The Absence of Stable Isotopes of Tc and Pm and Other Anomalies in the Distribution of β- stable Nuclei

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Rules are established for the distribution of atomic nuclei on the nuclear diagram; these rules are based on a criterion of the maximum binding energy of the isobar. All violations of these rules are linked to the filling of the nuclear shells. The absence of stable isotopes of the Tc and Pm is one of the particular cases of a violation of this type.

TO formulate the distribution rules for atomic nuclei, we use the criterion of maximum binding energy of an isobar: nuclei with the most densely packed neutrons and protons for a given mass number A are considered "bound" nuclei in the diagram of atomic nuclei given below. The possibility of using such a criterion was uncovered only recently, in connection with the accumulation of experimental data on the decay energies and masses of nuclei. Although the experimental data are incomplete (at present 38 isobars with maximum binding energy cannot be accurately established), they permit the formulation of certain rules.

The mass of the bound nucleus ${}_{Z}M^{A}_{\text{bound}}$ should satisfy the following inequalities:

for odd A

$$ {}_{Z+1}M^{A} - {}_{Z}M^{A}_{\text{bound}} > -0.78 \text{ MeV}, \quad \text{(Ia)}$$
$$ {}_{Z-1}M^{A} - {}_{Z}M^{A}_{\text{bound}} > +0.78 \text{ MeV}, \quad \text{(Ib)}$$

for even A (even Z)*

$$ {}_{Z+2}M^{A} - {}_{Z}M^{A}_{\text{bound}} > -1.56 \text{ MeV}, \quad \text{(IIa)}$$
$$ {}_{Z-1}M^{A} - {}_{Z}M^{A}_{\text{bound}} > +1.56 \text{ MeV}. \quad \text{(IIb)}$$

The corresponding differences in mass are given in the table of bound nuclei, compiled from data given in references 1-7**. From the list of bound nuclei it is seen that they contain β-active nuclei (with a decay energy < 0.78 MeV, equal to the difference in mass between neutron and proton). The diagram of atomic nuclei (see illustration) shows all known β-stable nuclei and all known β-active nuclei with decay energy < 0.78 MeV, and also certain β^-, β^+, and K-active nuclei of interest. The bound nuclei are marked by different symbols.

The diagram makes evident the following rules♀:

1) The differences $N - Z = I_{\text{bound}}$ between the number of neutrons and protons increases with A in the bound nuclei; in this case, because of the absence of odd-odd bound nuclei, I_{bound} assumes alternately two values for nuclei with even A; these values differ by two.

2) Nuclei with $N - Z$ constant (arranged on the diagram in one horizontal row) change their properties as A increases, in accordance with the following sequence: (a) non-bound β-active nuclei (as a rule not shown); (b) bound nuclei that are not minimum-mass isobars (frequently β^--active nuclei with decay energy less than 0.78 MeV); (c) β-stable bound nuclei, which are at the same time minimum-mass isobars; (d) non-bound β-stable nuclei; (e) β^+ and K-active nuclei (as a rule not shown). For nuclei with A even this sequence applies only to even-even nuclei.

These rules reflect the universally known fact that the increasing coulomb-repulsion energy of the protons in the nucleus is balanced by the ex-

[1] I. P. Selinov, *Atomic Nuclei and Nuclear Transmutations*, Moscow, 1951

[2] V. A. Kravtsov, Usp. Fiz. Nauk **54**, 3 (1954)

[3] N. S. Dzhelepov and L. N. Zyrianova **48**, 465 (1952)

[4] J. M. Cork, J. M. Le Blanc, W. H. Nester, and F. B. Stumpf, Phys. Rev. **88**, 685 (1952)

* Odd-odd nuclei are not considered, since as a rule they do not have the maximum binding energy. There exist only two very bound odd-odd isobars, namely H^2 and Li^6.

** See the remark in the table concerning the reliability of determination of the bound nucleus.

[5] J. M. Hollander, T. Perlman, and G. T. Seaborg, Revs. Mod. Phys. **25**, 469 (1953)

[6] A. B. Smith, C. G. Mitchell, and R. C. Caird, Phys. Rev. **87**, 454 (1952)

[7] V. A. Kravtsov, Usp. Fiz. Nauk **47**, 341 (1952)

[8] J. D. Knight, M. E. Bunker, B. Warren, and J. W. Starner, Phys. Rev. **91**, 889 (1953)

♀ The same symbol is used in the diagram to denote both bound nuclei, established with certainty, and nuclei that are assumed bound from their position on the diagram.

