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EMPIRICAL SADDLE-POINT- AND GROUND-STATE-MASSSES
AS A PROBE OF THE DROPLET MODEL

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EMPIRICAL SADDLE-POINT- AND GROUND-STATE-MASSSES AS A PROBE OF THE DROPLET MODEL

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ABSTRACT

On the basis of a compilation of experimentally determined fission barriers a detailed analysis of the isospin dependence of the fissility parameter is presented and compared with the liquid drop and droplet model predictions. Shortcomings of the droplet model in the description of strongly deformed nuclei requiring a further refinement show up. There is evidence for surprisingly low fission barriers for light nuclei.

1. INTRODUCTION

Our knowledge about highly deformed nuclei is mostly due to experimentally determined fission barriers. The fission barriers are, beside the ground state masses and the nuclear radii, one of the main

sources of experimental information for the droplet properties of nuclei. The aim of this work is to give a survey of the experimentally known fission barriers and to compare these data with the predictions of the liquid drop and the droplet model.

As fig. 1 indicates, the droplet fission barrier E_f^{DM} does not include shell effects. Therefore, the predictions of the droplet model cannot be compared with the measured fission barrier E_f directly; shell corrections at the ground state (δU_{gs}) as well as at the fission barrier (δU_{sad}) have to be considered.

$$E_f = E_f^{DM} - \delta U_{gs} + \delta U_{sad} \quad (1)$$

In case of the ground state shell corrections we are in a rather good position, because the nuclear ground state masses of all nuclei considered here are known with high accuracy. The ground state shell correction is defined as the difference between the empirical ground state mass and the ground state mass as predicted by the droplet model:

$$\delta U_{gs} = M_{exp} - M^{DM} \quad (2)$$

Thus, δU_{gs} is the difference of the ground state mass of the nucleus in its actual shape and the droplet mass of the same nucleus in its spherical shape. In analogy to this definition, δU_{sad} is the difference of the height of the actual saddle point of the nucleus and the height of the droplet barrier. This adheres to the definition as given by Myers in ref. (My77). Consequently, when measured fission barriers are compared with the predictions of the droplet model, the model is introduced twice: for the prediction of the fission barrier E_f^{DM} and for the ground state mass M^{DM} .

The shell correction at the fission barrier, however, is poorly known experimentally. On the other hand, there are qualitative arguments

(StN77) that the shell corrections for highly deformed nuclei, due to their loss of symmetry, are expected to be generally smaller than for spherical nuclei.

If the shell effect at the barrier δU_{sad} is expressed by relations (1) and (2), only empirically known masses and fission barriers as well as predictions of the droplet model enter in the expression:

$$\delta U_{\text{sad}} = E_f - E_f^{\text{DM}} + M_{\text{exp}} - M^{\text{DM}} \quad (3)$$

Thus, it may be justified to use the behaviour of this quantity as a probe of the droplet model: the shell effect at the barrier is expected to show only local structures. Any general trend should be included in the droplet model.

2. COMPILATION OF EMPIRICAL FISSION BARRIERS

In table 1, a compilation of empirical fission barriers is given. If both maxima of the double humped fission barriers E_A and E_B are determined, the data are given in table 2. In order to give a survey of the nuclei listed in these tables, they are shown in a chart of the nuclides in fig. 2. Fission barriers, derived from spontaneous fission half lives are not included in this compilation.

3. COMPARISON OF EMPIRICAL FISSION BARRIERS WITH PREDICTIONS OF THE DROPLET MODEL

In fig. 3 and 4, three quantities are plotted:

1. the sum of the empirical fission barrier and the ground state

shell correction as obtained from equ. (2),

2. the droplet fission barrier E_f^{DM} and

3. the empirical ground state shell correction $\delta U_{\text{gs}} = M^{\text{exp}} - M^{\text{DM}}$.

The difference between the quantities 1 and 2 should represent the shell correction at the fission barrier, which is expected to show only local structures. This quantity, however, clearly shows a general trend: In all cases it increases with increasing neutron number. The droplet model obviously fails to reproduce the behaviour of the fission barrier as a function of neutron excess.

4. DISCUSSION

In the frame of the liquid drop model (MyS67), the fissility parameter is given as the ratio of the Coulomb energy $E_c^{(0)}$ and twice the surface energy $E_s^{(0)}$ of a spherical nucleus:

$$X = \frac{E_c^{(0)}}{2 E_s^{(0)}} = \frac{Z^2}{A} \frac{a_c}{2 a_s} \frac{1}{1 - \chi} \quad (4)$$

The liquid drop model describes the ratio of the fission barrier E_f and the Coulomb energy of a spherical nucleus $E_c^{(0)}$ as a universal function of the fissility parameter x :

$$E_f / E_c^{(0)} = f(x) \quad (5)$$

Hence in the liquid drop model the fission barrier is defined by three parameters:

1. the Coulomb energy parameter a_c ,
2. the surface energy parameter a_s and
3. the parameter χ , describing the dependence of the fission barrier on the charge asymmetry parameter $I = (N - Z) / A$.

The Coulomb term a_c can be expressed by the nuclear radius constant r_0 :

$$a_c = 3/5 e^2/r_0 \quad (6)$$

As r_0 is experimentally known (i. e. by electron scattering) with good accuracy, the liquid drop fission barrier depends essentially only on two parameters, a_s and κ . In this work the value $r_0 = 1.18$ fm was used, except in table 3.

With the knowledge of r_0 , equation (5) as given by the liquid drop model of ref. (MyS67) can be further evaluated by the following approximative analytical expression for $x < 0.9$:

$$E_f = 0.7322 \frac{Z^2}{A^{1/3}} 10^6 \quad (7)$$

with

$$u = 0.368 - 5.057 x + 8.93 x^2 - 8.71 x^3$$

As proposed by Pauli and Ledergerber (Pal71) we compare in fig. 5 all measured fission barriers with the liquid drop model, by plotting the reduced fissility parameter defined as

$$\zeta = \frac{1}{x} \frac{Z^2}{A} \quad (8)$$

as a function of 1^2 . In the liquid drop model ζ can be expressed by:

$$\zeta = \frac{2}{x} \frac{a_s}{a_c} (1 - x \mid^2) \quad (9)$$

The three straight lines shown in fig. 5 represent different parametrizations of the liquid drop model as given in table 3.

For the experimentally determined fission barriers corrected for the ground state shell effect the corresponding reduced fissility parameters have been calculated by use of relations (7) and (8). In case of a double humped fission barrier, the maximum value was used.

Theoretically, the shell effect at the barrier δU_{sad} is expected to be of the order of 1 MeV or smaller (Mo79), that means of the same order of magnitude as the experimental uncertainties of most fission barriers and has been neglected.

It would be useful to include the droplet model in the same type of representation. Unfortunately, in this model additional terms depend on the deformation. Consequently, a reduced fissility parameter of the droplet model cannot be described as a function of 1^2 only. If, however, the reduced fissility parameter is calculated from the fission barriers predicted by the droplet model in the same way as from the experimental barriers i.e. by using relations (7) and (8) (fig. 6), it seems to be justified to represent the droplet model by an approximating function in fig 5.

Due to the large scatter of the data points in fig. 5 it is difficult to decide which of the various parametrizations or models should be favoured. But there is a striking effect: for the neutron deficient nuclei, the parameter ζ decreases dramatically in contrast to the predictions. In order to investigate this effect in more detail, the left part of fig. 5 is shown in fig. 7 identifying the fissioning nuclei. Obviously, the decrease of the reduced fissility parameter goes in line with a decreasing mass. For the elements lighter than Hg, some experimental barriers were measured at high angular momenta and analysed by use of the rotating liquid drop model. Others were determined with proton induced fission, where precompound processes have to be included into the analysis. Therefore the uncertainties of these barriers may be relatively high. However, the systematic decrease of ζ may be a hint that the basic approximation of the liquid drop or droplet model cannot be applied to these nuclei which are predicted to have a highly deformed dumbbell like shape at the saddle point. Proximity interactions between the oscillating nuclei may reduce the energy for this configuration considerably. It is interesting to note that the "Yukawa-plus-

-exponential" model of Krappe et al. (KrN79) which includes a proximity like force predicts appreciably lower fission barriers than the traditional liquid drop model (MyS67) for the lightest nuclei shown in fig. 7.

