760

International Atomic Energy Agency

INDC(CCP)-128/G+Sp.

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

Average Kinetic Energies of Fission Fragments

V.G. Vorob'eva, B.D. Kuz'minov, V.N. Manokhin

Translated by the IAEA

January 1979

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

Reproduced by the IAEA in Austria
January 1979
79-00737

INDC(CCP)-128/G+Sp.

Average Kinetic Energies of Fission Fragments

V.G. Vorob'eva, B.D. Kuz'minov, V.N. Manokhin

Translated by the IAEA
January 1979

78-9834
Translated from Russian

FEI-803

AVERAGE KINETIC ENERGIES OF FISSION FRAGMENTS

V.G. Vorob'eva, B.D. Kuz'minov, V.N. Manokhin
Institute of Physics and Power Engineering, Obninsk

ABSTRACT

An analysis is given of experimental data on the average kinetic energies of fission fragments for a fixed nucleonic composition and fixed excitation energy of the fissioning nuclei. The numerical data are referred to a common standard. This type of data on the average kinetic energies of fission fragments is needed for a large number of practical applications. A major part of the energy resulting from fission appears as kinetic energy in the fragments. The ranges of these fragments in condensed media are measured in microns. The thermal energy resulting from the slowing down of the fragments will therefore be released at almost the same point where the fission occurred. The spatial distribution of the instantaneous energy release will thus be proportional to the product of the fission number density and the kinetic energy of the fragments. An important problem in measurements of the energy dependence of fission cross-sections is the efficiency with which the fission events are recorded. This recording efficiency depends on the angular anisotropy and the kinetic energy of the fission fragments. The need therefore arises for data on the energy dependence of the kinetic energy of these fragments.

In cases where it is difficult to get direct measurements of the average number of prompt neutrons per fission, information about the energy dependence of the fragment kinetic energy can be used to derive the energy dependence of $\bar{\nu}$.

This information on the energy characteristics of fission fragments is also required in analysing the radiation stability of fuel claddings subjected to the effect of such fragments.

A vast amount of experimental material on the kinetic energies of fission fragments has already been accumulated. However, the variety of measuring techniques and energy calibration standards used makes it difficult to compare the results obtained by different authors. When the excitation energy of compound nuclei exceeds the threshold for a fission reaction with preliminary neutron emission, neither the excitation energy nor the nucleonic composition of the fissioning nuclei are single-valued. It is not always possible in such cases to determine the kinetic energy corresponding to a particular fissioning nucleus and a fixed excitation energy.

The first part of this paper contains an analysis of the existing experimental data on average fragment kinetic energies for a fixed nucleonic composition and fixed excitation energy of the fissioning nuclei; reference values are selected and their errors are estimated. All the numerical data on the fragment kinetic energies are referred to a common standard.

In the second part of the paper, we analyse the experimental data obtained from fission reactions which admit preliminary nucleon emission.

Most of the results on fragment kinetic energies have been obtained from measurements where either the spontaneous fission of californium-252 or the thermal-neutron-induced fission of uranium-235 are used for calibrating the fragment energy scale. In view of the fact that it is convenient to work with californium targets and that the spontaneous fission neutrons from californium-252 serve to standardize $\bar{\nu}$ measurements and fission neutron spectra, we decided to use the kinetic energy of fragments from the spontaneous fission of californium-252 to standardize the information on the average kinetic energies of fragments from other nuclei. The average fragment kinetic energy in the thermal-neutron-induced fission of uranium-235 was taken as an additional standard.

PART I. Table 1 compares the average kinetic energies in spontaneous fission of californium-252 measured by various authors. All the results, apart from those in Ref. [1], show good agreement within the indicated limits of error. The most likely explanation for the low value of E_k in Ref. [1] is scattering of the fragments on the walls of the flight tube. The same authors have given a different value for the fragment kinetic energy from spontaneous fission of californium-252 in a later paper [2]. We have therefore excluded the results in Ref. [1] from further consideration.

The values of the average kinetic energies given in Table 1 were obtained by two methods: 1) measurement of the time of flight of the fragments and 2) measurement of the ionization produced by the fragments in semiconductor detectors. These two methods give results which agree within the indicated limits of error. However, it is interesting that the results obtained by the first method give systematically smaller values for the fragment kinetic energy. It should be noted that the statistical error of the measurements in all the references quoted is extremely small: $\Delta = \sigma/\sqrt{N}$, where σ is the dispersion in the kinetic energy distribution of the fragments and N is the total number of events recorded. When $N \simeq 10^4$, $\Delta \simeq 0.10$ MeV, so that the error indicated by the authors is in fact the estimated systematic error of the method of measurement.

Table 2 lists the values of the fragment kinetic energy obtained by averaging the results of the various authors.

We have taken the average weighted value (186.3 ± 1.0) MeV as the standard since we believe the relationship between the measurement errors quoted by the authors (2.0 MeV for the time of flight and 1.0 MeV for the semiconductor detectors) to be fairly correct.

Table 3 gives the average fragment kinetic energies for thermal-neutron-induced fission of uranium-235 obtained by various measurement techniques. The accuracy of the calorimetry measurements [8, 9] is insufficient because of the various corrections that have to be made for the radiation accompanying the fission process. We have therefore excluded these results from consideration.

We have also ignored the early work in Ref. [7], where the time-of-flight method was used. The results of Milton and Fraser [1] are lower than they ought to be because of scattering of the fragments on the walls of the flight tube. However, knowing that the average fragment kinetic energy in the spontaneous fission of californium-252 as measured by Milton and Fraser is 3.6 MeV lower than the value taken as the standard, we can correct their results for other fissioning nuclei [1]. We thus have three results for the average fragment kinetic energy in the thermal-neutron-induced fission of uranium-235 which can be compared with each other: (171.9 ± 1.7) MeV - the corrected value from Ref. [1], (171.9 ± 1.4) MeV [4] and (172.7 ± 1.0) MeV [6]. These results show good internal agreement. In order to derive the recommended value of E_k, it is convenient to use the difference between the fragment kinetic energies in the spontaneous fission of californium-252 and the thermal-neutron-induced fission of uranium-235 so as to get a value of E_k relative to the chosen standard for californium-252. Table 4 shows the values of the difference $\Delta E_k = E_k(^{252}Cf) - E_k(^{235}U + n_{th})$ obtained by various methods.

The average value of the difference ΔE_k is (14.1 ± 0.4) MeV. We thus get $E_k = (172.2 \pm 0.4)$ MeV for the average fragment kinetic energy in the thermal-neutron-induced fission of uranium-235. The relative measurement error is shown. The absolute error is $\pm$ 1.4 MeV.

Average kinetic energies in the spontaneous fission of heavy nuclei are shown in Table 5. As a rule, only one or two sets of results are available for each nucleus. In these cases there is no point in averaging, so the table gives just the original results corrected to the various standards.

Table 6 lists average fragment kinetic energies for thermal-neutron-induced fission. In those cases where the information on the E_k values consists of results from several independent sources, the table shows the recommended values of E_k. The recommended values for thermal-neutron-induced fission of uranium-233, plutonium-239 and plutonium-241 are (171.5 ± 0.3), (178.6 ± 0.9) and (179.0 ± 0.6) MeV, respectively.

The following tables list the measured values of the fragment kinetic energies for fast-neutron-induced fission.

PART II. This section contains an analysis of the existing experimental data on the average fragment kinetic energies for fission induced by various particles. The experimental data obtained in fission reactions admitting preliminary nucleon emission are systematized. We believe it to be incorrect to determine the most probable nucleonic composition and fissioning nuclei excitation energy from the existing model representations since this work is too particular and individual and the results of the calculation depend on the particular concepts used. Table 19 therefore shows only the original experimental data: the target nucleus, the incident particle and its energy. All the experimental data have been referred to a common standard, namely the average fragment kinetic energy in spontaneous ^{252}Cf fission. The choice of the recommended value $E_k = 186.3 \pm 1.0$ MeV is justified in the first part of the paper.