Table of Bound Nuclei

A (mass number)	Element	Percentage of isotope content or half life	log ft or type of decay	$_{Z+1}M^A - {}_ZM^A_{bound}$ or $_{Z+2}M^A - {}_ZM^A_{bound}$ in MeV	$_{Z-1}M^A - {}_ZM^A_{bound}$ or $_{Z-2}M^A - {}_ZM^A_{bound}$ in MeV	Reliability of determination	Reference
1	2	3	4	5	6	7	8
1	H	99.98	—	—	0.78	+	1
2	H	0.016	—	—		(+)	
3	H	12.46 years	3.06	0.018		(+)	1
4	He	100	—	—		(+)	
5	He	<10^{-8} sec	$\alpha+n$	—0.02		(+)	3
6	Li	7.3	—	—	3.2	+	1
7	Li	92.7	—	—			
8	Be	<1 sec	$\alpha+\alpha$	—	(>12.8)	+	1
9	Be	100	—	—	14.0	+	1
10	Be	$2.7\cdot10^6$ years	13.7	—0.56		(+)	1
11	B	81.2	—	—			
12	C	98.9	—	—	(>13.4)	+	1
13	C	1.1	—	—			
14	C	5720 years	9.0	—0.156		(+)	1
15	N	0.38	—	—	8.8	+	5
16	O	99.76	—	—	(>10.5)	+	1
17	O	0.04	—	—	3.7	+	1
18	O	0.2	—	—		(+)	
19	F	100	—	—	4.5	+	1
20	Ne	90.5	—	—	(>5.3)	+	1
21	Ne	0.3	—	—	>2.1	+	1
22	Ne	9.2	—	—		(+)	
23	Na	100	—	—	4.1	+	1
24	Mg	78.6	—	—	(>2.7)	+	1
25	Mg	10.1	—	—	3.4	+	1
26	Mg	11.3	—	—			
27	Al	100	—	—	2.64	+	1
28	Si	92.2	—	—	(>4.65)	+	5
29	Si	4.7	—	—	3.7	+	1
30	Si	3.1	—	—		(+)	
31	P	100	—	—	1.8	+	1
32	S	95.1	—	—	(>1.7)	+	1
33	P	25 days	5.2	—0.26		(+)	5
34	S	4.2	—	—	(>5.7)	+	1
35	S	87.1 days	5.0	—0.167		(+)	1
36	S	0.01	—	+0.37		(+)	3
37	Cl	24.6	—	—	4.3	+	1
38	A	0.06			(>4.8)	+	1
39	A	15 years	~10	—0.565	3.31	+	5
40	A	99.6	—	+0.21		(+)	3
41	K	6.9	—	—	2.55	+	1
42	Ca	0.64	—	—	(>3.5)	+	1
43	Ca	0.13	—	—	0.81	+	1
44	Ca	2.13	—	—		(+)	
45	Ca	152 days	5.98	—0.254		(+)	1
46	Ca	0.003	—	—0.028 interpolated		(+)	2
47	Sc	5.4 days	5.65	0.62	2.06	+	2
48	Ti	73.4	—	—	4.3	+	6
49	Ti	5.5	—	—	1.8	+	1
50	Ti	5.3	—	+1.05		(+)	6
51	V	99.8	—	—	2.2	+	2
52	Cr	83.8	—	—	(>4.12)	+	2
53	Cr	9.6	—	—	2.0 interpolated	+	2
54	Cr	2.4	—	0.65		(+)	2
55	Mn	100	—	—	2.85	+	2
56	Fe	91.6	—	—	(>3.69)	+	2
57	Fe	2.2	—	—	1.0	+	2
58	Fe	0.3	—	+1.7		(+)	2
59	Co	100	—	—	1.56	+	2
60	Ni	26.1	—	—	4.3	+	2