In fig. 8, only the most recent data for $A > 180$ are shown. By this restriction the scatter is reduced considerably. Obviously the liquid drop model of Myers and Swiatecki (MyS67) is able to reproduce the fission barriers for these nuclei fairly well.

However, the data seem to indicate that the asymmetry parameter κ varies with I^2 , thus a parabola with a curvature similar to the droplet model may describe the effective fissility parameter in fig. 8 in a more adequate way than a straight line. The droplet model shows the same shortcoming of the isospin dependence as discussed previously in connection with figs. 3 and 4.

For practical use it may be helpful to approximate the fissility parameter as deduced from the data shown in fig. 8 by the following empirical formula:

$$X = \frac{Z^2}{A^{49.22} (1 - 0.3803 I^2 - 20.489 I^4)}$$

The appropriate empirical liquid drop fission barriers are obtained by means of relation (7).

5. CONSEQUENCES FOR THE DROPLET MODEL

The analysis of this work revealed that the droplet model does not reproduce the behaviour of the fission barrier as a function of neutron excess. Furthermore a drastic deviation for lighter nuclei showed up.

In order to improve the agreement of the droplet model with the fission barrier data, a redetermination of the model parameters was attempted. It turned out that a consistent description of the isospin dependence of ground state- and saddle point masses which are both involved in our analysis is not possible within the framework of the present droplet model. This finding indicates a shortcoming of the droplet model in the description of strongly deformed nuclei which calls for a basic refinement.

Compared with the liquid drop model the droplet model includes some indispensable fundamental extensions as e.g. the neutron skin. Therefore it seems unsatisfactory to us to return to the liquid drop model because of a better quantitative agreement with some selected data. The need for the consideration of the neutron skin clearly shows up in the description of nuclear charge radii. Fig. 10 shows a comparison between experimentally determined average slope of the nuclear charge radii for several isotopic sequences corrected for deformation effects and the predictions of the liquid drop and the droplet model. Obviously the droplet model describes the data very well whereas the liquid drop model is off by a factor of two.

6. CONCLUSION

Recently, the knowledge about the fission barriers has enlarged considerably. For some elements, the fission barriers are now available over a long range of isotopes. As this work shows, especially the knowledge about the dependence of the fission barriers on the neutron excess has now improved appreciably. Our analysis calls for a refinement of the droplet model in the description of strongly deformed nuclei. Furthermore there is evidence for a dramatic decrease of the effective fissility parameter for light nuclei.

We are indebted to W. D. Myers for providing us with his computer code for calculating droplet properties of nuclei.

TABLE 1

Compilation of experimentally determined fission barriers derived from measured fission cross sections and evaporation residue cross sections. References given in the forth column indicate the origin of measured data included in the analysis. Remarks are listed at the end of table 2.

Nucleus	Reaction	E_f (MeV)	Data	Ref.	Rem.
^{97}Rh	($^{35}\text{Cl}, f$ and ev. res.)	≥ 25.9	(BIB76)	(BeB77b) 1	
^{99}Ag	(p, f)	29 ± 1		(Ana79) 1	
^{109}Cd		34.0		(MøN80) 2	
^{127}La	($^{20}\text{Ne}, f$ and ev. res.)	20.4 ± 2.4	(PIF74)	(BeB77b) 1	
^{129}La	(p, f)	23 ± 2		(Ana79) 1	
^{149}Eu	($^{16}\text{O}, f$)	32.5 ± 2		(Si64) 1	
^{149}Tb	($^{40}\text{Ar}, f$ and ev. res.)	19.5 ± 1.6	(BrE76)	(BeB77a) 1	
^{152}Tb	(p, f)	29 ± 1		(Ana79) 1	
^{153}Tb	($^{20}\text{Ne}, f$ and ev. res./ $^{12}\text{C}, f$ and ev. res.)	28.5 ± 1.7		(PIF80) 1	
^{160}Dy		27.4		(MøN80) 2	
^{151}Ho	($^{35}\text{Cl}, f$ and ev. res.)	16.2 ± 1.7	(BIB76)	(BeB77b) 1	
^{157}Ho	($^{16}\text{O}, f$)	26.5 ± 2		(Si64) 1	

Nucleus	Reaction	E_f (MeV)	Data	Ref. Rem.
^{173}Lu	$(^4\text{He}, f)$	28.7 ± 2.5		(RaC67)
^{173}Lu		27.3		(Ha71) 2
^{173}Lu	$(^4\text{He}, f)$	28.0 ± 1	(RaC67)	(NoT72)
^{173}Lu	$(^4\text{He}, f)$	27.1		(IgI75)
^{173}Lu	$(^4\text{He}, f)$	31.5		(IgI80)
^{175}Ta	$(^{16}\text{O}, f)$	25.1 ± 2		(Si64) 1
^{179}Ta	$(^4\text{He}, f)$	27.5 ± 2.5		(RaC67)
^{179}Ta		26.2		(Ha71) 2
^{179}Ta	$(^4\text{He}, f)$	26.1 ± 1	(RaC67)	(NoT72)
^{179}Ta	$(^4\text{He}, f)$	25.4		(IgI75)
^{179}Ta	$(^4\text{He}, f)$	29.2		(IgI80)
^{178}W	$(^{19}\text{F}, f)$	23.0 ± 3.5		(SiC71) 1
^{179}W	$(^{14}\text{N}, f)$	25.2 ± 3.5		(SiC71) 1
^{180}W	$(^{11}\text{B}, f)$	28.7 ± 3.5		(SiC71) 1
^{180}W	$(^4\text{He}, f)$	23.9		(IgI75)
^{181}W	$(^4\text{He}, f)$	23.7		(IgI75)
^{182}W	$(^4\text{He}, f)$	24.2		(IgI75)
^{182}W	$(^4\text{He}, f)$	27.1		(IgI80)
^{184}W	$(^4\text{He}, f)$	24.9		(IgI75)
^{181}Re	$(^{12}\text{C}, f)$	24.0 ± 2		(Si64) 1
^{181}Re	$(^{16}\text{O}, f)$	23.9 ± 2		(Si64) 1
^{181}Re	$(^{22}\text{Ne}, f)$	24.3 ± 2		(Si64) 1
^{181}Re	$(^{12}\text{C}, f)$	25.0 ± 3.5	(Si64)	(SiC71) 1
^{185}Re	$(^4\text{He}, f)$	24.0 ± 1	(Kh66)	(NoT72)

Nucleus	Reaction	E_f (MeV)	Data	Ref. Rem.
^{185}Re	$(^4\text{He}, f)$	24.0		(IgI75)
^{185}Re	$(^4\text{He}, f)$	26.4		(IgI80)
^{176}Os	$(^{35}\text{Cl}, f \text{ and ev. res.})$	11.6 ± 1.8	(BiB76)	(BeB77b) 1
^{186}Os	$(^{16}\text{O}, f)$	24.2 ± 2		(Si64) 1
^{186}Os	$(^{12}\text{C}, f)$	25.7 ± 3.5		(SiC71) 1
^{186}Os	$(^{11}\text{B}, f)$	26.0 ± 3.5		(SiC71) 1
^{186}Os		22.5		(Ha71) 2
^{186}Os	$(^4\text{He}, f)$	23.4 ± 1	(NoG68)	(NoT72)
^{186}Os	$(^4\text{He}, f)$	22.1		(IgI75)
^{186}Os	$(^{12}\text{C}, f)$	22.8		(DeF77) 1,3
^{186}Os	$(^{12}\text{C}, f)$	21.3		(DeF77) 1,4
^{186}Os	$(^4\text{He}, f)$	24.0		(IgI80)
^{187}Os		22.5		(Ha71) 2
^{187}Os	$(^4\text{He}, f)$	22.7 ± 1	(NoG68)	(NoT72)
^{187}Os	$(^4\text{He}, f)$	22.2		(IgI75)
^{187}Os	$(^4\text{He}, f)$	24.7		(IgI80)
^{188}Os		23.7		(Ha71) 2
^{188}Os	$(^4\text{He}, f)$	24.2 ± 1	(NoG68)	(NoT72)
^{188}Os	$(^4\text{He}, f)$	22.1		(IgI75)
^{188}Os	$(^4\text{He}, f)$	25.3		(IgI80)
^{190}Os	$(^4\text{He}, f)$	23.3		(IgI75)
^{190}Os	$(^4\text{He}, f)$	26.3		(IgI80)
^{185}Ir	$(^{16}\text{O}, f)$	20.4 ± 2		(Si64) 1
^{187}Ir	$(^{12}\text{C}, f)$	21.8 ± 3.5		(SiC71) 1
^{187}Ir	$(^{12}\text{C}, f)$	20.1		(DeF77) 1,3
^{187}Ir	$(^{12}\text{C}, f)$	18.3		(DeF77) 1,4