Table 1

Experimental values of the average fragment kinetic energy in the spontaneous fission of californium-252

No.	E_k (MeV)	Method of measurement	Reference	Comment
1.	182.7 ± 1.7	Flight time	1	Large scattering of fragments in the walls of the flight tube
2.	185.4 ± 2.0	Flight time	2	
3.	185.7 ± 1.8	Flight time	3	
4.	186.5 ± 1.0	Semiconductor detectors	4	Calibration with heavy ions and allowance for mass
5.	184.9 ± 2.0	Flight time	5	
6.	186.7 ± 1.0	Semiconductor detectors	6	Calibration with heavy ions and allowance for mass and charge

Table 2

Averaged values of fragment kinetic energy in the spontaneous fission of californium-252

No.	Method of measurement	E_k (MeV)
1.	Average over results obtained by the time-of-flight method [2, 3, 5]	185.3 ± 2.0
2.	Average over results obtained from semi-conductor detectors [4, 6]	186.6 ± 1.0
3.	Arithmetic mean from the two types of measurement	186.0 ± 1.0
4.	Weighted mean from the two types of measurement	186.3 ± 1.0

Recommended value: (186.3 ± 1.0) MeV

Table 3

Experimental values of average fragment kinetic energy in thermal-neutron-induced fission of uranium-235

No.	E_k (MeV)	Method of measurement	Reference	Comment
1.	165 ± 2	Flight time	7	
2.	167 ± 1.6	Calorimeter	8	
3.	174 ± 4	Calorimeter	9	
4.	168.3 ± 1.7	Flight time	1	
5.	171.9 ± 1.4	Semiconductor detectors	4	Calibration with heavy ions
6.	172.7 ± 1.0	Semiconductor detectors	6	Calibration with heavy ions and allowance for charge

Table 4

Measured difference between average fragment kinetic energies in spontaneous fission of californium-252 and in thermal-neutron-induced fission of uranium-235

No.	E_k (MeV)	Method of measurement	Reference
1.	13.8	Time of flight	1
2.	14.6	Semiconductor detectors	4
3.	14.0	Semiconductor detectors	6
	14.0 ± 0.4	Average value	

The recommended value of the average fragment kinetic energy in thermal-neutron-induced fission of uranium-235 is E_k = 172.2 ± 0.4 MeV.

TABLE 5

Average fragment kinetic energies in spontaneous fission

Fissioning nucleus	E_K (MeV)	Referred to common standard	Reference
^{236}U	- 3,5±I x) -4.0 ±0,7x)	I68,7±I,4 I68,2±I,I	I0 II
^{240}Pu	- I.5±0,5x) + 3,7±2,Ix) - I,I±0,2x) + 0,7±0,4x)	I77,I±I,4 I82,3±2,5 I77,5±I,I I79,3±I,0	I2 I3 I4 40
^{242}Pu	0 ± 2 + 2,6±0,2x)	I79,0±2,0 I8I,6±0,2	I6 I5
^{244}Cm	I83,7±2,0 I86,6±I,6	I85,I±2,0 I88,9±I,6	5 I8
^{246}Cm	I84,2±2,7 I83.9±0,5	I84,5±2,7 I84,2±0,5	I9 38
^{248}Cm	I82,2±0,9 I79,0±2,0	I82,5±0,9 I82,3±2.0	38 20
^{250}Cm	I79,8±2,7	I79,I±2,7	2I
^{246}Cf	I95,6±2,0	I96,6±2,0	22
^{248}Cf	I85,0±3,0 I84.3±2,7	I89,3±3,0 I83,6±2,7	20 2I
^{250}Cf	I87,0±0,5 I84,3±2,7	I87,3±0,5 I83,6±2,7	38 2I
^{252}Cf	standard	I86,3±I,0	
^{254}Cf	I86,9±0,5 I85,0±2,7 I85,0±2,0 I86,I±2,8 I85,0±2,7	I87,3±0,5 I84,3±2,7 I88,3±2,0 I87,9±2,8 I84,3±2,7	38 2I 20 22 2I
^{253}Es	I88,0±3,0	I9I,3±3,0	20
^{254}Fm	I89 ±2	I92,3±2	20
^{256}Fm	I97,9±0,5	I98,2±0,5	38
^{252}No	202,4±I,2	202,2±I,2	39

TABLE 6

Average fragment kinetic energies in thermal-neutron-induced fission

Target nucleus	E_K (MeV)	Referred to common standard	Reference
^{229}Th	I63,6±0,5	I63,9±0,5	38
^{233}U	I67,6±I,7 I7I,7±0,3 I72,0±0,5 I7I,2±0,8 I7I,5±0,2 Recommended value	I7I,2±I,7 I7I,7±0,7 I7I,8±0,5 I7I,5±I,2 I7I,5±0,6 I7I,5±0,3	I I7 29 23 24
^{235}U	Recommended value	I72,2±0,4	
^{239}Pu	I75,0±I,7 I79,3±I,0 I77,7±0,8 I78,8±0,5 Recommended value	I78,6±I,7 I79,6±I,4 I77,5±0,8 I78,8±0,9 I78,6±0,9	I 23 25 24
^{241}Pu	I69,5±2,0 I70,4±2,5 I79,6±0,8 I78,7±0,5 Recommended value	I73,5±2,0 I74,0±2,5 I79,4±0,8 I78,7±0,5 I79,0±0,6	27 26 25 24
^{241}Am	I78,4±2,7	I82,0±2,7	26
^{245}Cm	I84,2±0,5	I84,5±0,5	38
^{249}Cf	I89,I±0,5	I89,4±0,5	38
^{251}Cf	I82,I±2,7	I85,0±2,7	28
^{254}Es	I94,3±0,5	I94,6±0,5	38
^{255}Fm	I92,5±2,9	I95,7±2,9	28

TABLE 7

Average fragment kinetic energies in neutron-induced fission of thorium-232*/

E_n (MeV)	E_k (MeV)	Referred to common standard	Reference	E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
I,2I	I6I,43±0,28	I6I,43±0,28	4I	I,90	I62,6I±0,I6	I62,6I±0,I6	35
I,32	I6I,74±0,I5	I6I,74±0,I5	4I	I,90	I69,03±0,05	I68,83±0,05	36
I,37	I6I,64±0,I5	I6I,64±0,I5	4I	2,0I	I62,7I±0,I5	I62,7I±0,I5	4I
I,39	I6I,36±0,22	I6I,36±0,22	35	2,09	I62,33±0,I5	I62,33±0,I5	4I
I,42	I62,I9±0,I5	I62,I9±0,I5	4I	2,I4	I62,I3±0,I5	I62,I3±0,I5	4I
I,47	I62,03±0,I5	I62,03±0,I5	4I	2,24	I62,77±0,I5	I62,77±0,I5	4I
I,52	I62,04±0,I5	I62,04±0,I5	4I	2,37	I63,40±0,I6	I63,40±0,I6	35
I,60	I62,24±0,I5	I62,24±0,I5	4I	2,87	I63,I2±0,22	I63,I2±0,22	35
I,63	I62,44±0,I5	I62,4I±0,I5	4I	2,97	I69,73±0,05	I69,53±0,05	36
I,65	I62,83±0,I6	I62,83±0,I6	35	3,30	I63,I0±0,I8	I63,I0±0,I8	35
I,70	I62,57±0,I5	I62,57±0,I5	4I	4,07	I70,20±0,I0	I70,0 ±0,I0	36
I,76	I62,63±0,I5	I62,63±0,I5	4I	4,8I	I70,42±0,04	I70,22±0,04	36
I,86	I62,55±0,I5	I62,55±0,I5	4I	5,60	I63,57±0,I8	I63,57±0,I8	35

*/ References [35, 41] and [36] quote the error in the measurement of the average fragment kinetic energy relative to E_k = 162.6 MeV for thorium-232 fission induced by 2.9 MeV neutrons and to E_k = 170.2 MeV for fission induced by 4.07 MeV neutrons, respectively.