A (mass number)	Element	Percentage of isotope content or half life	log ft or type of decay	${}_{Z+1}M^A - {}_ZM^A_{\text{bound}}$ or ${}_{Z+2}M^A - {}_ZM^A_{\text{bound}}$ in MeV	${}_{Z-1}M^A - {}_ZM^A_{\text{bound}}$ or ${}_{Z-2}M^A - {}_ZM^A_{\text{bound}}$ in MeV	Reliability of determination	Reference
1	2	3	4	5	6	7	8
61	Ni	1.25	—	—	1.42	+	2
62	Ni	3.7	—	—	(>3.6)	+	2
63	Ni	300 years	7.06	—0.063		(+)	1
64	Ni	1.16	—	+1.1		(+)	2
65	Cu	30.9	—	—	2.1	+	1
66	Zn	27.8	—	—	(>2.6)	+	1
67	Cu	58.8 hours	5.5	—0.577		(+)	2
68	Zn	18.6	—	—	(>3.0)	(+)	2
69	Ga	60.2	—	—	0.897	+	2
70	Zn	0.62	—	—1.18±0.2		?	2
71	Ga	39.8	—	—	2.1	+	2
72	Ge	27.4	—	—	6.52	+	2
73	Ge	7.9	—	—	1.5	+	2
74	Ge	36.3	—	+1.2		(+)	2
75	As	100	—	—	1.1	+	1
76	Se	9.0	—	—	2.2	+	2
77	As	40 hours	5.75	—0.7	2.46	+	5
78	Se	23.5	—	+3.1	5	+	2
79	Se	0.5·10⁴ years	~9	—0.150	2.1	+	5
80	Se	49.8	—	—0.16		(+)	2
81	Br	49.5	—	—	1.38	+	
82	Kr	11.5	—	—	3.5	+	2
83	Kr	11.48	—	—	0,98	+	2
84	Kr	57.0	—	0.7 interpolated	4.68	+	2
85	Kr	9.4 years	9.22	—0.695	2.5	+	1
86	Kr	17.4	—	—1.18		(+)	2
87	Rb	16·10¹⁰ years	16.5	—0.27	3.6	+	2
88	Sr	82.7	—	—	7.0	+	2
89	Y	100	—	—	1.463	+	1
90	Zr	51.4	—	—	2.83	+	2
91	Zr	11.2	—	—	1.55	+	2
92	Zr	17.1	—	+1.25	(>4.7)	+	2
93	Zr	15·10⁶ years	11.5	—0.060	3.1	+	1
94	Zr	17.4	—	—1.14	(>6.8)	+	2
95	Mo	15.7	—	—	0.91	+	5
96	Mo	16.6	—	+2.8	3.6	+	2
97	Mo	9.5	—	—	1.93	+	2
98	Mo	23.8	—	+0.04 interpolated		(+)	2
99	Tc	5·10⁵ years	12.7	—0.29	1.37	+	5
100	Ru	12.7	—	—	2.4 interpolated	+	2
101	Ru	17.0	—	—	1.5	+	1
102	Ru	31.3	—	+1.1		(+)	2
103	Ru	43. days	8.25	—0.75		(+)	5
104	Ru	18.3	—	—1.2 interpolated		(+)	2
105	Rh	3.6 hours	5.5	—0.57	2.01	+	5
106	Pd	27.2	—	+2.7	3.57	+	2
107	Pd	7·10⁶ years	11	—0,035	1.2	+	1
108	Pd	26.8	—	+0,18		(+)	2
109	Ag	48.6	—	—	1.1	+	1
110	Cd	12.4	—	—	1.23±0,24	?	2
111	Cd	12.7	—	—	1.0	+	1
112	Cd	24.1	—	+1.9	4.32	+	2
113	Cd	12.2	∞	—0.18	2.1	+	5
114	Cd	28.9	—	—0.31		(+)	2
115	In	6·10¹⁴ years	23.2	—0.63	1.45	+	1
116	Sn	14.4	—	—	2.5	+	2
117	Sn	7.54	—	—	1.73	+	2
118	Sn	24.0	—	—	(>1.5)	+	5
119	Sn	8.6	—	—	2.7	+	1
120	Sn	33.0	—	+2,15		(+)	2