Nucleus	Reaction	E_f (MeV)	Data	Ref. Rem.
189Ir	($^4\text{He}, f$)	22.4 $\pm$ 2.5	(RaC67)	
189Ir		21.7	(Ha71)	2
189Ir	($^4\text{He}, f$)	22.6 $\pm$ 1	(RaC67)	
189Ir	($^4\text{He}, f$)	19.7	(IgI75)	
189Ir	($^4\text{He}, f$)	22.1	(IgI80)	
191Ir	($^4\text{He}, f$)	23.6 $\pm$ 2.5	(RaC67)	
191Ir		22.8	(Ha71)	2
191Ir	($^4\text{He}, f$)	23.7 $\pm$ 1	(RaC67)	
191Ir	($^4\text{He}, f$)	20.6	(IgI75)	
191Ir	($^4\text{He}, f$)	23.4	(IgI80)	
190Pt	($^{16}\text{O}, f$)	19.8 $\pm$ 2	(Si64)	1
192Pt	($^4\text{He}, f$)	19.2	(IgI75)	
192Pt	($^4\text{He}, f$)	22.1 $\pm$ 0.8	(IgI80)	
193Pt	($^4\text{He}, f$)	20.0	(IgI75)	
193Pt	($^4\text{He}, f$)	23.8 $\pm$ 0.6	(IgI80)	
194Pt	($^4\text{He}, f$)	20.1	(IgI75)	
194Pt	($^4\text{He}, f$)	23.8 $\pm$ 0.6	(IgI80)	
196Pt	($^4\text{He}, f$)	22.5	(IgI75)	
196Pt	($^4\text{He}, f$)	25.6 $\pm$ 0.6	(IgI80)	
191Au	($^{16}\text{O}, f$)	18.4 $\pm$ 2	(Si64)	1
195Au	($^4\text{He}, f$)	18.6	(IgI75)	
195Au	($^4\text{He}, f$)	21.6 $\pm$ 0.8	(IgI80)	
197Au	($^4\text{He}, f$)	20.6	(IgI75)	
197Au	($^4\text{He}, f$)	24.7 $\pm$ 0.7	(IgI80)	
182Hg	($^{86}\text{Kr}, xn$)	9.0	(ReG75)	1

Nucleus	Reaction	E_f (MeV)	Data	Ref. Rem.
186Hg	($^{86}\text{Kr}, xn$)	11.5	(ReG79)	1
192Hg	($^{86}\text{Kr}, xn$)	15.7	(ReG79)	1
194Hg	($^{12}\text{C}, f$)	19.4 $\pm$ 3.5	(SiC71)	1
194Hg	($^{12}\text{C}, f$)	17.5	(DeF77)	1,3
194Hg	($^{12}\text{C}, f$)	16.5	(DeF77)	1,4
196Hg	($^4\text{He}, f$)	18.7	(IgI75)	
196Hg	($^4\text{He}, f$)	20.7 $\pm$ 0.8	(IgI80)	
198Hg	(p, f)	21.8 $\pm$ 0.7	(Kh66)	
198Hg	(p, f)	20.4 $\pm$ 1	(MoT72)	
198Hg	($^4\text{He}, f$)	19.5	(IgI75)	
198Hg	($^4\text{He}, f$)	21.8 $\pm$ 0.8	(IgI80)	
199Hg	($^4\text{He}, f$)	20.2	(IgI75)	
199Hg	($^4\text{He}, f$)	23.9 $\pm$ 0.7	(IgI80)	
200Hg	($^4\text{He}, f$)	21.2	(IgI75)	
200Hg	($^4\text{He}, f$)	24.5 $\pm$ 0.6	(IgI80)	
201Tl	($^4\text{He}, f$)	22.3 $\pm$ 0.5	(Kh66)	
201Tl	($^4\text{He}, f$)	19.9 $\pm$ 2.0	(HuC62)	
201Tl	($^4\text{He}, f$)	22.5 $\pm$ 1.5	(BuG64)	
201Tl	($^4\text{He}, f$)	22.3 $\pm$ 1	(NoT72)	
201Tl	($^4\text{He}, f$)	19.5	(IgI75)	
201Tl	($^4\text{He}, f$)	23.5	(IgI80)	
198Pb	($^{16}\text{O}, f$)	17.0 $\pm$ 2	(Si64)	1
204Pb	(e, e' f)	24.0 $\pm$ 1.5	(TuC76)	
206Pb	(e, e' f)	26.8 $\pm$ 1.5	(TuC76)	

Nucleus	Reaction	E_f (MeV)	Data	Ref.	Rem.
^{206}Pb	(e,e'f)	26.0 ± 0.5		(KeD77)	
^{207}Pb	(e,e'f)	26.9 ± 1.5		(TüC76)	
^{207}Pb	(e,e'f)	26.2 ± 0.5		(KeD77)	
^{208}Pb	(e,e'f)	27.6 ± 0.5		(DrP76)	
^{208}Pb	(e,e'f)	28.6 ± 1.5		(TüC76)	
^{208}Pb	(e,e'f)	27.6 ± 0.5		(KeD77)	
^{207}Bi	(p,f)	21.2 ± 0.5		(Kh66)	
^{207}Bi	(p,f)	21.9 ± 1	(Kh66)	(MoT72)	
^{207}Bi	(^4He ,f)	19.9		(IgI75)	
^{207}Bi	(^4He ,f)	23.3		(IgI80)	
^{209}Bi	(p,f)	22.6 ± 0.5		(Kh66)	
^{209}Bi	(p,f)	23.3 ± 1	(Kh66)	(MoT72)	
^{209}Bi	(e,e'f)	25.5 ± 1.5		(TüZ74)	
^{209}Bi	(^4He ,f)	21.9		(IgI75)	
^{209}Bi	(e,e'f)	23.4 ± 0.5		(DrP76)	
^{209}Bi	(e,e'f)	24.3 ± 1.5	(TüZ74)	(TüC76)	
^{209}Bi	(^4He ,f)	24.5		(IgI80)	
^{208}Po	(^4He ,f)	17.9		(IgI75)	
^{208}Po	(^4He ,f)	20.2		(IgI80)	
^{210}Po	(^4He ,f)	18.6 ± 2.0		(HuG62)	
^{210}Po	(^4He ,f)	20.4 ± 0.5		(Kh66)	
^{210}Po	(^4He ,f)	20.5 ± 1	(Kh66)	(MoT72)	
^{210}Po	(p,f)	21.4 ± 1	(Kh66)	(MoT72)	
^{210}Po	(^4He ,f)	19.1 ± 0.8	(Kh66)	(FrB73)	
^{210}Po	(^4He ,f)	19.2 ± 0.8		(ItK73)	
^{210}Po	(^4He ,f)	18.2		(IgI75)	
^{210}Po	(^4He ,f)	21.3		(IgI80)	
^{211}Po		21.5		(Ha71)	2