TABLE 8

Average fragment kinetic energies in the neutron-induced fission of protactinium-231

Reactor neutrons	I66,8±2	I67,I±2	23

TABLE 9

Average fragment kinetic energies in the neutron-induced fission of uranium-233

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
Thermal	Recommended value	I7I,5	
0,026	- 0,09±0,I3*)	I7I,4I±0,I3	32
0,05	0,06±0,I5*)	I7I,50±0,I5	
0,07	I72,02±0,I	I7I,52±0,I	35
0,I0	0,26±0,II*)	I7I,76±0,II	32
0,I5	0,40±0,I2*)	I7I,90±0,I2	
0,20	0,37±0,I6*)	I7I,87±0,I6	
0,22	I72,25±0,I	I7I,75±0,I	35
0,29	I72,39±0,I	I7I,89±0,I	
0,30	0,23±0,I2*)	I7I,73±0,I2	32
0,30	0,8I±0,24*)	I72,3I±0,24	3I
0,40	I72,46±0,I	I7I,96±0,I	35
0,40	0,34±0,I6*)	I7I,84±0,I6	32
0,40	0,62±0,24*)	I72,I2±0,24	3I
0,50	0,67±0,37*)	I72,I7±0,37	
0,50	0,44±0,I7*)	I7I,94±0,I7	32
0,52	I72,55±0,I	I7I,85±0,I	35
0,60	0,38±0,I9*)	I7I,88±0,I9	32
0,63	I72,42±0,I	I7I,92±0,I	35
0,70	0,34±0,I5*)	I7I,84±0,I5	32
0,76	0,00±0,2I*)	I7I,50±0,2I	3I
0,78	I72,29±0,I	I7I,79±0,I	35
0,80	0,2I±0,I6*)	I7I,7I±0,I6	32
0,95	I72,28±0,I	I7I,78±0,I	35
0,95	0,65±0,34*)	I72,I5±0,34	3I
I,00	0,26±0,29*)	I7I,76±0,29	32
I,04	I72,36±0,I	I7I,86±0,I	35
I,09	0,54±0,28*)	I72,04±0,28	3I
I,I3	I72,33±0,I	I7I,83±0,I	35
I,24	I72,26±0,I	I7I,76±0,I	
I,28	0,70±0,26*)	I72,20±0,26	3I

(Table 9 continued)

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
I,35	I72,48±0,I	I7I,98±0,I	35
I,45	I72,38±0,I	I7I,88±0,I	
I,53	0,67±0,20*)	I72,I7±0,20	3I
I,56	I72,33±0,I	I7I,83±0,I	35
I,73	0,73±0,2I*)	I72,23±0,2I	3I
I,74	I72,35±0,I	I7I,85±0,I	
I,89	I72,36±0,I	I7I,86±0,I	
I,92	0,98±0,37*)	I72,48±0,37	3I
I,94	I72,36±0,I	I7I,86±0,I	35
2,I4	I72,36±0,I	I7I,86±0,I	
2,I6	0,9I±0,34*)	I72,4I±0,34	3I
2,36	I72,3I±0,I	I7I,8I±0,I	35
2,54	I72,37±0,I	I7I,87±0,I	
2,75	I72,23±0,I	I7I,73±0,I	
2,94	I72,38±0,I	I7I,88±0,I	
3,I5	I72,22±0,I	I7I,72±0,I	
3,34	I72,36±0,I	I7I,86±0,I	
3,55	I72,I9±0,I	I7I,69±0,I	
3,75	I72,30±0,I	I7I,80±0,I	
3,86	I72,24±0,I	I7I,74±0,I	
3,98	I72,I5±0,I	I7I,65±0,I	
4,70	0,29±0,24	I7I,79±0,24	3I

*) Difference between the average kinetic energies for fission induced by fast and thermal neutrons.

The values shown represent the measurement errors relative to E_k for thermal-neutron-induced uranium-233 fission.

TABLE 10

Average fragment kinetic energies in the neutron-induced fission of uranium-235

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
Thermal	I72,2	I72,2	35
0,08	- 0,38±0,32[x)]	I7I,82±0,32	3I
0,I2	I72,40±0,I	I72,40±0,I	35
0,I2	0,0 ±0,4[x)]	I72,20±0,4	34
0,20	I72,36±0,I	I72,36±0,I	35
0,20	- 0,I0±0,2I[x)]	I72,I0±0,2I	33
0,28	I72,3I±0,I	I72,3I±0,I	35
0,28	- 0,55±0,23[x)]	I7I,65±0,23	3I
0,30	I72,35±0,I	I72,35±0,I	35
0,30	+ 0,26±0,20[x)]	I72,46±0,20	33
0,35	- 0,7I±0,30[x)]	I7I,49±0,30	3I
0,35	+ 0,05±0,I8[x)]	I72,25±0,I8	33
0,40	I72,25±0,I	I72,25±0,I	35
0,40	+ 0,I9±0,I9[x)]	I72,39±0,I9	33
0,45	- 0,05±0,20[x)]	I72,I5±0,20	33
0,48	- 0,08±0,23[x)]	I72,I2±0,23	3I
0,50	I72,27±0,I0	I72,27±0,I0	35
0,50	- 0,I2±0,2I[x)]	I72,08±0,2I	33
0,50	- 0,I5±0,4 [x)]	I72,05±0,40	34
0,60	I72,40±0,I0	I72,40±0,I0	35
0,60	+ 0,I3±0,20[x)]	I72,33±0,20	33
0,68	+ 0,I7±0,32[x)]	I72,37±0,32	3I
0,70	I72,49±0,I	I72,49±0,I	35
0,70	- 0,05±0,24[x)]	I72,I5±0,24	33
0,75	I72,52±0,I	I72,52±0,I0	35
0,77	+ 0,33±0,32[x)]	I72,53±0,32	3I
0,80	I72,I7±0,I	I72,I7±0,I	35
0,87	+ 0,07±0,23[x)]	I72,27±0,23	3I
0,90	I72,34±0,I0	I72,34±0,I0	35
0,90	- 0,03±0,25	I72,I7±0,25	33
I,00	I72,35±0,I	I72,35±0,I0	35
I,09	+ 0,05±0,42[x)]	I72,25±0,42	3I
I,I0	I72,35±0,I0	I72,35±0,I0	35

(Table 10 continued)

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
I,20	I72,3I±0,I0	I72,3I±0,I0	35
I,30	I72,3I±0,I0	I72,3I±0,I0	35
I,35	I72,44±0,I0	I72,44±0,I0	35
I,40	I72,35±0,I0	I72,35±0,I0	35
I,45	+ 0,I7±0,25*)	I72,37±0,25	3I
I,50	I72,38±0,I0	I72,38±0,I0	35
I,60	I72,50±0,I0	I72,50±0,I0	
I,70	I72,46±0,I0	I72,46±0,I0	
I,75	I72,49±0,I0	I72,49±0,I0	
I,80	I72,27±0,I0	I72,27±0,I0	
I,85	I72,20±0,I0	I72,20±0,I0	
I,90	I72,30±0,I0	I72,30±0,I0	
I,90	- 0,03±0,33*)	I72,I7±0,33	3I
2,00	I72,22±0,I0	I72,22±0,I0	35
2,25	I72,28±0,I0	I72,28±0,I0	35
2,30	I72,37±0,I0	I72,37±0,I0	35
2,46	- 0,I0±0,37*)	I72,I0±0,37	3I
2,53	I72,II±0,I0	I72,II±0,I0	35
2,75	I72,33±0,I0	I72,33±0,I0	
3,00	I72,22±0,I0	I72,22±0,I0	
3,50	I72,22±0,I0	I72,22±0,I0	
5,00	I7I,79±0,I0	I7I,79±0,I0	
5,00	- 0,I5±0,I5*)	I72,05±0,I5	3I
6,00	I7I,46±0,I0	I7I,46±0,I0	35
6,00	- 0,50±0,20*)	I7I,70±0,20	34

*) Difference between the kinetic energies for fission induced by fast and thermal neutrons.

The values shown represent the measurement errors relative to E_k for thermal-neutron-induced uranium-233 fission.