A (mass number)	Element	Percentage of isotope content or half life	log *ft* or type of decay	$_{Z+1}M^A - {}_{Z}M^A_{bound}$ or $_{Z+2}M^A - {}_{Z}M^A_{bound}$ in MeV	$_{Z-1}M^A - {}_{Z}M^A_{bound}$ or $_{Z-2}M^A - {}_{Z}M^A_{bound}$ in MeV	Reliability of determination	Reference
1	2	3	4	5	6	7	8
121	Sn	400 days	9,4	—0.38		(+)	2
122	Sn	4.8	—	—0.49		(+)	2
123	Sb	42.7	—	+0.09	1.41	+	2
124	Te	4.63	—	—	2.1	+	2
125	Sb	2.7 hours	9.4	—0.76	2.4	+	5
126	Te	18.7	—	+0.84	(>2)	+	2
127	Te	9.3 hours	5.6	—0.9	1.9	+	2
128	Te	31.7	—	—1.56±0,2		?	2
129	I	$1.7\cdot10^7$ years	13,4	—0,17	2.6	+	2
130	Xe	4.05	—	+2.53	3.4	+	2,6
131	Xe	21.2	—	—	0.97	+	2
132	Xe	26.9	—		3.1		2
133	Xe	5.7 days	5.7	—0.43	1.93	+	5
134	Xe	10.5	—		(>3.9)		2
135	Cs	$2\cdot10^6$ years	13.9	—0.21	1.15	+	5
136	Ba	7.8	—		0.27	—*	2
137	Ba	11.3	—	—	1.2	+	5
138	Ba	71.7	—	—	5.1		1
139	La	99.9	—	—	2.27	+	1
140	Ce	88.5	—	—	4.91	+	5
141	Ce	33.1 days	7.72	—0.56	2.9	+	1
142	Ce	11.1	—				
143	Nd	12.2	—	—	0.93	+	5
144	Nd	23.9	—		(>3.5)		1
145	Nd	8.3	—	—	3.2	+	1
146	Nd	17.2	—	—	(>3)	+	1
147	Pm	3.5 hours	7.6	—0.227	0.91	+	1
148	Sm	11.3	—	—			
149	Sm	13.9	—	—	1.1	+	1
150	Sm	7.5	—	—	>3.0	+	5
151	Sm	500 years	8.3	—0.076	1.1	+	5
152	Sm	26.6	—				
153	Eu	52.2	—	—	>0.80	+	5
154	Gd	2.15	—	—			
155	Eu	1.72 years	7.1	—0.3	1.9	+	1
156	Gd	20.8	—		>3.3		1
157	Gd	15.7	—	—	1.8	+	1
158	Gd	24.8	—		(>2.5)		1
159	Tb	100	—	—	>0.95	+	1
160	Dy	2.3	—	—			
161	Tb	240 days	6.7	—0.52	>1.5	+	4
162	Dy	25.5	—				
163	Dy	25.0	—	—			
164	Dy	28.1	—				
165	Ho	100	—	—	1.3	+	1
166	Er	32.9	—	—	(>1.9)	+	5
167	Er	24.4	—	—			
168	Er	26.9	—				
169	Er	9.4 days	6.10	—0.33		(+)	1
170	Er	14.2	—				
171	Tu	500 days	6.3	—0.10	≥1.49	+	5
172	Yb	11,9	—	—		(+)	
173	Yb	16.2	—	—			

* *Note added in proof.* Certain mass differences in the table are based on reference 2, published after this article was submitted. According to that reference, another violation of rule 2 is observed: the $_{54}Xe^{136}_{82}$ nucleus has a greater binding energy than the $_{56}Ba^{136}_{80}$ nucleus, designated as bound on the diagram and in the table. This is apparently due to presence of a closed shell $N = 82$ in Xe ^{136}