Nucleus	Reaction	E_f (MeV)	Data	Ref.	Rem.
^{211}Po	(^4He ,f)	19.7 ± 1	(Kh66)	(NoT72)	
^{211}Po	(^4He ,f)	17.2		(IgI75)	
^{211}Po	(^4He ,f)	20.5		(IgI80)	
^{212}Po	(^4He ,f)	18.6 ± 0.5		(Kh66)	
^{212}Po	(^4He ,f)	19.5 ± 1	(Kh66)	(NoT72)	
^{212}Po	(^4He ,f)	16.3		(IgI75)	
^{212}Po	(^4He ,f)	19.7		(IgI80)	
^{213}At	(^4He ,f)	15.8 ± 2.0		(HuG62)	
^{213}At	(^4He ,f)	16.8 ± 0.5		(Kh66)	
^{213}At	(^4He ,f)	17.0 ± 1	(Kh66)	(NoT72)	
^{213}At	(^4He ,f)	14.3		(IgI75)	
^{213}At	(^4He ,f)	17.2		(IgI80)	
^{216}Rn	(^7Li ,f and xn)	13.1 ± 1.0		(FrB73)	
^{208}Ra	(^{40}Ar ,xn)	5.4		(ScF80)	1
^{225}Ra	(^3He , η ef)	9.0	(KoS73)	(My77)	
^{225}Ra	(n,f)	6.5 ± 0.5		(BaN68)	
^{226}Ra	(n,f)	8.5 ± 0.5		(BaN68)	
^{226}Ra	(^4He ,f)	8.5 ± 0.5		(Zhn68)	
^{226}Ra	(n,f)	8.3		(BaI70)	
^{227}Ra	(n,f)	8.5 ± 0.5		(BaN68)	
^{227}Ra	(n,f)	8.30		(BaI70)	
^{227}Ra	(d,pf)	8.0	(KoS73)	(My77)	
^{212}Ac	(^{40}Ar ,xn)	5.2		(ScF80)	1
^{226}Ac	(^3He ,tf)	8.0	(KoS73)	(My77)	
^{227}Ac	(^3He ,df)	7.3		(KoS73)	

Nucleus	Reaction	E _f (MeV)	Data	Ref.	Rem.
228Ac	(³ He,pf)	7.2		(KoS73)	
217Tl	(⁴⁰ Ar,xn)	4.8		(ScF80)	1
229Tl	(n,f)	6.4		(VoG73)	
231Tl		6.2 _{+0.2}		(VaH73)	2
232Tl	(γ,f)	5.40 _{+0.22}		(HiW53)	
232Tl	(γ,f)	5.8	(KaB58)	(Ha59)	
232Tl		5.95		(Hy64)	2
232Tl		6.0 _{+0.2}		(VaH73)	2
233Tl	(n,f)	6.0 _{+0.2}		(HiW53)	
233Tl	(n,f)	6.4	(HuH55)	(Ha59)	
233Tl		6.44		(Hy64)	2
233Tl		6.4 _{+0.2}		(VaH73)	2
234Tl		6.1 _{+0.2}		(VaH73)	2
232Pa	(n,f)	5.4 _{+0.4}		(HiW53)	
232Pa	(n,f)	6.2	(HuH55)	(Ha59)	
232Pa		6.18		(Hy64)	2
232Pa	(n,f)	6.25 _{+0.11}		(Yo69)	
232Pa		6.3 _{+0.2}		(VaH73)	2
233U	(γ,f)	5.18 _{+0.27}		(HiW53)	
233U	(γ,f)	5.4	(KaB58)	(Ha59)	
233U		5.49		(Hy64)	2
233U	(n,f)	5.8 _{+0.1}		(YoD71)	
233U		5.7 _{+0.3}		(VaH73)	2
234U	(d,pf)	5.2	(ScN58)	(Ha59)	
234U	(d,pf)	5.27		(NoS59)	

Nucleus	Reaction	E _f (MeV)	Data	Ref.	Rem.
234U		6.0 _{+0.2}		(VaH73)	2
235U	(n,f)	5.2 _{+0.4}		(HiW53)	
235U	(γ,f)	5.31 _{+0.27}		(HiW53)	
235U	(n,f)	5.7	(HuH55)	(Ha59)	
235U		5.75		(Hy64)	2
235U		5.8 _{+0.2}		(VaH73)	2
236U	(d,pf)	5.8	(ScN58)	(Ha59)	
236U	(d,pf)	5.79		(NoS59)	
236U		5.9 _{+0.2}		(VaH73)	2
237U	(n,f)	6.3	(HuH55)	(Ha59)	
237U		6.40		(Hy64)	2
237U		6.1 _{+0.2}		(VaH73)	2
238U	(γ,f)	5.08 _{+0.15}		(HiW53)	
238U	(γ,f)	5.8	(KaB58)	(Ha59)	
238U	(⁴ He, ⁴ He f)	5.6 _{+0.2}		(Wi64)	
238U		5.80		(Hy64)	2
238U		5.8 _{+0.2}		(VaH73)	2
239U	(n,f)	5.5 _{+0.2}		(HiW53)	
239U	(n,f)	6.2	(HuH55)	(Ha59)	
239U	(d,pf)	6.34		(NoS59)	
239U		6.15		(Hy64)	2
239U		6.2 _{+0.2}		(VaH73)	2
240U		5.7 _{+0.2}		(VaH73)	2
237Np	(γ,f)	5.6	(KaB58)	(Ha59)	
237Np		5.49		(Hy64)	2
237Np		5.6 _{+0.3}		(VaH73)	2
238Np	(n,f)	5.3 _{+0.4}		(HiW53)	

Nucleus	Reaction	E_f (MeV)	Data	Ref.	Rem.
^{238}Np	(n,f)	6.0	(HuH55)	(Ha59)	
^{238}Np	(n,f)	5.98 ± 0.12		(Vo69)	
^{238}Np		6.04		(Hy64)	2
^{238}Np		6.0 ± 0.2		(VaH73)	2
^{239}Pu	(γ ,f)	5.31 ± 0.25		(HiW53)	
^{239}Pu	(γ ,f)	5.4	(KaB58)	(Ha59)	
^{239}Pu		5.48		(Hy64)	2
^{239}Pu		5.8 ± 0.2		(VaH73)	2
^{240}Pu	(d,pf)	4.7	(StN58)	(Ha59)	
^{240}Pu	(d,pf)	4.77		(NoS59)	
^{240}Pu		5.9 ± 0.2		(VaH73)	2
^{241}Pu	(n,f)	6.3	(HuH55)	(Ha59)	
^{241}Pu		5.9 ± 0.2		(VaH73)	2
^{242}Pu		5.8 ± 0.3		(VaH73)	2
^{243}Pu		5.8 ± 0.2		(VaH73)	2
^{244}Pu		5.4 ± 0.3		(VaH73)	2
^{245}Pu		5.4 ± 0.2		(VaH73)	2
^{241}Am	(γ ,f)	6.0	(KaB58)	(Ha59)	
^{241}Am		5.9 ± 0.3		(VaH73)	2
^{242}Am	(n,f)	6.4	(HuH55)	(Ha59)	
^{242}Am	(n,f)	6.46		(BoG65)	
^{242}Am	(n,f)	6.35 ± 0.12		(Vo69)	
^{242}Am		6.4 ± 0.2		(VaH73)	2
^{244}Am	(n,f)	6.21	(BuS61)	(Ha71)	
^{244}Am		6.3 ± 0.2		(VaH73)	2

Nucleus	Reaction	E_f (MeV)	Data	Ref.	Rem.
^{245}Cm		6.2 ± 0.2		(VaH73)	2
^{247}Cm		5.9 ± 0.2		(VaH73)	2
^{249}Cm		5.5 ± 0.2		(VaH73)	2
^{249}Bk		5.9 ± 0.2		(VaH73)	2
^{250}Bk	(n,f)	5.80		(VoD70)	
^{253}Cf		5.3 ± 0.3		(VaH73)	2

TABLE 2

Compilation of experimentally determined fission barriers E_A and E_B . The reference given in the fifth column indicates the origin of the measured data. Remarks are listed at the end of table 2.