TABLE 11

Average fragment kinetic energy for neutron-induced fission of uranium-238

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
I,3	I72,65± 0,25	I72,65±0,25	37[x)]
I,4	I72,50± 0,20	I72,50±0,20	
I,5	I72,55± 0,I5	I72,55±0,I5	
I,5	I72,34± I,0	I72,64±I,0	34[xx)]
I,9	I72,48± 0,I5	I72,48±0,I5	
2,22	I72,50± 0,I5	I72,48±0,I5	
2,3I	I72,63± 0,I5	I72,63±0,I5	
2,43	I72,38± 0,I5	I72,38±0,I5	
2,72	I72,36± 0,I5	I72,36±0,I5	
2,90	I72,23± 0,I5	I72,23±0,I5	
3,35	I72,25±0,I5	I72,25±0,I5	
3,85	I72,04± 0,I5	I72,04±0,I5	
5,30	I7I,63± 0,I5	I7I,63±0,I5	
5,6	I70,0 ± 0,7	I70,3 ±0,7	
Reactor neutrons	I70,I ± 2,0	I70,4 ±2,0	23

x) The measurement error relative to E_k for uranium-238 fission induced by 1.9 MeV neutrons is given.

xx) Average values for given neutron energy.

TABLE 12

Average fragment kinetic energy for neutron-induced fission of neptunium-237

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
0,7	I75,48±0,I5	I75,48±0,I5	35[*)]
I,0	I75,38±0,I5	I75,38±0,I5	
I,3	I75,40±0,I5	I75,40±0,I5	
I,6	I75,42±0,I5	I75,42±0,I5	
2,I	I75,2I±0,I5	I75,2I±0,I5	
2,55	I75,23±0,I5	I75,23±0,I5	
3,8	I74,97±0,I5	I74,97±0,I5	
4,5	I74,52±0,I5	I74,52±0,I5	
5,4	I74,36±0,I5	I74,36±0,I5	
Reactor neutrons	I74,0 ±2,0	I74,3 ±2,0	23

*) The measurement error relative to E_k = 175.38 MeV for neptunium-237 fission induced by 1.0 MeV neutrons is given. The measurement error relative to the chosen standard E_k = 172.2 MeV for thermal-neutron-induced fission of uranium-235 is ±0.3 MeV. Relative to the californium standard, the error is ±0.7 MeV.

TABLE 13

Average fragment kinetic energy in neutron-induced fission of plutonium-235

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
Thermal	I77,7	I78,6	35
0,08	I77,67±0,I	I78,57±0,I	
0,I6	I77,79±0,I	I78,69±0,I	
0,28	I77,79±0,I	I78,69±0,I	
0,40	I77,65±0,I	I78,55±0,I	
0,50	I77,62±0,I	I78,52±0,I	
0,60	I77,63±0,I	I78,53±0,I	
0,72	I77,44±0,I	I78,34±0,I	
0,82	I77,46±0,I	I78,36±0,I	
0,9I	I77,48±0,I	I78,38±0,I	
I,0I	I77,40±0,I	I78,30±0,I	
I,II	I77,46±0,I	I78,36±0,I	
I,2I	I77,27±0,I	I78,I7±0,I	
I,3I	I77,23±0,I	I78,I3±0,I	
I,4I	I77,28±0,I	I78,I8±0,I	
I,5I	I77,28±0,I	I78,I8±0,I	
I,6I	I77,29±0,I	I78,I9±0,I	
I,72	I77,30±0,I	I78,20±0,I	
I,82	I77,I5±0,I	I78,05±0,I	
I,92	I77,20±0,I	I78,I0±0,I	
2,02	I77,I3±0,I	I78,03±0,I	
2,I2	I77,I0±0,I	I78,00±0,I	
2,22	I77,00±0,I	I77,90±0,I	
2,32	I77,00±0,I	I77,90±0,I	
2,52	I76,99±0,I	I77,89±0,I	
2,72	I76,98±0,I	I77,89±0,I	
2,92	I77,00±0,I	I77,90±0,I	
3,07	I76,85±0,I	I77,75±0,I	
3,20	I76,75±0,I	I77,65±0,I	
3,35	I76,70±0,I	I77,60±0,I	
3,50	I76,6I±0,I	I77,5I±0,I	
4,00	I76,22±0,I	I77,I2±0,I	
4,45	I76,I5±0,I	I75,90±0,I	
5,30	I75,00±0,I	I75,90±0,I	

The measurement error given is relative to the kinetic energy for thermal-neutron-induced fission of plutonium-239.

TABLE 14

Average fragment kinetic energy for neutron-induced fission of plutonium-240

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
0,85	I77,86±0,I5	I77,86±0,I5	37[x)]
I,03	I78,I4±0,I5	I78,I4±0,I5	
I,23	I78,49±0,I5	I78,49±0,I5	
I,33	I78,24±0,I5	I78,24±0,I5	
I,44	I78,II±0,I5	I78,II±0,I5	
I,54	I78,I3±0,I5	I78,I3±0,I5	
I,59	I78,I4±0,I5	I78,I4±0,I5	
I,64	I78,00±0,I5	I78,00±0,I5	
I,69	I78,I5±0,I5	I78,I5±0,I5	
I,74	I78,20±0,I5	I78,20±0,I5	
I,80	I78,I4±0,I5	I78,I4±0,I5	
I,85	I78,I5±0,I5	I78,I5±0,I5	
I,94	I78,03±0,I5	I78,03±0,I5	
2,15	I77,97±0,I5	I77,97±0,I5	
2,35	I77,59±0,I5	I77,59±0,I5	
2,55	I77,68±0,I5	I77,68±0,I5	
2,75	I77,7I±0,20	I77,7I±0,20	
2,80	I77,64±0,20	I77,64±0,20	
2,95	I77,76±0,20	I77,76±0,20	
3,I5	I77,07±0,30	I77,07±0,30	
3,30	I76,70±0,30	I76,70±0,30	
4,90	I76,79±0,20	I76,79±0,20	

x) The measurement error given is relative to E_k = 178.2 MeV for plutonium-240 fission induced by 1.3 MeV neutrons. The measurement error relative to the standard E_k = 172.2 MeV for thermal-neutron-induced fission of uranium-235 is ±0.5 MeV. Relative to the californium standard, the error is ±0.9 MeV.

TABLE 15

Average fragment kinetic energy in the neutron-induced fission of plutonium-241

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
Thermal	I79,6	I79,0	37*)
0,28	I79,27±0,I	I78,67±0,I	
0,40	I79,42±0,I	I78,82±0,I	
0,55	I79,24±0,I	I78,64±0,I	
0,70	I79,I7±0,I	I78,57±0,I	
0,85	I79,29±0,I	I78,69±0,I	
I,00	I79,24±0,I	I78,64±0,I	
I,33	I79,I8±0,I	I78,58±0,I	
I,54	I79,05±0,I	I78,45±0,I	
I,74	I79,I0±0,I	I78,50±0,I	
I,94	I78,78±0,I	I78,I8±0,I	
2,I5	I78,99±0,I	I78,39±0,I	
2,36	I78,87±0,I	I78,27±0,I	
2,56	I78,82±0,I	I78,22±0,I	
2,74	I78,64±0,I	I78,04±0,I	
5,00	I78,39±0,I	I77,79±0,I	

*) The measurement error given is relative to the fragment kinetic energy for the thermal-neutron-induced fission of plutonium-241.

TABLE 16

Average fragment kinetic energy for neutron-induced fission of plutonium-242

E_n (MeV)	E_K (MeV)	Referred to common standard	Reference
0,7	I78,76±0,I5	I78,76±0,I5	24*)
0,92	I79,05±0,I5	I79,05±0,I5	
I,I2	I78,65±0,I5	I78,65±0,I5	
I,45	I78,50±0,I5	I78,50±0,I5	
I,73	I78,65±0,I5	I78,65±0,I5	
I,94	I78,60±0,I5	I78,60±0,I5	
2,I4	I78,60±0,I5	I78,60±0,I5	
2,37	I78,79±0,I5	I78,79±0,I5	
2,56	I78,50±0,I5	I78,50±0,I5	
2,69	I78,29±0,I5	I78,29±0,I5	
2,85	I78,55±0,I5	I78,55±0,I5	
2,94	I78,35±0,I5	I78,35±0,I5	
3,I5	I78,37±0,I5	I78,35±0,I5	
3,37	I78,20±0,I5	I78,20±0,I5	
3,95	I78,33±0,I5	I78,33±0,I5	
4,40	I77,04±0,I5	I77,04±0,I5	
4,90	I77,25±0,I5	I77,25±0,I5	

*) The quoted measurement error is relative to E_k for plutonium-242 fission induced by 1.1 MeV neutrons. Relative to the californium standard, the error is ±0.9 MeV.