A (mass number)	Element	Percentage of isotope content or half life	log *ft* or type of decay	$_{Z+1}M^A - {}_ZM^A_{bound}$ or $_{Z+2}M^A - {}_ZM^A_{bound}$ in MeV	$_{Z-1}M^A - {}_ZM^A_{bound}$ or $_{Z-2}M^A - {}_ZM^A_{bound}$ in MeV	Reliability of determination	Reference
1	2	3	4	5	6	7	8
174	Yb	31.8	—				
175	Yb	99 hours	6.4	—0.5		(+)	1
176	Yb	12.0	—				
177	Lu	6.9 days	6.8	—0.49	1.3	+	5
178	Hf	27.1	—	—			
179	Hf	13.8	—	—			
180	Hf	35.1	—				
181	Ta	100	—	—	1.02	+	5
182	W	26.3	—	—			
183	W	14.3	—	—			
184	W	30.6	—				
185	W	73 days	7.5	—0.57	⩾1.7	+	5
186	W	28.6	—	—			
187	Re	$4\cdot10^{12}$ years	17.7	—0.043	1.32	+	1
188	Os	13.3	—	—	>2.07	+	1
189	Os	16.1	—	—	>1.2	+	5
190	Os	26.4	—				
191	Os	15 days	5.34	—0.27		(+)	
192	Os	41.0	—				
193	Ir	61.5	—	—	1.16	+	
194	Pt	32.8	—	—	(>2.5)	+	
195	Pt	33.7	—	—	>1.8	+	5
196	Pt	25.4	—	+1.02		(+)	7
197	Pt	18 hours	6.3	—0.73	>1.65	+	7
198	Pt	7.2	—	—1.02	(>3.6)	+	7
199	Au	33 days	7.8	—0.46	1.8	+	7
200	Hg	23.2	—	—	(>2.4)	+	7
201	Hg	13.5	—	—	>1.5	+	5
202	Hg	29.6	—	+1.4 interpolated		(+)	7
203	Hg	43.5 days	—	—0.487	>1.9	+	7
204	Hg	6.69	—	—0.56		(+)	7
205	Tl	70.5	—	—	1.75	+	7
206	Pb	25.1	—	+9.4 interpol.	2.9 interpol.	+	7
207	Pb	21.1	—	+1.8 interpol.	1.44	+	7
208	Pb	53.4	—	+3.9	(>4.9)	+	7
209	Pb	3.24 hours	5.64	—0.68	1.8	+	1
210	Pb	22 years	6.02	—1.24	(>1.8)	+	1
211	Bi	2.16 min		—0.25	1.39	+	7
212	Po	$3.4\cdot10^{-7}$ sec	α	+1.41	2.83	+	7
213	Po	$4.4\cdot10^{-5}$ sec		—0.6	1.25	+	7
214	Po	$1.4\cdot10^{-4}$ sec	α	—1.0	4.55	+	7
215	At	10^{-4} sec	α	+0.37 interpolated	1.1	+	7
216	Em	10^{-5} sec	α		1.6	+	7
217	At	0.021 sec		—0.56	1.78 interpol.	+	7
218	Em	0.019 sec	α	(>1.77)	3.63	+	7
219	Em	3.92 sec		—0.62		(+)	7
220	Em	54.4 sec	α	—0.41		(+)	7
221	Fr	4.8 min		—0.046	1.58 interpolated	+	7
222	Ra	38 sec	α	(2.2)	12.33	+	7
223	Ra	11.2 days	α	+3.2	1.2	+	7
224	Ra	3.64 days	α	+0.13		(+)	7
225	Ra	14.8 days	6.08	—0.2		(+)	7
226	Ra	1622 years	α	—0.84		(+)	7
227	Ac	21.7 years	∼5	—0.37	1.21 interpolated	+	7
228	Th	1.9 years	α	+2.32	(>2.58)	+	7
229	Th	$7\cdot10^{3}$ years	α	—	1.0	+	7
230	Th	$8\cdot10^{4}$ years	α	+0.37	3.35	+	7
231	Th	25.5 hours	5.07	—0.32		(+)	7
232	Th	$1.5\cdot10^{10}$ years	α	—0.96		(+)	7
233	Po	27.9 days	6.63	—0.62	1.23	+	7
234	U	$2.5\cdot10^{5}$ years	α	+3.0	4.1	+	7

Diagram of the nuclei. The mass number A is plotted horizontally, and the difference between the number of protons and neutrons is plotted vertically.