Nucl. Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{228}Ra (t,pf)	7.5	8.2		(WeB76)	
^{228}Ra	7.0	8.1		(Br80)	2
^{228}Ra (t,pf)	8.0 ± 0.5	8.5 ± 0.5	(WeB76)	(BjL80)	
^{226}Ac (^3He , ^4He f)	6.0 ± 0.6	7.7 ± 0.3		(Ha77)	
^{227}Th (^3He ,tf)	5.9 ± 0.3	6.6 ± 0.3		(Ha77)	
^{227}Th (^3He ,tf)	5.9	6.5	(Sp75)	(HaK78)	
^{228}Th (^3He ,df)	6.18	6.49		(Sp74)	
^{228}Th	6.2	6.5		(Br80)	2
^{228}Th (^3He ,df)	6.2 ± 0.3	6.5 ± 0.3	(Ha77)	(BjL80)	
^{229}Th (^3He , ^4He f)		6.3 ± 0.2		(BaB74)	
^{229}Th	5.9	6.0		(Br80)	2
^{229}Th (n,f)		6.5 ± 0.3	(YoG73)	(BjL80)	
^{230}Th (t, ^4He f)		6.5 ± 0.3		(BaH74)	
^{230}Th	5.5	7.0		(Br80)	2
^{230}Th misc.	6.1 ± 0.2	6.5 ± 0.3		(GoO59, GoD65, BaH74)	(BjL80)
^{231}Th (n,f)	6.03	6.24		(YuR71)	
^{231}Th (n,f)	6.15	6.50		(JaL72)	
^{231}Th (d,pf)		6.22 ± 0.20		(BaB74)	
^{231}Th	6.05	6.05		(Br80)	2
^{231}Th (n,f)	6.0 ± 0.1	6.1 ± 0.3	(YuR71, JaL72)	(BjL80)	
^{232}Th (t,pf)		5.75	(C+B70)	(BaH74)	
^{232}Th (t,pf)	< 5.50	6.15 ± 0.20		(BaH74)	
^{232}Th	5.3	6.3		(Br80)	2
^{232}Th (t,pf)	5.8 ± 0.2	6.2 ± 0.2	(BaH74)	(BjL80)	
^{233}Th (n,f)		6.28 ± 0.20	(MuV71)	(BaB74)	
^{233}Th	6.0	6.3		(Br80)	2
^{233}Th (n,f)	6.3 ± 0.2	6.3 ± 0.2	(HeS55, La65)	(BjL80)	
^{234}Th (t,pf)		6.05	(C+B70)	(BaH74)	
^{234}Th (t,pf)	6.15 ± 0.20	6.52 ± 0.20		(BaH74)	
^{234}Th	6.00	6.65		(Br80)	2
^{234}Th (t,pf)	6.1 ± 0.2	6.5 ± 0.2	(BaH74)	(BjL80)	
^{230}Pa (^3He ,tf)	5.6	5.65		(GaB76)	
^{230}Pa	5.4	5.8		(Br80)	2
^{230}Pa (^3He ,tf)	6.1	6.1	(GaB76)	(BjL80)	
^{231}Pa (^3He ,df)	5.75 ± 0.30	5.85 ± 0.30		(BaB74)	
^{231}Pa (^3He ,df)	5.95	5.7		(GaB76)	
^{231}Pa	5.6	6.0		(Br80)	2
^{231}Pa (^3He ,df)	5.9 ± 0.2	5.9 ± 0.3	(BaB74, GaB76)	(BjL80)	
^{232}Pa (d,pf)	5.75 ± 0.30	6.10 ± 0.30		(BaB74)	
^{232}Pa (^3He ,tf)	6.55	5.90		(GaB76)	
^{232}Pa	6.0	6.1		(Br80)	2
^{232}Pa misc.	6.1 ± 0.3	6.2 ± 0.2		(MuV71, BaB74, GaB76)	(BjL80)
^{233}Pa (^3He ,df)	5.85 ± 0.30	6.00 ± 0.30		(BaB74)	
^{233}Pa (^3He ,df) < 5.3		6.0		(GaB76)	
^{233}Pa	5.9	6.2		(Br80)	2
^{233}Pa (^3He ,df)	6.1 ± 0.3	6.1 ± 0.3	(BaB74, GaB76)	(BjL80)	

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{231}U	$^3\text{He,tf}$	5.2	5.4		(GaB76)	
^{231}U		5.2	5.2		(Br80)	2
^{231}U	$^3\text{He,tf}$	5.8	5.2	(GaB76)	(BjL80)	
^{232}U	$^3\text{He,df}$	5.54 ± 0.20	5.45 ± 0.20		(BaH74)	
^{232}U	$^3\text{He,df}$	5.6	5.7		(GaB76)	
^{232}U		5.5	5.4		(Br80)	2
^{232}U	$^3\text{He,df}$	5.2 ± 0.2	5.1 ± 0.3	(BaH74)	(BjL80)	
^{233}U	(n,f)	<5.80	<5.80	(Ja64)	(BjL80)	
^{234}U	(d,pf)	6.20	5.95		(BaB71)	
^{234}U	(d,pf)	6.20 ± 0.25	5.95 ± 0.25		(BaH74)	
^{234}U	(d,pf)	6.20	5.95	(BaB71)	(BaH74)	
^{234}U		6.00	5.80		(Br80)	2
^{234}U	(d,pf)	5.6 ± 0.2	5.5 ± 0.2	(BaB71)	(BjL80)	
^{235}U	(n,f)	5.9	6.0	(JaS69,BNL325)	(WeT72)	
^{235}U	(t,pf)	6.10 ± 0.30	5.65 ± 0.30	(BrC70)	(BaB74)	
^{235}U		6.0	5.9		(Br80)	2
^{235}U	misc.	5.9 ± 0.2	5.6 ± 0.2	(La62,BrC70)	(BjL80)	
^{236}U	(d,pf)	6.1	5.8		(BaB71)	
^{236}U	(t,pf)	5.70 ± 0.20	5.68 ± 0.20		(BaH74)	
^{236}U	(d,pf)	6.1	5.8	(BaB71)	(BaH74)	
^{236}U		5.75	5.75		(Br80)	2
^{236}U	misc.	5.6 ± 0.2	5.5 ± 0.2	(BaB71,BaH74,SoP74)	(BjL80)	
^{237}U	(n,f)	6.3	5.7		(ThW72)	
^{237}U	(t,pf)	6.35 ± 0.30	5.95 ± 0.30	(BrC70)	(BaB74)	
^{237}U		6.3	5.9		(Br80)	2
^{237}U	(n,f)	6.1 ± 0.2	5.9 ± 0.2	(RoP72)	(BjL80)	
^{238}U	(t,pf)	5.77	5.65	(CrB70)	(BaH74)	

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{238}U	(t,pf)	5.9	6.1		(BaH74)	
^{238}U	(t,pf/ γ ,f)					
		5.9	6.1			
^{238}U				(BaH74,DiA75,CaD76)	(GaB77b)	
^{238}U		6.1	5.9		(Br80)	2
^{238}U	misc.	5.7 ± 0.2	5.7 ± 0.2	(NcNB74,BaH74)	(BjL80)	
^{239}U	(n,f)	6.25		(HuH55)	(WeT72)	
^{239}U	(n,f)	6.55 ± 0.30	6.30 ± 0.30	(La62)	(BaB74)	
^{239}U		6.3	5.7		(Br80)	2
^{239}U	(n,f)	6.3 ± 0.2	6.1 ± 0.2	(SoP74)	(BjL80)	
^{240}U	(t,pf)	5.75	5.95		(BaH74)	
^{240}U	(t,pf)	5.8	5.6	(CrB70)	(BaH74)	
^{240}U		6.35	5.80		(Br80)	2
^{240}U	(t,pf)	5.7 ± 0.2	5.5 ± 0.2	(BaH74)	(BjL80)	
^{233}Np	$^3\text{He,tf}$	5.35	4.95		(GaB76)	
^{233}Np		5.0	5.1		(Br80)	2
^{233}Np	$^3\text{He,tf}$	5.4	4.7	(GaB76)	(BjL80)	
^{234}Np	$^3\text{He,df}$	5.35 ± 0.30	5.00 ± 0.30		(BaB74)	
^{234}Np	$^3\text{He,tf}/^3\text{He,df}$					
		5.6	5.5		(GaB76)	
^{234}Np		5.5	5.4		(Br80)	2
^{234}Np	misc.	5.5 ± 0.2	5.1 ± 0.2	(BaB74,GaB76)	(BjL80)	
^{235}Np	$^3\text{He,df}$	5.6 ± 0.3	5.2 ± 0.3		(BaB74)	
^{235}Np	$^3\text{He,tf}/^3\text{He,df}$					
		5.8	5.3		(GaB76)	
^{235}Np		6.0	5.5		(Br80)	2
^{235}Np	misc.	5.5 ± 0.2	5.2 ± 0.2	(BaB74,GaB76)	(BjL80)	
^{236}Np	$^3\text{He,d}$	5.7 ± 0.3	5.2 ± 0.3		(BaB74)	