TABLE 17

Average fragment kinetic energy for radium-226 fission in the (^3He,pf) reaction

E_{exc} (MeV)	E_k (MeV)	Referred to common standard	Reference
7,80	I57,3±I,0	I57,6±I,0	30
8,90	I59,0±0,75	I59,3±0,75	
9,90	I58,5±0,80	I58,8±0,70	
I0,90	I57,I±0,50	I57,4±0,50	
II,90	I57,3±0,35	I57,6±0,35	
9,90	I47,2±2,0	I47,5±2,0	
I0,90	I50,I±I,0	I50,4±I,0	
II,90	I49,9±0,50	I50,2±0,50	

TABLE 18

Average fragment kinetic energy for radium-226 fission in the (^3He,tf) reaction

E_{exc} (MeV)	E_k (MeV)	Referred to common standard	Reference
7,I0	I58,7±0,5	I59,0±0,5	30
8,00	I59,0±0,45	I59,3±0,45	
9,00	I58,7±0,30	I59,0±0,30	
I0,I	I57,8±0,35	I58,I±0,35	
II,I	I57,5±0,35	I57,8±0,35	
I2,I	I57,0±0,40	I57,3±0,40	
I3,I	I55,4±0,40	I55,7±0,40	
I4,I	I54,0±0,55	I54,0±0,55	
9,0	I50,0±I,6	I50,3±I,6	
I0,I	I49,8±I,0	I50,I±I,0	
II,I	I49,8±0,75	I50,I±0,75	
I2,I	I48,8±0,50	I49,I±0,50	
I3,I	I49,8±0,30	I50,I±0,30	
I4,I	I50,5±I,0	I50,8±I,0	

TABLE 19

Average fragment kinetic energies for charged-particle-induced fission

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MeV)	Accepted standard E_k	$E_K \pm \Delta$ (MeV)	Reference
^{141}Pr	^{16}O	I66,0	III,2±6,6	I85,7	III,8±6,6	42
^{159}Tb	^{12}C	I25,0	II7,5±4,8		II8,I±4,8	42
^{159}Tb	^{16}O	I66,0	I24,3±4,4		I24,9±4,4	42
^{165}Ho	^{12}C	I25,0	I22,0±5,2		I22,6±5,2	42
^{169}Tm	^{12}C	I25,0	I22,3±4,2		I22,9±4,2	42
^{169}Tm	^{16}O	I66,0	I32,2±4,0		I32,8±4,0	42
^{170}Er	^{16}O	I66,0	I27,0±5,0	I86,0	I27,3±5,0	43
		I5I,0	I28,0±5,0		I28,3±5,0	
		I36,0	I24,0±5,0		I24,3±5,0	43
		I20,0	I24,0±5,0		I24,3±5,0	
^{nat}Yb	p	I000,0	I06,0±3,0	I86,0	I06,3±3,0	44
^{174}Yb	^{12}C	I25,0	I29,0±5,0		I29,3±5,0	43
^{174}Yb	^{12}C	I09,0	I27,0±5,0		I27,3±5,0	43
^{175}Lu	^{12}C	I25,0	I3I,4±4,0	I85,7	I32,0±4,0	42
^{175}Lu	^{16}O	I66,0	I37,8±3,9	I85,7	I38,4±3,9	42
^{182}W	^{4}He	I20,0	I28,0±4,0	I86, 0	I28,3±4,0	43
^{182}W	^{4}He	I00,0	I25,0±4,0		I25,3±4,0	43
^{nat}W	p	I000,0	III,5±3,0		III,8±3,0	44
^{182}W	^{16}O	I65,0	I47,0±4,0	I86,0	I47,3±4,0	43
		I44,0	I46,0±4,0		I46,3±4,0	
		I27,0	I46,0±4,0		I46,3±4,0	
		II5,0	I44,0±4,0		I44,3±4,0	
		I02,0	I44,0±4,0		I44,3±4,0	
^{197}Au	p	I000,0	I26,5±3,0		I26,8±3,0	44
^{197}Au	^{3}He	25,5	I40,3±2,0	I85,7	I40,9±2,0	45
^{197}Au	^{4}He	43,0	I38,0±4,0		I38,6±4,0	46
^{197}Au	^{4}He	70,0	I42,I±4,0	I85,7	I42,7±4,0	43
^{197}Au	^{4}He	I20,0	I43,0±4,0	I86,0	I43,3±4,0	43
		I20,0	I43,0±4,0		I43,3±4,0	
		I00,0	I4I,0±4,0		I4I,3±4,0	
		80,0	I40,0±4,0		I40,3±4,0	
		80,0	I40,0±4,0		I40,3±4,0	

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MeV)	Accepted standard E_k	$E_K \pm \Delta$ (MeV)	Reference
^{197}Au	^{4}He	70,0	I42,0±4,0	I86,0	I42,3±4,0	43
		60,0	I38,0±4,0		I38,3±4,0	43
^{197}Au	^{12}C	I25,0	I47,2±3,6	I85,7	I47,8±3,6	42
^{197}Au	^{16}O	I66,0	I55,6±3,4		I56,2±3,4	
^{198}Pt	^{12}C	77,2	I5I,6±2,0	I86,0	I5I,9±2,0	47
^{nat}Tl	^{3}He	25,5	I4I,7±2,0	I8I,9	I46,I±2,0	45
^{nat}Tl	^{4}He	43,0	I43,0±5,0	I85,7	I43,6±5,0	46
^{206}Pb	^{3}He	25,5	I45,4±2,0	I8I,9	I49,8±2,0	45
^{206}Pb	^{4}He	39,8	I43,8±5,0	I86,0	I4I,I±5,0	47
		50,9	I45,I±3,0		I45,4±3,0	
		63,8	I47,0±3,0		I47,3±3,0	
^{nat}Pb	^{4}He	43,0	I46,0±5,0	I85,7	I46,6±5,0	46
^{209}Bi	^{2}H	2I,5	I43,0±5,0	I85,7	I43,6±5,0	46
^{209}Bi	p	27,0	I42,9±2,0	I86,0	I43,2±2,0	
		39,3	I43,7±2,0	I86,0	I44,0±2,0	
		52,7	I45,0±2,0	I86,0	I45,3±2,0	
		36,I	I48,8	I86,0	I49,I	48
		I000,0	I37,2±2,0	I86,0	I37,5±2,0	49
		2900,0	I33,0±2,0		I33,3±2,0	49
^{209}Bi	^{3}He	22,I	I46,5±2,0	I8I,9	I50,9±2,0	45
		25,5	I47,3±2,0		I5I,7±2,0	
^{209}Bi	^{4}He	42,0	I50,0±3,0	I85,7	I50,6±3,0	50
		43,0	I48,0±4,0	I85,7	I48,6±4,0	46
		I20,0	I48,0±4,0	I86,0	I48,3±4,0	43
		I20,0	I52,0±4,0		I52,3±4,0	
		I00,0	I47,0±4,0		I47,3±4,0	
		I00,0	I50,0±4,0		I50,3±4,0	
		80,0	I48,0±4,0		I48,3±4,0	
		80,0	I48,0±4,0		I48,3±4,0	
		65,0	I50,0±4,0		I50,3±4,0	
		60,0	I47,0±4,0		I47,3±4,0	
		40,0	I46,0±4,0		I46,3±4,0	
^{209}Bi	^{12}C	I25,0	I58,7±3,0	I85,7	I59,3±3,0	42
^{209}Bi	^{16}O	I66,0	I66,3±3,0		I66,9±3,0	
^{226}Ra	^{2}H	9,8	I55,8±2,0	I8I,9	I60,2±2,0	45