A (mass number)	Element	Percentage of isotope content or half life	log ft or type of decay	$_{Z+1}M^A - _ZM^A_{\text{bound}}$ or $_{Z+2}M^A - _ZM^A_{\text{bound}}$ in MeV	$_{Z-1}M^A - _ZM^A_{\text{bound}}$ or $_{Z-2}M^A - _ZM^A_{\text{bound}}$ in MeV	Reliability of determination	Reference
1	2	3	4	5	6	7	
235	U	$7.7\cdot10^8$ years	α	+0.18	1.4	+	7
236	U	10^8 years	α	+0.046		(+)	7
237	U	6.63 days	6,04	—0.511		(+)	5
238	U	$5\cdot10^9$ years	α	$-1.56\pm0,60$		?	7
239	Np	2.31 days		—0.715	>1.2	+	7
240	Pu	6000 years	α	+1.17	2.516	+	7,5
241	Pu	10 years		—0.18	>0.89	+	7,8

Notes on Table:

a) A line is drawn through column 5 if the nuclei $_{Z+1}M^A$ and $_{Z+2}M^A$ are β^+ or K-active [in this case equations (Ia) and (IIa) are always satisfied];

b) the figure in column 6 is placed in parentheses in the case of bound nuclei with even A, when the nucleus $_{Z-2}M^A$ is β-active and the determination is based on the decay energy of the odd-odd nucleus $_{Z-1}M^A$;

c) A + is placed in column 7 when the nodal nucleus is definitely established, and a (+) is placed when equations (Ib) and (IIb) cannot be verified for β^- active bound nuclei and for individual β-stable even-even isobars; a negative result of such a verification is not very likely. The doubtful cases A = 70, 110, 128, and 238 are marked?; here the data in the literature are contradictory and insufficiently accurate, and the average of two measurement data, cited in reference 2 cannot be considered fully reliable;

d) if interpolated data from survey articles [2,7] are used, the abbreviation (int) is placed next to the figures in columns 5 and 6.

cess neutrons. Of interest are the cases of violation of these rules. As can be seen from the diagram, violations occur in those regions, where the nuclei with filled proton and neutron shells (doubly-magic nuclei) are located to the side of the basic line of bound nuclei. Near the doubly-magic nuclei $_{20}Ca^{40}_{20}$, $_{20}Ca^{48}_{28}$, the sequence is disrupted in the variation of the property of the nuclei (rule 2) for $N - Z$ = 3 and 8 respectively: the β^- active nucleus A^{39} is located between the β-stable nuclei Cl^{37} and K^{41}, as a result of the anomalously high binding energy of the K^{39} nucleus. The β^--stable nucleus Ca^{48} is located among β^--active nuclei; it is followed by three β^--active nuclei: Ti^{52}, Cr^{56}, and Fe^{60}, and only then by the β-stable nucleus Ni^{64}. In the vicinity of the "peripherally" located doubly-magic nuclei $_{28}Ni^{68}_{40}$, $_{40}Zr^{90}_{50}$ [9], and $_{58}Ce^{140}_{82}$ [10,11] rule 2 is violated for $N - Z$ equal to 7,9,10,11,12,13,14 and 20, 23, 25, and 28, respectively (see diagram). Also Also violated is rule for the bound nuclei Cu^{67} Y^{89}, Zr^{90}, Zr^{91}, Mo^{95}, and Nd^{143}, respectively. The character of these violations points to an anomalously large binding energy of Ni^{68}, Zr^{90}, and Ce^{140}. In those cases when the doubly-magic nuclei $_2He^4_2$, $_8O^{16}_8$, $_{50}Sn^{120}_{70}$ [9] and $_{82}Pb^{208}_{125}$ follow rigorously the curve of bound nuclei, no violation of rules 1 and 2 is observed.

The dotted lines on the diagram denote the absence of bound nuclei with N = 17, 39, 43, 73, 91, 95, and 131, and with Z = 41 (Nb) and 59 (Pr). As is well known, there are no β-stable nuclei with N = 19, 21, 35, 39, 45, 61, 84, 115, and 123, and with Z = 43 (Tc) and 61 (Pm). These two series of numbers have only N = 39 in common. The absence of bound nuclei for seven values of N (and it is possible that there may be more values, for the experimental data are incomplete) cannot be considered an anomaly. In fact, in bound nuclei with A odd, I_{bound} increases, as a rule by two for certain values of Z, because N also increases by two. If these transient isotopes have an odd Z, there will be two bound isotopes with odd Z, and there will be no bound nucleus with odd N (for example, the sequence of bound nuclei $_{14}Si^{19}$, $_{15}P^{31}_{16}$, $_{15}P^{33}_{18}$, $_{16}S^{35}_{19}$ contains no bound nucleus with N = 17, but contains instead two bound phosphorus isotopes with Z = 15). If the transient isotopes have an