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{236}Np	$(^3\text{He}, t\epsilon/^3\text{He}, df)$					
		5.75	5.40		(GAB76)	
^{236}Np		5.7	5.4		(Br80)	2
^{236}Np	misc.	5.8 ± 0.2	5.6 ± 0.2	(BAB74, GAB76)	(BjL80)	
^{237}Np	$(^3\text{He}, df)$	5.7 ± 0.3	5.2 ± 0.3		(BAB74)	
^{237}Np	$(^3\text{He}, df)$	5.7	5.3		(GAB76)	
^{237}Np		6.2	5.5		(Br80)	2
^{237}Np	$(^3\text{He}, df)$	5.7 ± 0.2	5.4 ± 0.2	(BAB74, GAB76)	(BjL80)	
^{238}Np	(d, pf)	6.05	5.85		(BAB71)	
^{238}Np	(n, f)		5.6		(FUB68)	
^{238}Np	(d, pf)	6.0 ± 0.3	6.0 ± 0.3		(BAB74)	
^{238}Np	$(^3\text{He}, t\epsilon)$	6.15	5.55		(GAB76)	
^{238}Np		6.0	5.6		(Br80)	2
^{238}Np	misc.	6.1 ± 0.2	6.0 ± 0.2			
	(StS68, BrD70, BAB74, SoP74, GAB76)				(BjL80)	
^{239}Np	$(^3\text{He}, df)$	5.85 ± 0.30	5.50 ± 0.30		(BAB74)	
^{239}Np	$(^3\text{He}, df)$	5.70	5.20		(GAB76)	
^{239}Np		6.3	5.0		(Br80)	2
^{239}Np	$(^3\text{He}, df)$	5.9 ± 0.2	5.4 ± 0.2	(BAB74, GAB76)	(BjL80)	
^{232}Pu	$(^4\text{He}, n\epsilon)$	5.3 ± 0.4			(Ha77)	5
^{234}Pu	$(^{10}\text{B}, n\epsilon)$	5.8 ± 0.7		(KUS67)	(Ha77)	5
^{235}Pu	$(^4\text{He}, 2n\epsilon)$	5.0			(BrB71)	6
^{235}Pu	$(^4\text{He}, 2n\epsilon)$	4.6 ± 0.2		(BrB71)	(BrB73)	6
^{235}Pu	$(^4\text{He}, 2n)$	5.0 ± 0.2	4.9 ± 0.4		(FID78)	
^{235}Pu			5.1 ± 0.4		(BjL80)	2
^{236}Pu	$(^4\text{He}, 2n\epsilon)$	5.0			(BrB71)	6
^{236}Pu		4.5 ± 0.4			(BjL80)	2

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{237}Pu	$(^4\text{He}, n\epsilon/^4\text{He}, 2n\epsilon/d, 2n\epsilon)$					
			5.4		(BrB71)	2,6
^{237}Pu	$(^4\text{He}, 2n\epsilon/d, 2n\epsilon)$		5.4 ± 0.2	(RuV71, Ten71)	(BrB73)	6
^{237}Pu	$(^3\text{He}, t\epsilon)$	5.6	5.1		(GAB76)	
^{237}Pu	$(^4\text{He}, xn)$	5.3	5.0		(DeF78)	
^{237}Pu	$(^4\text{He}, 2n)$	5.3 ± 0.2	5.0 ± 0.4		(FID78)	
^{237}Pu		5.6	5.4		(Br80)	2
^{237}Pu		5.9	5.2		(BjL80)	2
^{236}Pu			5.6		(BrB71)	2,6
^{236}Pu	$(^4\text{He}, 2n\epsilon/^4\text{He}, 4n\epsilon)$		5.35 ± 0.2	(Co58)	(BrB73)	
^{238}Pu	$(^3\text{He}, df)$	5.90 ± 0.20	5.20 ± 0.30		(BaH74)	
^{238}Pu	$(^3\text{He}, df)$	6.2	4.6		(GAB76)	
^{238}Pu	$(^4\text{He}, xn)$	5.8	5.0		(DeF78)	
^{238}Pu		6.0	5.3		(Br80)	2
^{238}Pu		5.5 ± 0.2	5.0 ± 0.2		(BjL80)	2
^{239}Pu	(d, pf)	6.27	5.42		(BAB71)	
^{239}Pu	$(^4\text{He}, 3n\epsilon/d, pnf/d, pf)$	6.27 ± 0.3	5.15 ± 0.2			
	(WIR59, PoS70, BrB71)				(BrB73)	6
^{239}Pu	(d, pf)	6.43 ± 0.2			(BAB74)	
^{239}Pu	$(^4\text{He}, xn)$	6.4	5.3		(DeF78)	
^{239}Pu		6.4	5.5		(Br80)	2
^{239}Pu		6.2 ± 0.2	5.5 ± 0.2		(BjL80)	2
^{240}Pu	$(p, p' \epsilon/d, pf)$					
		5.95	5.25		(BrB69)	
^{240}Pu	(d, pf)	6.05	5.55		(BAB71)	
^{240}Pu	$(^4\text{He}, 2n\epsilon)$		5.35		(BrB71)	6
^{240}Pu	$(^4\text{He}, n\epsilon/^4\text{He}, 3n\epsilon/d, pnf)$		5.0		(BrB71)	6
^{240}Pu	$(^4\text{He}, 2n\epsilon)$	6.00 ± 0.3	5.35 ± 0.2		(BrB71)	
^{240}Pu	(t, pf)	5.80 ± 0.20	5.45 ± 0.20		(BaH74)	6
^{240}Pu	(d, pf)	6.67	5.33		(GoH78)	

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{240}Pu		6.0	5.5		(Br80)	2
^{240}Pu		5.6 ± 0.2	5.1 ± 0.2		(BjL80)	2
^{241}Pu	(d,pf/t,df/t,pf)	5.8		(BrC70)	(BrB71)	
^{241}Pu	^4He , 2nf)		5.25		(BrB71)	6
^{241}Pu	(n,f)	6.05		(HuH55)	(WeT72)	
^{241}Pu	(n,f)		5.45	(MiT68, PoS70)	(WeT72)	
^{241}Pu		5.95 ± 0.30			(BrB73)	2
^{241}Pu	(t,pf)	6.25 ± 0.20			(BaB74)	
^{241}Pu		6.15	5.70		(Br80)	2
^{241}Pu		6.1 ± 0.2	5.4 ± 0.2		(BjL80)	2
^{242}Pu	(d,pf)	6.1	5.5		(BaB71)	
^{242}Pu	(d,pf)	6.1 ± 0.3		(BaB71)	(BrB73)	
^{242}Pu	(t,pf)	5.60	5.65		(BaH74)	
^{242}Pu	(t,pf)	5.60	5.05	(GrB70)	(BaH74)	
^{242}Pu		5.7	5.5		(Br80)	2
^{242}Pu	misc.	5.6 ± 0.2	5.1 ± 0.2	(BuS61, KaP70, B173, BaH74)	(BjL80)	
^{243}Pu	(d,pf/t,df)					
		5.8		(BrC70)	(BrB71)	
^{243}Pu	(n,f)	5.8		(HuH55)	(WeT72)	
^{243}Pu	(n,f)		5.2	(LaS69, Au71)	(WeT72)	
^{243}Pu		5.7 ± 0.3			(BrB73)	2
^{243}Pu	(n,f)		5.18		(PoR73)	
^{243}Pu	(n,f)	6.05 ± 0.20		(AuF71)	(BaB74)	
^{243}Pu		5.85	5.60		(Br80)	2
^{243}Pu	(n,f)	5.9 ± 0.2	5.2 ± 0.2	(Bu60, AuF71)	(BjL80)	
^{244}Pu	(t,pf)	5.55	4.90	(GrB70)	(BaH74)	
^{244}Pu	(t,pf)	< 5.60	5.35 ± 0.20		(BaH74)	
^{244}Pu		5.55	5.30		(Br80)	2
^{244}Pu	(t,pf)	5.4 ± 0.2	5.0 ± 0.2	(BaH74)	(BjL80)	