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MeV)	Accepted standard E_K	$E_K \pm \Delta$ (MeV)	Reference
^{226}Ra	p	I3,0	I56,I	I86,0	I56,4	5I
		9,0	I58,0$^{x)}$	I86,0	I58,3$^{x)}$	52
		II,0	I56,0$^{x)}$		I56,3$^{x)}$	
		I3,0	I54,0$^{x)}$		I54,3$^{x)}$	
		I3,0	I54,8$^{x)}$	I86,0	I55,I$^{x)}$	53
		I6,0	I53,2$^{x)}$		I53,5$^{x)}$	
^{226}Ra	d	I6,0	I54,5$^{x)}$		I54,8$^{x)}$	
		I9,0	I54,5$^{x)}$		I54,8$^{x)}$	
^{226}Ra	^3He	23,5				
^{226}Ra	(^3He,pf)	E_{exc}				
		7,80	I57,3±I,0	I86,0	I57,6±I,0	54
		8,90	I59,0±0,75		I59,3±0,75	
		9,90	I58,5±0,70		I58,8±0,70	
		I0,90	I57,I±0,50		I57,4±0,50	
		II,90	I57,3±0,35		I57,7±0,35	
		9,90	I47,2±2,0		I47,5±2,0	
		I0,90	I50,I±I,0		I50,4±I,0	
		II,90	I49,9±0,50		I50,2±0,50	
^{226}Ra	(^3He,tf)	E_{exc}				
		7,I	I58,7±0,50	I86,0	I59,0±0,50	54
		8,0	I59,0±0,45		I59,3±0,45	
		9,0	I58,7±0,30		I59,0±0,30	
		I0,I	I57,8±0,35		I58,I±0,35	
		II,I	I57,5±0,35		I57,8±0,35	
		I2,I	I57,0±0,40		I57,3±0,40	
		I3,I	I55,4±0,40		I55,7±0,40	
		I4,I	I54,0±0,55		I54,3±0,55	
		9,0	I50,0±I,6		I50,3±I,6	
		I0,I	I49,8±I,0		I50,I±I,0	
		II,I	I49,8±0,75		I50,I±0,75	
		I2,I	I48,8±0,50		I49,I±0,50	
		I3,I	I49,8±0,30		I50,I±0,30	
		I4,I	I50,5±I,0		I50,8±I,0	

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MeV)	Accepted standard E_K	$E_K \pm \Delta$ (MeV)	Reference
^{226}Ra	^{2}H	II,7	I54,9±2,0	I8I,9	I59,3±2,0	45
		I4,0	I54,9±2,0		I59,3±2,0	
^{226}Ra	^{3}He	20,9	I57,7±2,0	I8I,9	I62,I±2,0	45
		23,9	I58,9±2,0		I63,3±2,0	
		23,4	I58,9±I,6		I63,3±I,6	
^{226}Ra	^{4}He	20,9	I57,7±I,6		I62,I±I,6	
		22,I	I59,7±2,0		I64,I±2,0	
		27,I	I60,3±2,0		I64,7±2,0	
		30,8	I65,0±4,0	I8I,9	I69,4±4,0	50
		38,7	I65,0±4,0		I69,4±4,0	
^{230}Th	H	6,8	I62,4±2,0	I8I,9	I66,8±2,0	45
		8,0	I62,6±2,0		I67,0±2,0	
^{230}Th	^{2}H	I2,0	I66,3±2,0	I85,7	I66,9±2,0 xx)	55
		I4,0	I67,3±2,0	I85,7	I67,9±2,00 xx)	55
		I4,0	I65,0±I,4	I85,7	I65,6±I,4	57
^{230}Th	^{4}He	25,7	I67,5±2,0	I85,7	I68,I±2,0 xx)	45
		29,5	I66,0±2,0		I66,6±2,0	
		25,7	I69,6±2,0	I85,7	I70,2±2,0	58
		29,5	I66,0±2,0		I66,6±2,0	
^{232}Th	^{2}H	I3,2	I59,0±3,0	I65,0	I66,2±3,0	56
^{232}Th	H	I3,0	I64,45±I,4	I86,5	I64,25±I,4	59
		20,0	I64,22±I,4		I64,02±I,4	
		27,0	I64,00±I,4		I63,80±I,4	
		35,0	I67,77±I,4		I67,57±I,4	
		40,0	I60,00±I,4		I69,80±I,4	
		45,0	I6I,22±I,4		I6I,02±I,4	
		53,0	I60,77±I,4		I60,57±I,4	
^{232}Th	^{4}He	2I,4	I72,5±3,2	I85,7	I73,I±3,2	60
		22,I	I70,5±3,5		I7I,I±3,5	
		25,7	I7I,3±3,2		I7I,9±3,2	
		33,0	I70,5±3,5		I7I,I±3,5	
		65,0	I68,0±4,5		I68,6±4,5	
		2I,8	I69,I±2,0	I65,7	I69,7±2,0 xx)	55
		25,7	I68,2±2,0		I68,8±2,0	
		29,5	I67,0±2,0		I67,6±2,0	

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MэV)	Accepted standard E_K	$E_K \pm \Delta$ (MэV)	Reference
^{232}Th	^{4}He	22,I	I7I,4±2,0	I85,7	I72,0±2,0	58
		25,7	I7I,4±2,0		I72,0±2,0	
		29,5	I70,7±2,0		I7I,3±2,0	
		26,4	I64,0±3,0	I65,0	I7I,2±3,0	56
		23,5	- 0,9±0,6		I7I,3±0,6	6I
		27,0	- I,9±0,5		I70,3±0,5	
		30,0	- 2,0±0,5		I70,2±0,5	
		33,0	- 2,2±0,5		I70,0±0,5	
		35,0	- 2,6±0,5		I69,6±0,5	
		38,0	- 2,8±0,5		I69,4±0,5	
		24,0	I68,67$^{x)}$	I86,5	I68,47$^{x)}$	62
		25,7	I68,00$^{x)}$		I67,80$^{x)}$	
		30,0	I67,33$^{x)}$		I67,I3$^{x)}$	
		35,0	I67,00$^{x)}$		I66,80$^{x)}$	
^{232}Th	^{12}C	I25,0	I76,3±8,8	I85,7	I76,9±8,8	42
^{232}Th	^{16}O	I66,0	I90,I±8,8		I90,7±8,8	42
^{232}Th	^{18}O	I02,5	I78,8$^{x)}$	I86,0	I79,I$^{x)}$	63
		I25,6	I78,2$^{x)}$		I78,5$^{x)}$	63
^{233}U	P	7,00	I73,50$^{x)}$	I86,0	I73,80$^{x)}$	64
		8,50	I72,75$^{x)}$		I73,05$^{x)}$	
		II,50	I7I,26$^{x)}$		I7I,56$^{x)}$	
		I0,00	I72,06$^{x)}$		I72,36$^{x)}$	
		I3,00	I70,94$^{x)}$		I7I,24$^{x)}$	
^{233}U	^{2}H	I4,00	I78,4±I,8	I86,0	I78,7±I,8	57
^{233}U	^{4}He	25,7	I74,9±2,0	I85,7	I75,5±2	55
		2I,8	I76,3±2,0		I76,9±2,0	
		29,5	I74,2±2,0		I74,8±2,0	
		25,5	I70,3±2,0	I8I,9	I74,7±2,0	45
		22,I	I75,5±2,0	I85,7	I76,I±2,0	58
		25,7	I74,6±2,0		I75,2±2,0	
		29,7	I73,9±2,0		I74,5±2,0	
^{235}U	^{2}H	I3,0	I72,I±2,0$^{x)}$	I86,0	I72,4±2,0$^{x)}$	65
^{235}U	P	8,0	I72,75$^{x)}$	I86,0	I73,05$^{x)}$	64
		8,80	I72,I9$^{x)}$		I72,49$^{x)}$	
		9,50	I72,I3$^{x)}$		I72,43$^{x)}$	

