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FISSION PROPERTIES OF SUPERHEAVY NUCLEI*

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Heights of (static) spontaneous-fission barriers of heaviest nuclei are calculated within a macroscopic–microscopic approach. Even–even, odd-A and odd–odd nuclei with proton number Z=96–120 are considered.

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1. Introduction

One of important fission properties of a nucleus is height, $B_{\rm f}^{\rm st}$, of its (static) spontaneous-fission barrier. We concentrate on this property in the present paper. For superheavy nuclei, this quantity is needed for calculations of cross sections for their synthesis (*cf.* *e.g.* Refs. [1–4]). There exists a number of calculations of $B_{\rm f}^{\rm st}$ (*cf.* *e.g.* Refs. [5–10]), differing between themselves in the approach used and/or in nuclei considered. The objective of this paper is to extend our previous calculations [11] in a number of considered nuclei, in particular, to include odd-A and odd–odd nuclei.

The calculations are done within a macroscopic–microscopic approach, with the Yukawa-plus-exponential model used for the macroscopic part of the potential energy and the Strutinski shell correction, based on the Woods-Saxon single-particle potential, taken for the microscopic part. Details of the approach are specified in Ref. [12]. A large, 7-dimensional deformation space $\{\beta_\lambda\}, \lambda = 2, 3, ..., 8$, is used in the analysis. To get the static fission trajectory, at each value of the quadrupole deformation β_2 (describing the elongation of a nucleus), the energy of a nucleus is minimized in the remaining degrees of freedom. It is checked, however, if parameters of all these degrees of freedom change in a continuous way along the trajectory. This allows one to avoid an artificial jumping from one valley of the energy to another with omission of the saddle point, which would lead to an artificial

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lowering of $B_{\rm f}^{\rm st}$. Axial symmetry of a nucleus is assumed. In consideration of odd-A and odd–odd nuclei, a possible specification energy is not taken into account. Nuclei with proton number Z=96-120 are considered.

2. Results

Figure 1 gives an example of the static spontaneous-fission barrier, calculated for the deformed superheavy nucleus $^{278}112$. For so heavy nucleus, a smaller, 4-dimensional space $\{\beta_\lambda\}, \lambda = 2, 4, 6, 8$, is sufficient for the analysis. One can see that there is no macroscopic barrier for such a heavy nucleus and that the whole barrier is created by shell effects.

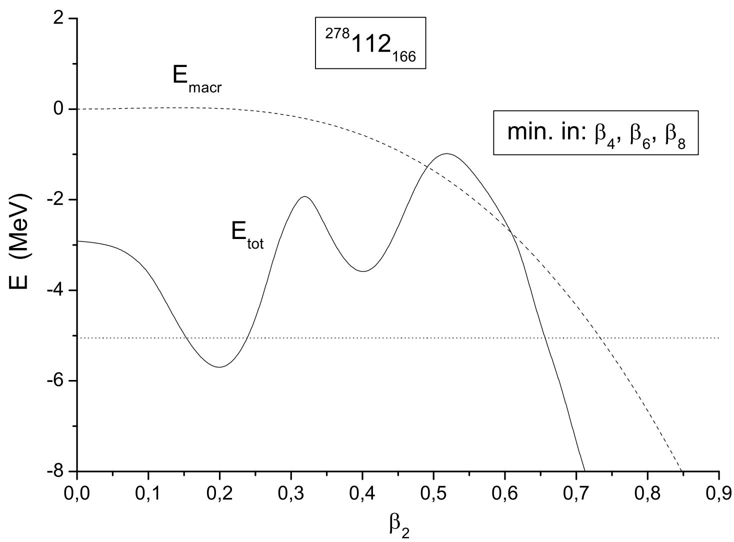

Fig. 1. Spontaneous-fission barrier for the nucleus $^{278}112$.

Figure 2 shows systematics of the barrier heights obtained for nuclei with proton number Z = 106–115 and neutron number N = 146–181. One can see that even for such heavy nuclei as those with Z=115, the heights may be quite large, up to about 7 MeV.

Table I gives values of $B_{\rm f}^{\rm st}$ calculated for 301 nuclei with proton number Z = 106–120. Each nucleus is specified by its proton Z and neutron N numbers. To make the table as compact as possible, only $B_{\rm f}^{\rm st}$ is given for each nucleus. For many of the considered nuclei, however, other properties of them, as equilibrium deformations β_λ^0, masses M, α-decay energies Q_α and neutron separation energies $S_{\rm n}$, calculated within the same approach, may be found in Refs. [12–15].

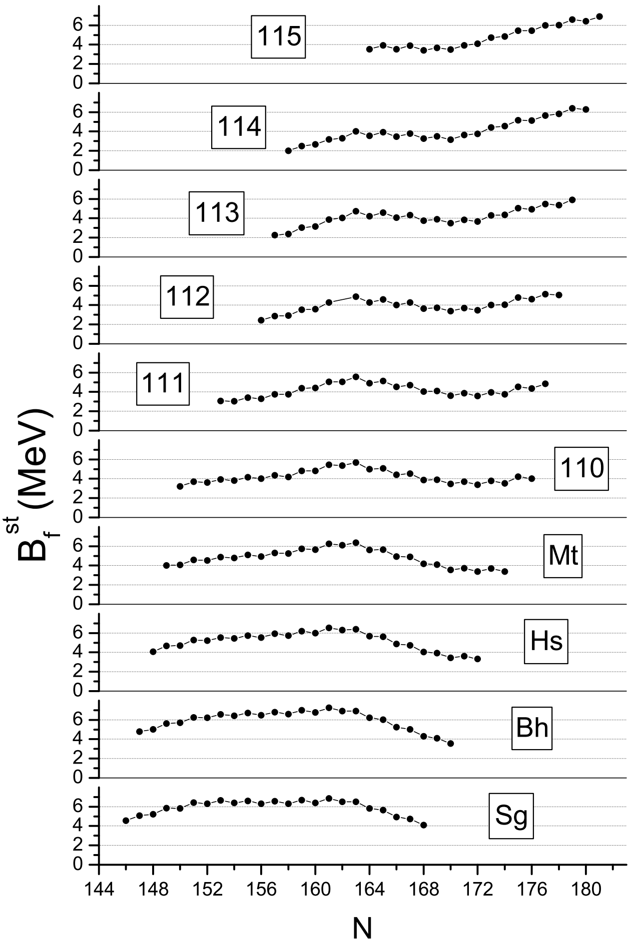

Fig. 2. Systematics of the calculated barrier heights.

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TABLE I

Heights of the spontaneous-fission barriers $B_{\mathrm{f}}^{\mathrm{st}}$ (in MeV).

N	$B_{\mathrm{f}}^{\mathrm{st}}$	N	$B_{\mathrm{f}}^{\mathrm{st}}$	N	$B_{\mathrm{f}}^{\mathrm{st}}$	N	$B_{\mathrm{f}}^{\mathrm{st}}$	N	$B_{\mathrm{f}}^{\mathrm{st}}$
		157	6.8	170	3.5	154	3.8	166	4.5
Z=106		158	6.6	171	3.7	155	4.2	167	4.7
		159	7.0	172	3.3	156	4.0	168	4.1
146	4.6	160	6.8			157	4.4	169	4.1
147	5.1	161	7.3	Z=109		158	4.2	170	3.6
148	5.2	162	7.0			159	4.9	171	3.9
149	5.9	163	6.9	149	4.0	160	4.8	172	3.6
150	5.8	164	6.2	150	4.1	161	5.5	173	4.0
151	6.4	165	6.0	151	4.6	162	5.4	174	3.8
152	6.3	166	5.3	152	4.6	163	5.7	175	4.5
153	6.6	167	5.0	153	4.9	164	5.0	176	4.4
154	6.4	168	4.3	154	4.8	165	5.1	177	4.8
155	6.7	169	4.1	155	5.1	166	4.5		
156	6.3	170	3.6	156	5.0	167	4.6	Z=112	
157	6.6			157	5.3	168	3.9		
158	6.3	Z=108		158	5.2	169	3.9	156	2.5
159	6.7			159	5.7	170	3.5	157	2.9
160	6.4	148	4.1	160	5.7	171	3.7	158	2.9
161	6.9	149	4.7	161	6.2	172	3.4	159	3.5
162	6.5	150	4.7	162	6.1	173	3.8	160	3.6
163	6.5	151	5.3	163	6.4	174	3.5	161	4.3
164	5.8	152	5.3	164	5.6	175	4.3	163	4.9
165	5.7	153	5.6	165	5.6	176	4.1	164	4.3
166	5.0	154	5.4	166	4.9			165	4.6
167	4.8	155	5.8	167	4.9	Z=111		166	4.0
168	4.1	156	5.6	168	4.2			167	4.3
		157	5.9	169	4.2	153	3.1	168	3.6
Z=107		158	5.7	170	3.6	154	3.0	169	3.8
		159	6.2	171	3.7	155	3.4	170	3.4
147	4.8	160	6.0	172	3.4	156	3.3	171	3.7
148	5.0	161	6.6	173	3.7	157	3.8	172	3.5
149	5.6	162	6.3	174	3.4	158	3.8	173	4.0
150	5.7	163	6.4			159	4.4	174	4.1
151	6.3	164	5.7	Z=110		160	4.4	175	4.8
152	6.2	165	5.6			161	5.1	176	4.6
153	6.6	166	4.9	150	3.2	162	5.1	177	5.2
154	6.4	167	4.7	151	3.7	163	5.6	178	5.1
155	6.8	168	4.1	152	3.6	164	4.9		
156	6.5	169	4.0	153	3.9	165	5.1	Z=113	
		162	3.3	173	4.8	173	5.1	173	5.2
157	2.3	163	4.1	174	4.9	174	5.2	174	5.3
158	2.4	164	3.6	175	5.5	175	5.7	175	5.9
159	3.1	165	4.0	176	5.5	176	5.7	176	5.7
160	3.2	166	3.5	177	6.0	177	6.2	177	6.1
161	3.9	167	3.8	178	6.1	178	6.2	178	5.9
162	4.1	168	3.3	179	6.6	179	6.6	179	6.2
163	4.8	169	3.5	180	6.5	180	6.4	180	6.1
164	4.2	170	3.2	181	6.9	181	6.8	181	6.3
165	4.6	171	3.7			182	6.4	182	6.0
166	4.1	172	3.8	Z=116				183	6.1
167	4.4	173	4.4			Z=118			
168	3.8	174	4.5	170	3.5			Z=120	
169	4.0	175	5.2	171	4.0	170	3.6		
170	3.5	176	5.1	172	4.2	171	4.2	172	4.3
171	3.8	177	5.7	173	4.8	172	4.4	173	4.9
172	3.7	178	5.8	174	4.9	173	5.0	174	5.0
173	4.3	179	6.4	175	5.5	174	5.1	175	5.6
174	4.4	180	6.3	176	5.4	175	5.7	176	5.4
175	5.1			177	6.0	176	5.5	177	5.7
176	4.9	Z=115		178	6.0	177	6.0	178	5.5
177	5.5			179	6.5	178	5.9	179	5.9
178	5.4	164	3.6	180	6.4	179	6.3	180	5.7
179	5.9	165	3.9	181	6.8	180	6.1	181	6.0
		166	3.5	182	6.4	181	6.5	182	5.5
Z=114		167	3.9			182	6.1	183	5.7
		168	3.4	Z=117				184	5.1
158	2.0	169	3.7			Z=119			
159	2.5	170	3.5	170	3.8				
160	2.7	171	4.0	171	4.4	171	4.5		
161	3.2	172	4.2	172	4.6	172	4.6		

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