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{245}Pu	(n,f)	5.5			(WeT72)	2
^{245}Pu	(n,f)	5.5 ± 0.3		(AuF71)	(BrB73)	
^{245}Pu	(n,f)	5.72 ± 0.20			(BaB74)	
^{245}Pu		5.5	5.4		(Br80)	2
^{245}Pu	(n,f)	5.6 ± 0.2	5.0 ± 0.2	(AuF71)	(BjL80)	
^{246}Pu		5.4	5.3		(Br80)	2
^{237}Am	(p, 2nf)		4.80 ± 0.2	(PoS70)	(BrB73)	6
^{238}Am	(p, 2nf)		5.3		(BrB71)	2, 6
^{238}Am	^4He , 3nf/d, 2nf/p, 2nf)					
			5.4 ± 0.2			
				(Gi56, PoS70, BrE72)	(BrB73)	6
^{239}Am	^4He , 2nf/d, 2nf/p, 2nf)					
^{239}Am	(p, 2nf)		5.40	(LaS69)	(BrB71)	6
^{239}Am	^4He , 2nf/d, 2nf/p, 2nf)		5.5		(BrB71)	2, 6
		5.80 ± 0.3	4.65 ± 0.2			
^{239}Am	^4He , 3nf/d, 2nf/p, 2nf)			(LaS69, BrB71, BrE72)	(BrB73)	6
			4.6 ± 0.2			
^{239}Am	^3He , tf)	5.3	5.5	(Gi56, PoS70, BrE72)	(BrB73)	6
^{239}Am	^4He , 2n)	6.2 ± 0.2	4.8 ± 0.4		(GaB76)	
^{239}Am		6.3			(FiLD78)	
^{239}Am		6.2 ± 0.2			(Br80)	2
					(BjL80)	2
^{240}Am	^4He , nf/d, 2nf/p, 2nf)		6.05	(BjB67)	(BrB71)	6
^{240}Am	^4He , 2nf/d, 2nf/p, 2nf)					
			5.2	(LaS69)	(BrB71)	6

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{240}Am	(p, 2nf/d, 2nf/t, 3nf)	6.45 ± 0.3	5.50 ± 0.2			
^{240}Am	(^4He , 2nf/d, 2nf/p, 2nf)			(BjB67, BrB71, BrE72)	(BrB73)	6
^{240}Am	(^3He , df)	6.35 ± 0.20		(LaS69, BrB71, BrE72)	(BrB73)	6
^{240}Am	(^3He , tf/ ^3He , df)				(Bab74)	
^{240}Am		6.45	5.45		(GAB76)	
^{240}Am		6.30			(Br80)	2
^{240}Am		6.5 ± 0.2	5.2 ± 0.3		(BjL80)	2
^{241}Am	(^4He , nf/d, 2nf/p, 2nf)	6.2		(BjB67)		
^{241}Am	(p, 2nf)	5.70 ± 0.3	4.55 ± 0.2	(LaS69, BrE72)	(BrB73)	6
^{241}Am	(p, 2nf/d, 2nf/t, 3nf)	4.5 ± 0.2				
^{241}Am	(^3He , df)	6.0 ± 0.2		(BjB67, BrB71, BrE72)	(BrB73)	6
^{241}Am	(^3He , df)	6.0	5.1		(Bab74)	
^{241}Am		6.4			(GAB76)	
^{241}Am		6.0 ± 0.2	5.1 ± 0.3		(Br80)	2
^{241}Am					(BjL80)	2
^{242}Am	(d, pf)	6.35	6.40		(Bab71)	
^{242}Am	(n, f)	6.4		(BoA68)		
^{242}Am	(d, 2nf/n, 2nf)	6.0			(BrB71)	2,6
^{242}Am	(p, 2nf)	5.1			(BrB71)	2,6
^{242}Am	(p, 2nf)	5.05 ± 0.20				
^{242}Am	(d, 2nf/n, 2nf, t, 3nf)			(BrE72, LaS69)	(BrB73)	6
^{242}Am		6.40 ± 0.3	4.95 ± 0.2			
^{242}Am	(d, pf)	6.38 ± 0.20		(BrB71, BrE72, FlP67, PoD62)	(BrB73)	6
^{242}Am	(^3He , tf)	6.40	5.05		(Bab71)	
^{242}Am		6.3			(GAB76)	
^{242}Am		6.3 ± 0.2	5.4 ± 0.3		(Br80)	2
^{242}Am					(BjL80)	2

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{243}Am	(d, 2nf/n, 2nf)		6.0			
^{243}Am	(p, 2nf/d, pnf)				(BrB71)	6
^{243}Am	(^3He , df)	5.75 ± 0.3	4.90 ± 0.2	(PoS70, BrE72)	(BrB73)	6
^{243}Am	(^3He , df)	5.98 ± 0.2			(Bab74)	
^{243}Am	(^3He , df)	5.75	4.95		(GAB76)	
^{243}Am		6.3			(Br80)	2
^{243}Am		5.9 ± 0.2	5.4 ± 0.3		(BjL80)	2
^{244}Am	(d, pf)	6.15	5.45		(Bab71)	
^{244}Am	(n, f)	6.3			(StG65)	
^{244}Am	(d, 2nf/t, 3nf)	6.25 ± 0.3	4.80 ± 0.2			
^{244}Am	(d, pf)	6.18 ± 0.20		(BjB69, BrB71, BrE72)	(BrB73)	6
^{244}Am	(^3He , tf)	6.4	5.65		(Bab71)	
^{244}Am		6.2			(GAB77a)	
^{244}Am		6.3 ± 0.2	5.4 ± 0.3		(Br80)	2
^{244}Am					(BjL80)	2
^{245}Am		5.55 ± 0.3			(BrB73)	2
^{245}Am	(t, pf)	5.88 ± 0.20			(Bab74)	
^{245}Am	(^3He , df)	5.65	5.05		(GAB77a)	
^{245}Am		6.10			(Br80)	2
^{245}Am		5.9 ± 0.2	5.2 ± 0.3		(BjL80)	2
^{247}Am		5.2 ± 0.3			(BrB73)	2
^{247}Am	(t, ^4He , f)	5.6 ± 0.2			(Bab74)	
^{247}Am		5.9			(Br80)	2
^{247}Am	(t, ^4He , f)	5.5 ± 0.2			(BjL80)	
^{241}Cm	(^4He , 2nf)		5.0		(BrB71)	6
^{241}Cm	(^4He , 2nf)		5.2 ± 0.2	(BrB71)	(BrB73)	6
^{241}Cm	(^3He , tf)	6.00	5.65		(GAB76)	
^{241}Cm		6.5			(Br80)	2
^{241}Cm		6.3 ± 0.3	4.3 ± 0.5		(BjL80)	2

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{242}Cm	$(^4\text{He}, 2\text{nf})$		4.7		(BrB71)	6
^{242}Cm	$(^3\text{He}, \text{df})$	6.25	4.60		(GaB76)	
^{242}Cm		6.2			(Br80)	2
^{242}Cm		5.8 $\pm$ 0.4	4.0 $\pm$ 0.5		(BjL80)	2
^{243}Cm	$(^4\text{He}, 3\text{nf})$		4.80	(WoU71)	(BrB71)	6
^{243}Cm	$(^4\text{He}, 3\text{nf}/\text{d}, 2\text{nf})$					
		5.8 $\pm$ 0.3	4.0 $\pm$ 0.2			
^{243}Cm	$(^3\text{He}, \text{tf})$	5.95	5.50	(PoS70, BrB71, WoU72)	(BrB73)	6
^{243}Cm		6.55			(GaB76)	
^{243}Cm		6.4 $\pm$ 0.3			(Br80)	2
					(BjL80)	2
^{244}Cm	$(^4\text{He}, 3\text{nf})$		4.4	(WoU71)	(BrB71)	6
^{244}Cm	$(^3\text{He}, \text{df})$	6.12 $\pm$ 0.20	< 4.9		(BaH74)	
^{244}Cm	$(^3\text{He}, \text{df})$	6.2	4.6		(GaB76)	
^{244}Cm	$(^3\text{He}, \text{d}, \text{t})$	6.25			(Br80)	
^{244}Cm		5.8 $\pm$ 0.2	4.3 $\pm$ 0.3		(BjL80)	2
^{245}Cm	$(^4\text{He}, 3\text{nf})$		4.9	(WoU71)	(BrB71)	6
^{245}Cm	(n, f)	6.3		(NoK71)	(BrB71)	
^{245}Cm	$(^4\text{He}, 3\text{nf})$	6.3 $\pm$ 0.3	4.4 $\pm$ 0.2	(BrB71, WoU72)	(BrB73)	6
^{245}Cm	(n, f)	6.38 $\pm$ 0.20		(NoK71)	(BaB74)	
^{245}Cm		6.3			(Br80)	2
^{245}Cm		6.2 $\pm$ 0.2			(BjL80)	2
^{246}Cm	$(^4\text{He}, 3\text{nf})$		4.5	(WoU71)	(BrB71)	6
^{246}Cm		6.2	4.7		(Br80)	2
^{246}Cm		5.7 $\pm$ 0.2	4.2 $\pm$ 0.3		(BjL80)	2
^{247}Cm	(n, f)	6.1		(NoK71)	(BrB71)	
^{247}Cm	(n, f)	6.1 $\pm$ 0.3		(NoK71)	(BrB73)	
^{247}Cm	(n, f)	6.2 $\pm$ 0.2		(NoK71)	(BaB74)	
^{247}Cm		6.15			(Br80)	2