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MeV)	Accepted standard E_K	$E_K \pm \Delta$ (MeV)	Reference
^{235}U	p	I0,50	I71,88[x)]	I86,0	I72,I8[x)]	64
		II,50	I71,06[x)]		I71,36[x)]	
		I2,50	I70,76[x)]		I71,06[x)]	
		I3,00	I70,56[x)]		I70,86[x)]	
^{235}U	^{4}He	23,5	3,4±0,7		I75,6±0,7	6I
		27,0	2,5±0,7		I74,7±0,7	
		30,0	2,5±0,7		I74,7±0,7	
		35,0	I,3±0,7		I74,0±0,7	
		38,0	I,9±0,7		I74,I±0,7	
^{235}U	(γ,f)	25,9	I70,6±2,0	I86,0	I70,9±2,0	66
^{238}U	^{2}H	I3,0	I72,5±2,0[x)]	I86,0	I72,8±2,0[x)]	65
		I3,2	I67,0±3,0[x)]	I65,0	I74,2±3,0[x)]	56
^{238}U	p	8,00	I74,06[x)]	I86,0	I74,36[x)]	64
		8,50	I74,00[x)]		I74,30[x)]	
		9,00	I73,8I[x)]		I74,II[x)]	
		9,25	I73,83[x)]		I74,I3[x)]	
		9,50	I73,8I[x)]		I74,II[x)]	
		9,75	I73,83[x)]		I74,I3[x)]	
		I0,00	I73,69[x)]		I73,99[x)]	
		I0,25	I73,56[x)]		I73,86[x)]	
		I0,50	I73,50[x)]		I73,80[x)]	
		I0,75	I73,25[x)]		I73,55[x)]	
		II,00	I73,I3[x)]		I73,43[x)]	
		II,50	I72,94[x)]		I73,24[x)]	
		I2,00	I72,75[x)]		I73,05[x)]	
		I2,50	I72,38[x)]		I72,68[x)]	
		I3,00	I72,I9[x)]		I72,49[x)]	
		I000,0	I6I,0±4,0	I86,0	I6I,3±4,0	49
		2900,0	I62,0±2,0		I62,3±2,0	
^{238}U	^{4}He	25,7	I76,0±3,2	I85,7	I76,6±3,2	60
		33,0	I74,7±3,5		I75,3±3,5	
		65,0	I73,0±4,0		I73,6±4,0	
		27,8	I75,0±5,0	I8I,9	I79,4±5,0	67
		30,4	I75,0±5,0		I79,4±5,0	
		32,6	I75,0±5,0		I79,4±5,0	
		34,2	I76,0±5,0		I80,4±5,0	

Target nucleus	Particle	Particle energy (MeV)	$E_K \pm \Delta$ (MeV)	Accepted standard E_K	$E_K \pm \Delta$ (MeV)	Reference
^{238}U	^{4}He	35,6	I77,0±5,0		I8I,4±5,0	
		29,4	I73,0±4,0	I85,7	I73,6±4,0	50
		42,0	I7I,0±4,0		I7I,6±4,0	
		26,4	I76,0±3,0	I74,0	I8I,0±3,0	56
		2,4	$I79,5^{+I,5}_{-0,7}$	I86,0	$I79,8^{+I,5}_{-0,7}$	68
		27,0	5,6±0,7		I77,8±0,7	6I
		30,0	4,I±0,7		I76,3±0,7	
		35,0	4,0±0,7		I76,2±0,7	
		38,0	4,0±0,7		I76,2±0,7	
^{238}U	^{12}C	I25,0	I83,2±4,0	I85,7	I83,8±4,0	42
^{238}U	^{16}O	I66,0	I85,6±4,0		I86,2±4,0	
^{238}U	(γ,f)	25,0	I70,9±2,0	I86,0	I7I,2±2,0	66
		33,0	I70,0	I86,5	I69,8	69
^{237}Np	^{2}H	I3,0	I8I,3±0,2$^{x)}$	I86,0	I8I,6±0,2$^{x)}$	70
	(d,2n)		I82,9±0,25$^{x)}$		I83,2±0,25$^{x)}$	
		I3,0	I82,3±2,0$^{x)}$	I86,0	I82,6±2,0$^{x)}$	65
^{239}Pu	^{2}H	I3,0	I8I,0±2,0$^{x)}$	I86,0	I8I,3±2,0$^{x)}$	65
^{240}Pu	p	I3,0	I83,2±2,0$^{x)}$	I86,0	I83,5±2,0$^{x)}$	65
^{240}Pu	^{2}H	7,6	I76,2±3,0	I85,7	I76,8±3,0	57
		9,0	I78,0±2,0		I78,6±2,0	
		II,4	I78,5±I,0	I85,7	I79,I±I,0	57
		I4,0	I75,8±I,0		I76,4±I,0	
^{240}Pu	^{12}C	I25,0	I85,6±4,6	I85,7	I86,2±4,6	42
^{240}Pu	^{16}O	I66,0	I92,7±4,6	I85,7	I93,3±4,6	42
^{242}Pu	^{3}H	I7,0	I84,03±0,04	I86,0	I84,33±0,04	7I
^{242}Pu	(d,2n)	(s.f)	I78,I±2,0	I85,7	I78,7±2,0	57
^{242}Pu	^{2}H	I4,0	I79,2±I,4	I85,7	I79,8±I,4	57
^{241}Am	^{2}H	I5,0		I86,0		
	(d,pf)	E_{exc}				
		4,5	I8I,8±0,37		I82,I±0,37	7I
		5,4	I82,2±0,37		I82,5±0,37	
		5,8	I82,0±0,37		I82,3±0,37	
		6,4	I82,[illegible]±0,37		I82,8±0,37	
		6,8	I82,6±0,37		I82,9±0,37	
		7,4	I82,3±0,37		I82,6±0,37	
^{241}Am	(d,pf)	7,8	I82,0±0,37		I82,3±0,37	
		8,4	I82,0±0,37		I82,3±0,37	
		8,8	I8I,75±0,37		I82,05±0,37	
		9,4	I8I,3±0,37		I8I,6±0,37	
		9,8	I8I,2±0,37		I8I,5±0,37	
		I0,4	I80,8±0,37		I8I,I±0,37	
		I0,8	I80,4±0,37		I80,7±0,37	
		II,5	I80,2±0,37		I80,5±0,37	
^{246}Cm	^{18}O	93,7	I87,I$^{x)}$	I86,0	I87,4$^{x)}$	63
		I02,5	I88,7$^{x)}$		I89,0$^{x)}$	
		I05,2	I87,0$^{x)}$		I87,3$^{x)}$	
		I25,6	I85,9$^{x)}$		I86,2$^{x)}$	

x) No correction for neutron emission from the fragments has been introduced into the value of E_k.

xx) Time of flight.

