, and R. R. Edwards, *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), Paper No. 52, National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Div. 4, p. 489.

[7] D. R. Nethaway, thesis, Washington University, September, 1959 (unpublished).

[8] J. C. D. Milton and J. S. Fraser, Phys. Rev. **111**, 877–885 (1958).