Nucl.	Reaction	E_A (MeV)	E_B (MeV)	Data	Ref.	Rem.
^{247}Cm	(n, f)	6.0 $\pm$ 0.2		(BaB71a)	(BjL80)	
^{248}Cm	$(\text{p}, \text{p}' \text{f})$	6.15 $\pm$ 0.20	< 4.6		(BaH74)	
^{248}Cm		6.0	5.0		(Br80)	2
^{248}Cm	$(\text{p}, \text{p}' \text{f})$	5.7 $\pm$ 0.2		(BaH74)	(BjL80)	
^{249}Cm	(n, f)	5.6		(NoK71)	(BrB71)	
^{249}Cm	(n, f)	5.5 $\pm$ 0.3		(NoK71)	(BrB73)	
^{249}Cm	(d, pf)	5.8 $\pm$ 0.2			(BaB74)	
^{249}Cm		5.65			(Br80)	2
^{249}Cm	(n, f)	5.6 $\pm$ 0.2		(BaB71a)	(BjL80)	
^{250}Cm	(t, p)	5.15 $\pm$ 0.20	3.90 $\pm$ 0.30		(BaH74)	
^{250}Cm		5.5	4.4		(Br80)	2
^{250}Cm	(t, p)	5.3 $\pm$ 0.2		(BaH74)	(BjL80)	
^{245}Bk	$(^3\text{He}, \text{tf})$	6.20	< 5.80		(GaB77a)	
^{245}Bk		6.60			(Br80)	2
^{246}Bk	$(^3\text{He}, \text{df}/^3\text{He}, \text{tf})$					
		6.60	< 5.70		(GaB77a)	
^{246}Bk		6.40			(Br80)	2
^{247}Bk	$(^3\text{He}, \text{df})$	6.00	< 5.50		(GaB77a)	
^{247}Bk		6.50			(Br80)	2
^{248}Bk	$(^3\text{He}, \text{tf})$	6.76	< 5.00		(GaB77a)	
^{248}Bk		6.50			(Br80)	2
^{249}Bk	$(^3\text{He}, \text{d})$	6.05 $\pm$ 0.20			(BaB74)	
^{249}Bk	$(^3\text{He}, \text{df})$	5.80	< 5.00		(GaB77a)	
^{249}Bk		6.30			(Br80)	2
^{249}Bk	$(^3\text{He}, \text{d})$	6.10 $\pm$ 0.2		(BaB74)	(BjL80)	

REMARKS:

Nucl.	Reaction	E _A (MeV)	E _B (MeV)	Data	Ref.	Rem.
²⁵⁰ Bk	(n,f)	6.10 _{+0.2}	4.1 _{+0.3}	(VoD70)	(BjL80)	1. It is assumed that the experiment is only sensitive to the liquid drop barrier.
²⁵⁰ Cf		5.5 _{+0.35}	3.6 _{+0.35}	(Ly74)	(JuH77)	2. Analysed data: see cited work
²⁵⁰ Cf	(n,f)	5.6 _{+0.3}		(VoG72, Si73)	(BjL80)	3. ¹ crit extracted from empirical formula of (GiJ73)
²⁵¹ Cf		6.15			(Br80)	4. ¹ crit taken from Bass model (Ba74)
²⁵² Cf		5.30			(Br80)	5. ¹ crit delayed fission
²⁵³ Cf	(n,f)	5.6 _{+0.3}		(MoN71)	(BaB74)	6. Isomeric fission
²⁵³ Cf		5.30			(Br80)	
²⁵³ Cf	(n,f)	5.4 _{+0.3}		(MoN71)	(BjL80)	
²⁴⁹ Es	(³ He,tf)	6.20	<5.80		(GaB77a)	
²⁴⁹ Es		6.80			(Br80)	
²⁵⁰ Es	(³ He,df/ ³ He,tf)	6.90	<5.60		(GaB77a)	
²⁵⁰ Es		6.70			(Br80)	
²⁵¹ Es	(³ He,df)	6.35	<5.20		(GaB77a)	
²⁵¹ Es		6.60			(Br80)	
²⁵⁵ Es	(d,p)	5.4 _{+0.3}			(BrC80)	
²⁵⁶ Es	(t,p)	4.8 _{+0.3}			(BrC80)	
²⁵⁵ Fm	(³ He,d)	5.7 _{+0.3}			(BrC80)	

TABLE 3 : Different parametrizations of the liquid drop model *)

ref	a_s	κ
MyS67	18.36	1.78
SeP67	19.73	2.74
PaL71	19.01	2.84

*) calculated with $r_0 = 1.20$ fm

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FIGURE CAPTIONS

Fig. 1: Schematic diagram to show how the total fission barrier is related to the droplet fission barrier and to the shell corrections at the barrier and in the ground state. The figure is taken from (My77).

Fig. 2: Part of the chart of the nuclides. Nuclei for which the fission barrier was determined experimentally are indicated by an asterisk.

Fig. 3: Comparison of empirical fission barriers for $80 \leq Z \leq 96$ with the droplet model.

◆: Sum of the experimental fission barrier and the ground state shell correction for nuclei from table 1.
 straight line: linear fit to these data.
 dotted line: droplet fission barrier (My77).
 dashed line: ground state shell correction ($N^{\text{exp}} - N^{\text{DM}}$).

Fig. 4: Comparison of empirical barriers E_A and E_B with the droplet model.

◆: Sum of the experimental fission barrier and the ground state shell correction for nuclei from table 2.
 straight line: linear fit to these data.
 dotted line: droplet fission barrier (My77).
 dashed line: ground state shell correction ($N^{\text{exp}} - N^{\text{DM}}$).

Fig. 5: The reduced fissility parameter ζ as a function of $I^2 = (N - Z)^2/A^2$. The data from tables 1 and 2 are compared with different models. In case both values for E_A and E_B are given, the maximum value was used.

Fig. 6: Approximation of the droplet fission barriers of the nuclei contained in tables 1 and 2 by a liquid drop parametrization. Isotopic sequences follow a line parallel to the fit.

Fig. 7: Neutron deficient part of fig. 5. The data points are marked with the element symbol and the mass number.

Fig. 8: The most recent data ((BjL80), (Br80), (Igl80), (ReG79), (ScF80)) are shown and approximated by a fitted parabola in order to get an empirical description of the fissility parameter x (see equ. 10). For further description see fig. 5.

Fig. 9: Slopes AR of sharp cut off radii as a function of neutron number averaged over isotopic sequences for different elements (taken from MyS81). The experimental values were deduced from a compilation of measured rms-radii (AnC78) by correcting for the influence of deformation (NoN80) and diffuseness.

Fig. 1:

Fig. 2:

Fig. 3a:

Fig. 4a:

Fig. 3b:

Fig. 4b:

Fig. 4c:

Fig. 6:

Fig. 7:

Fig. 4d:

Fig. 5:

Fig. 8:

Fig. 9: