NUCLEON SEPARATION ENERGIES FOR HEAVIEST NUCLEI*

O. Parkhomenko, I. Muntian, Z. Patyk and A. Sobiczewski

A. Sołtan Institute for Nuclear Studies, Hoża 69, 00-681 Warsaw, Poland

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Neutron separation energy, calculated within a macroscopic-microscopic approach, is presented for about 300 very heavy nuclei with proton number $Z = 102$–120. Systematics of this energy, treated as a function of neutron number N, is illustrated.

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1. Introduction

We concentrate in this paper on the neutron separation energy S_n of the heaviest nuclei. This quantity is obtained from masses of nuclei, calculated within a macroscopic–microscopic approach described in Refs. [1, 2]. In our previous discussion of S_n [3], it was found that the calculated values describe quite well the experimental ones for heaviest nuclei. The latter are obtained from experimental values of masses of respective nuclei [4]. The rms value of the discrepancies, obtained for 201 nuclei (from Po to No, with neutron number $N > 126$), for which experimental values of nuclear masses are well established, is 257 keV, *i.e.* quite small. Basing on this, we extend in this paper the calculations to heavier nuclei, for which S_n is not known experimentally, but it is much needed for calculation of other important quantities, *e.g.* cross sections for synthesis of these nuclei (*cf. e.g.* Refs. [5–7]).

2. Results

As most of the nuclei, for which we are going to present the calculated S_n, are well deformed, it is worth noticing that theoretical description of S_n is better for such nuclei than for spherical and transitional ones. This is illustrated in Table I, where rms of discrepancies between calculated and

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experimental values of S_n are given. Besides our macroscopic-microscopic model, specially adapted to heavy nuclei (HN) [1], two other macro-micro approaches with the macroscopic part of mass given by: Finite-Range Liquid Drop Model (FRLDM) [8] and Thomas–Fermi (TF) model [9], semi-empirical (SE) [10] and Hatree–Fock (HF) [11] approaches are considered. The HF calculations [11], quoted here for a comparison, use a 10-parameter Skyrme effective interaction to obtain the mean field. The pairing interaction is treated in them in the BCS approximation and is described by a 4-parameter δ function. In the first row of the table, rms values obtained for all 201 (spherical, transitional and deformed) nuclei with Z=84-102 and $N > 126$, for which experimental values of nuclear masses are well established, are given. The second row gives rms obtained for only these 154 of the above nuclei, which are well deformed (as these, we consider nuclei with the deformation energy $E_{\rm def} > 2$ MeV [12]). One can see that the rms values are really smaller in the latter case.

TABLE I

Rms values (in keV) of discrepancies between S_n, calculated within the SE, HN, FRLDM, TF and HF approaches, and experimental ones.

nuclei	SE	HN	FRLDM	TF	HF
all (201)	129	257	236	251	317
deformed (154)	118	188	203	215	294

Table II presents values of S_n calculated within our approach (HN) for about 300 very heavy nuclei with proton number $Z = 102$–120. Each nucleus is specified by its proton Z and neutron N numbers. The table includes 3 nuclei: ^{255}No, ^{256}No and ^{257}No, for which experimental values of S_n are known and can give us an idea how good are the calculations for these very heavy nuclei. The values are: 5.94 MeV, 7.10 MeV and 5.67 MeV, respectively. One can see that the calculated values deviate from them by 0.13 MeV, -0.09 MeV and 0.10 MeV, respectively, *i.e.* rather little. To have the size of the table as small as possible, we give only S_n for each nucleus. For many of the considered nuclei, however, deformations and masses of them may be found in Refs. [2, 13].

TABLE II

Calculated values of S_n in MeV.

N	S_n	N	S_n	N	S_n	N	S_n	N	S_n
Z=102		152	7.56	159	5.44	150	8.24	157	5.81
146	8.59	153	6.07	160	6.41	151	7.05	158	6.79
147	7.23	154	7.01	161	5.36	152	7.82	159	5.56
148	8.23	155	5.77	162	6.23	153	6.30	160	6.69
149	6.97	156	6.77	Z=103		154	7.23	161	5.56
150	7.97	157	5.58	148	8.51	155	6.01	162	6.41
151	6.83	158	6.59	149	7.21	156	6.99	Z=104	
148	8.77	159	6.38	168	6.31	173	5.45	178	6.30
149	7.44	160	7.26	169	5.00	174	6.48	Z=113	
150	8.50	161	6.25	170	6.24	175	5.42	166	7.52
151	7.30	162	7.05	Z=109		176	6.10	167	6.49
152	8.08	163	5.38	156	8.49	Z=111		168	7.29
153	6.55	164	6.21	157	7.20	160	8.57	169	6.22
154	7.48	165	5.02	158	8.32	161	7.34	170	7.22
155	6.28	166	6.10	159	7.09	162	8.41	171	6.16
156	7.25	Z=107		160	8.06	163	6.63	172	7.23
157	6.07	154	8.26	161	6.96	164	7.33	173	6.05
158	7.06	155	7.00	162	7.84	165	6.24	174	6.97
159	5.92	156	7.99	163	6.15	166	7.07	175	5.97
160	6.84	157	6.77	164	6.76	167	6.00	176	6.57
161	5.81	158	7.81	165	5.67	168	6.86	177	5.48
162	6.63	159	6.61	166	6.64	169	5.72	178	6.32
Z=105		160	7.48	167	5.41	170	6.76	179	5.52
150	8.76	161	6.48	168	6.47	171	5.81	180	6.24
151	7.52	162	7.25	169	5.18	172	6.85	Z=114	
152	8.33	163	5.56	170	6.37	173	5.69	168	7.52
153	6.78	164	6.35	171	5.23	174	6.57	169	6.47
154	7.74	165	5.16	172	6.44	175	5.55	170	7.40
155	6.51	166	6.22	Z=110		176	6.25	171	6.32
156	7.49	167	4.90	156	8.67	177	5.07	172	7.46
157	6.29	168	6.10	157	7.40	178	5.97	173	6.30
158	7.29	Z=108		158	8.52	Z=112		174	7.27
159	6.14	154	8.54	159	7.29	164	7.50	175	6.15
160	7.03	155	7.21	160	8.32	165	6.49	176	6.78
161	6.01	156	8.24	161	7.15	166	7.31	177	5.79
162	6.80	157	6.99	162	8.11	167	6.22	178	6.91
163	5.17	158	8.05	163	6.38	168	7.10	179	5.57
164	6.04	159	6.85	164	7.06	169	5.90	180	6.50
Z=106		160	7.78	165	5.96	170	7.21	181	5.32
152	8.56	161	6.73	166	6.90	171	6.00	182	6.11
153	7.03	162	7.54	167	5.71	172	7.04	183	5.06
154	8.01	163	5.83	168	6.68	173	5.87	184	5.79
155	6.76	164	6.54	169	5.47	174	6.80	Z=115	
156	7.73	165	5.40	170	6.64	175	5.83	170	8.01
157	6.55	166	6.44	171	5.61	176	6.41	171	6.65
158	7.53	167	5.17	172	6.66	177	5.28	172	7.72

Finally, Figs. 1 and 2 present the calculated S_n in a graphical form, as a function of neutron number N, for even–even nuclei with proton number Z=82-120. We present these results in two figures, to make them more clear. To better see the systematics of the calculated S_n, more isotopes of each element are considered in the figures than in the table. One can easily see strong effects of the spherical shell at $N = 126$ and the deformed one at $N = 162$. The effect of the deformed shell at $N = 152$ is much weaker.

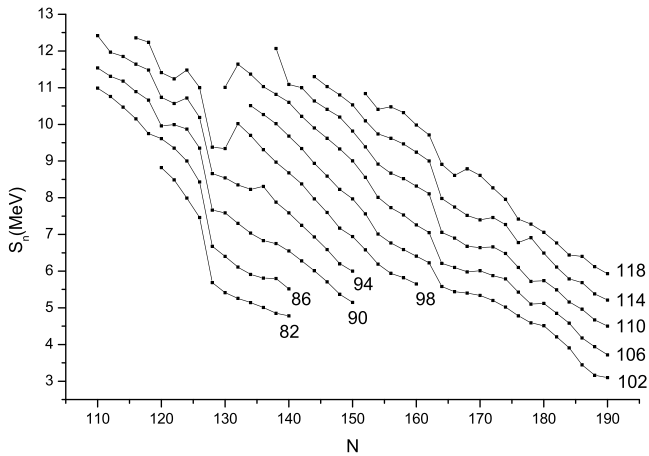

Fig. 1. Neutron separation energy S_n as a function of neutron number N for even–even nuclei with $Z = 82(4)118$.

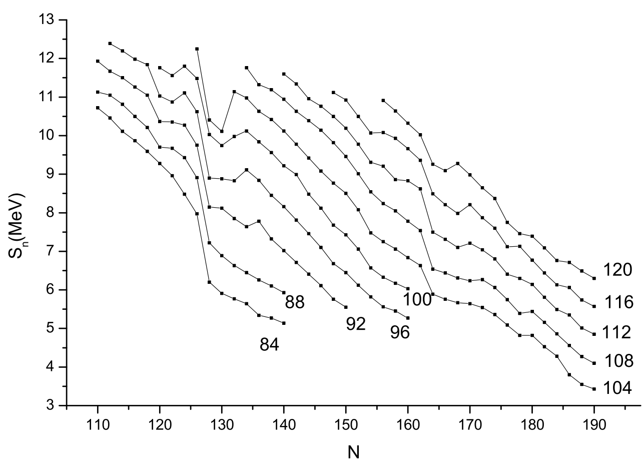

Fig. 2. Same as in Fig. 1, but for nuclei with Z=84(4)120.

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