REFERENCES

1. Milton S.C.D. and Fraser J.S. Canad. J.Phys. 1962,40,1626.
2. Milton S.C.D. and Fraser J.S. Bull.Am.Phys.Soc.,1963,8,370.
3. Stanley L. Whetstone, Jr. Phys.Rev.,1963, 131, 1232.
4. Schmitt H.W., Neiler J.N., Walter F.J. Phys.Rev., 1966, 141, 1146.
5. BARASHKOV, Yu.A., VASIL'EV, Yu.A., MASLOV, V.I., PAVLOVSKIJ, E.S., SARAEVA, M.K., SIDOROV, L.V., SURIN, V.M., TOROPOV, P.V., PETRZHAK, K.A., SHPAKOV, V.I., Yad. Fiz. 13 6 (1971) 1162.
6. Kaufman S.B., Steinberg E.P., Wilkins B.D. et al. Instr. and Methods 1974, 115, 47.
7. William E. Stein Phys.Rev., 1957, 108, 94.
8. Gunn S.R., Hicks H.G., Levy H.B., Stevenson P.C. Phys. Rev., 1957, 107, 1642.
9. Stevenson P.C., Hicks H.G., Armstrong J.C.,Jr. S.R.Gunn. Phys. Rev., 1960, 117, 186.
10. Whittehouse, W.J., Galbraith W. Phil.Mag., 1950, 41, 429.
11. KOVRIGIN, B.S., PETRZHAK, K.A., At. Ehnerg. 4 6 (1958) 547.
12. Kostovaya T.A. Proc. of the second United Nations. Intern. Confer. of the Peaseful Uses of Atomic Energy, Geneva, 1958, 15, 433.
13. Taraskar J., Melkonian E. Phys.Rev., 1971, C4, No.4, 1391.
14. Deruytter A.J., Wegener G. Proc. of a Symposium, Rochester IAEA-SM-174/35, 1974, v.II, 51.
15. D'YACHENKO, N.P., KABENIN, V.N., KOLOSOV, N.P., KUZ'MINOV, B.D., SERGACHEV, A.I., Yad. Fiz. 17 4 (1973) 696.
16. Smith A.B., Fields P.R., Friedman A. Phys.Rev., 1957, 106, 779.
17. OKOLOVICH, V.N., BOL'SHOV, V.I., GORDEEVA, L.D., SMIRENKIN, G.N., At. Ehnerg. 15 (1963) 419.
18. ALKHAZOV, I.D., KOSTOCHKIN, O.I., KOVALENKO, S.S., MALKIN, L.Z., PETRZHAK, K.A., SHPAKOV, V.I., Yad. Fiz. 11 (1970) 501.
19. Frances Pleasonton, Robert L. Ferguson, Franz Plasil and C.E.Bemis, Jr.Phys.Rev.,1973, C8, 1018.
20. Brandt R.B., Thompson S.G., Gatti R., Phillips L. Phys.Rev., 1963, 131, 2617.
21. Darleane C. Hoffman, Georg P.Ford, and John P.Balagna Phys.Rev., 1973, C7, 276.
22. Friedman A.M.,Meadows J.W., Smith A.B., Fields P.R., J.Milsted, J.Walen. Phys.Rev., 1963, 131, 1203.
23. Michael J.Bennet, N.E.Stein. Phys.Rev., 1967, 156, 1277.
24. VOROB'EVA, V.G., D'YACHENKO, N.P., KOLOSOV, N.P., KUZ'MINOV, B.D., SERGACHEV, A.I., Yad. Fiz. 19 5 (1974) 954.
25. Neiler J.N., Walter F.J. and Schmitt H.W. Phys.Rev., 149 (1966) 894.
26. BARANOV, I.A., KRIVOKHATSKIJ, A.S., ROMANOV, Yu.F., SKOVORODIN, N.V., Izv. Akad. Nauk SSSR, Ser. Fiz. 32 4 (1968) 693.

27. BORUKHOVICH, G.Z., PETROV, G.A., Yad. Fiz. 4 4 (1968) 791.
28. Ragaini R.C., E.K.Hulet, R.W.Lougheed J. Wild. Phys. Rev., 1974, C9, No.1, 399.
29. Pleasonton F. Phys.Rev., 1968, 174, 1500.
30. Konecny E., Specht H.J., J.Weber Proceedings of a Symposium, Rochester IAEA-SM-174/20, 1974, v.II, 3.
31. Blyumkina Yu.A., Bondarenko I.I., Kusnetsov V.F., Nesterov V.G., Okolovitch V.N., Smirenkin G.N., Usachev L.N. Nucl.Phys., 1964, 52, 648.
32. BOLDEMAN, J.W., WALSH, R.L., in: Nejtronnaya Fizika (Neutron Physics), Part 4 (1974) 121.
33. Ajitanand N.N., Boldeman J.W. Nucl.Phys., 1970,144,1.
34. Meadows J.W. Phys.Rev., 1969, 177, 4, 1817.
35. VOROB'EVA, V.G., D'YACHENKO, N.P., KUZ'MINOV, B.D., SERGACHEV, A.I., Institute of Physics and Power Engineering Preprint, FEI-367 (1973).
36. Holubarsch W., Pfeiffer E., Gönnenwein F. Nucl. Phys., 1971, A171, No.3, 631.
37. VOROB'EVA, V.G., D'YACHENKO, N.P., KUZ'MINOV, B.D., SERGACHEV, A.I., Yadernye Konstanty No. 15 (1974) 3.
38. Unik J.P., Gindler J.E., Glendenin L.E., Flynn K.F., Gorski A., Sjoblom R.K. Proceedings of a Symposium Rochester IAEA-SM-174/209, 1974, v. II, 19.
39. Bemis C.E. et al. Phys.Rev., 1977, C15, 705.
40. BASOVA, B.G., KOROSTYLEV, V.A., RABINOVICH, A.F., RYAZANOV, D.K., Voprosy atomnoj nauki i tekhniki, Yadernye Konstanty No. 24 (1977) 19.
41. D'YACHENKO, N.P., KUZ'MINOV, B.D., MITROFANOV, V.F., SERGACHEV, A.I., in: Nejtronnaya Fizika (Neutron Physics), Part 3 (1977) 167.
42. Viola V.E., Jr., Sikkeland T. Phys.Rev.,1963,v.130, 2044.
43. Phys. Rev., 1966, v. 142, p. 696. Aut: F.Plasil, D.S.Burnett, H.C.Britt, S.G.Thompson.
44. KOTOV, A.A., SEMENCHUK, G.G., ANDRONENKO, L.N., ANDRONENKO, M.N. et al., Yad. Fiz. 20 (1974) 467.
45. Britt H.C., Wegner H.E., Gursky J.S. Phys.Rev., 1963, v. 129, p. 2239.
46. Huizenga J.R., Vandenbosch R. Phys.Rev., 1962, v.127, p. 212.
47. Unik J.P., Cuninghame J.G., Croall I.F. Proceedings of a Symposium Vienna, IAEA-SM-122/58. 1969, p. 717.
48. Plasil F., Robert L. Ferguson, Pleasonton F., Schmitt H.W, Phys. Rev.,1973, v. C7, p. 1186.
49. KOTOV, A.A., SEMENCHUK, G.G., BOCHAGOV, B.A., GORSHKOV, B.L. et al., Yad. Fiz. 17 (1973) 950.
50. Unik J.P., Huizenga J.R. Phys.Rev., 1964, v.134, B90.
51. Konecny E., Schmitt HW.Phys.Rev., 1968, v. 172, p.1213.
52. Konecny E., Hornberg W.W. Schmitt H. Nucl.Phys., v. A139, p. 513, 1969.
53. Perry D.G., Fairhall A.W. Phys.Rev., 1971, v. C4, p.977.
54. Konecny E., Specht H.J.,Weber J. Proceedings of a Symposium, Rochester IAEA-SM-174/20, 1974, v. II, p.3.
55. Stanley L., Whetstone Jr. Phys.Rev., 1964, v.133, B 613.

56. BOCHAGOV, B.A., VASIL'EV, S.S., SEMENCHUK, G.G., SOLYAKIN, G.E., Yad. Fiz. 1 (1965) 461
57. Erkkila B.H., Leachman R.B. Nucl.Phys., 1968, v. A108, p. 689.
58. Britt H.C., Whetstone S.L. Phys.Rev., 1964, v.133, B603.
59. Croall I.F., Cuninghame J.G. Nucl.Phys.,1969, v. A125, p. 402
60. Burnett D.S. University of California Radiation Laboratory Report UCRL-11006. Oct., 1963.
61. OKOLOVICH. V.N.. PAVLOV, A.F., Yad. Fiz. 14 (1971) 514.
62. PAVLOV, A.F., OKOLOVICH, V.N., D'YACHENKO, P.P., KUZ'MINOV, B.D., Yad. Fiz. 17 (1973) 1143.
63. Ferguson R.L.Plasil F., Freiesleben H., Bemis C.E.Phys.Rev., 1973, v. C8, p. 1104.
64. Pleasonton F., Burnett S.C.,Schmitt H.W.Phys.Rev., 1973, v. C7, p. 2510.
65. Ferguson R.L., Plasil F., Alam G.D., Schmitt H.W. Nucl.Phys., 1971, v. A172, p. 33.
66. A.De Clercq, E.Jacobs, D.De Frenne, H.Thierens. Phys.Rev., 1976, v. C13, p. 1536.
67. Seki Massao. J.Phys.Soc.Japan., 1965, v. 20, p. 190.
68. Weber J., Specht H.J.,Konecny E., Heuneman D. Nucl.Phys., 1974, v. A221, p. 414.
69. Hogg G.R. Nucl.Phys., 1965, v. 72, p. 167.
70. Bacharach S.L., Hoeper P.S., Morrissey J.A., Temperley J.K. Phys.Rev., 1974, v. C10, p. 2636.
71. Weber J., Erdal R.B.,Gavron A., Wilhelmy J. Phys.Rev., 1976, v. C13, p. 189.