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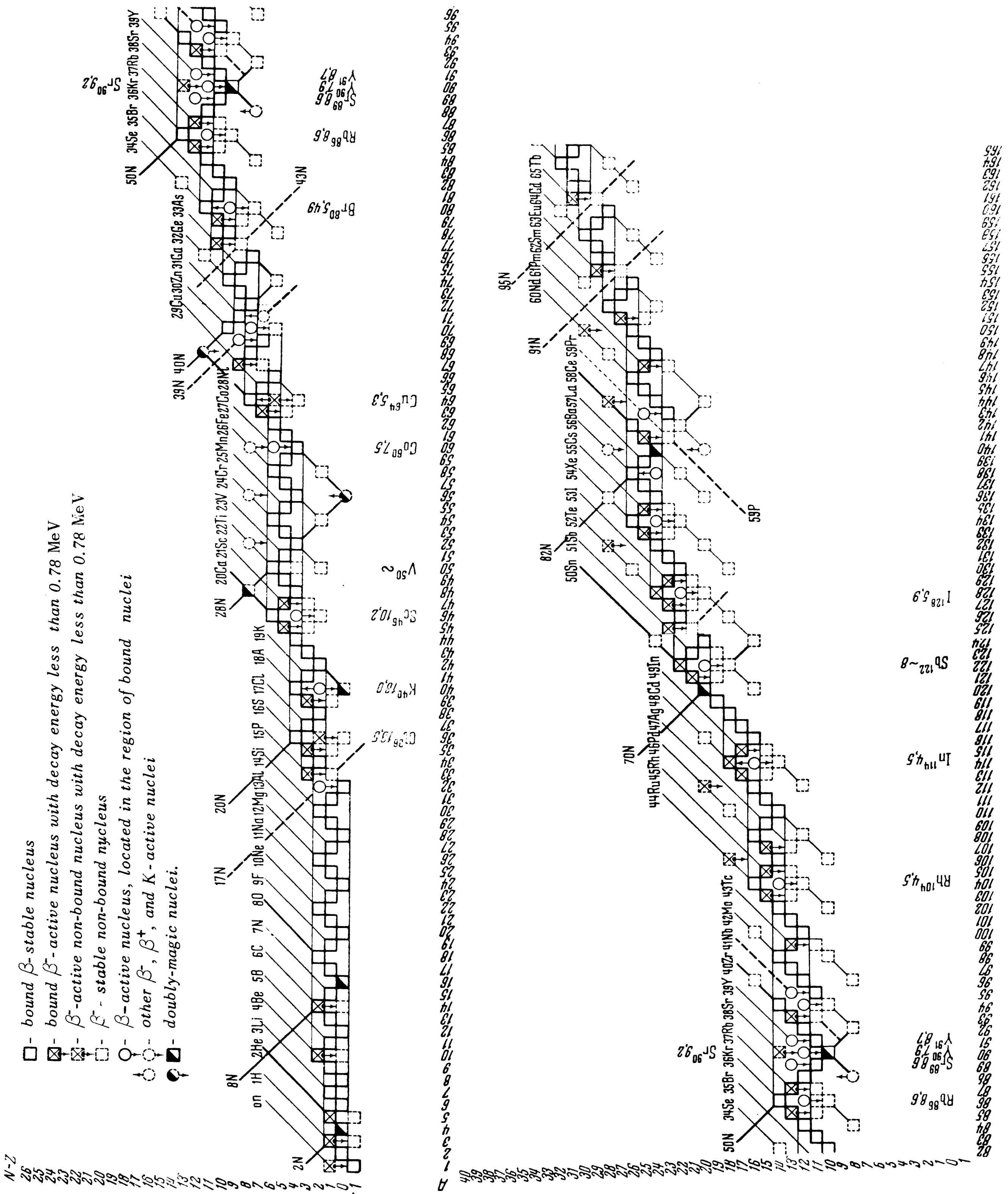
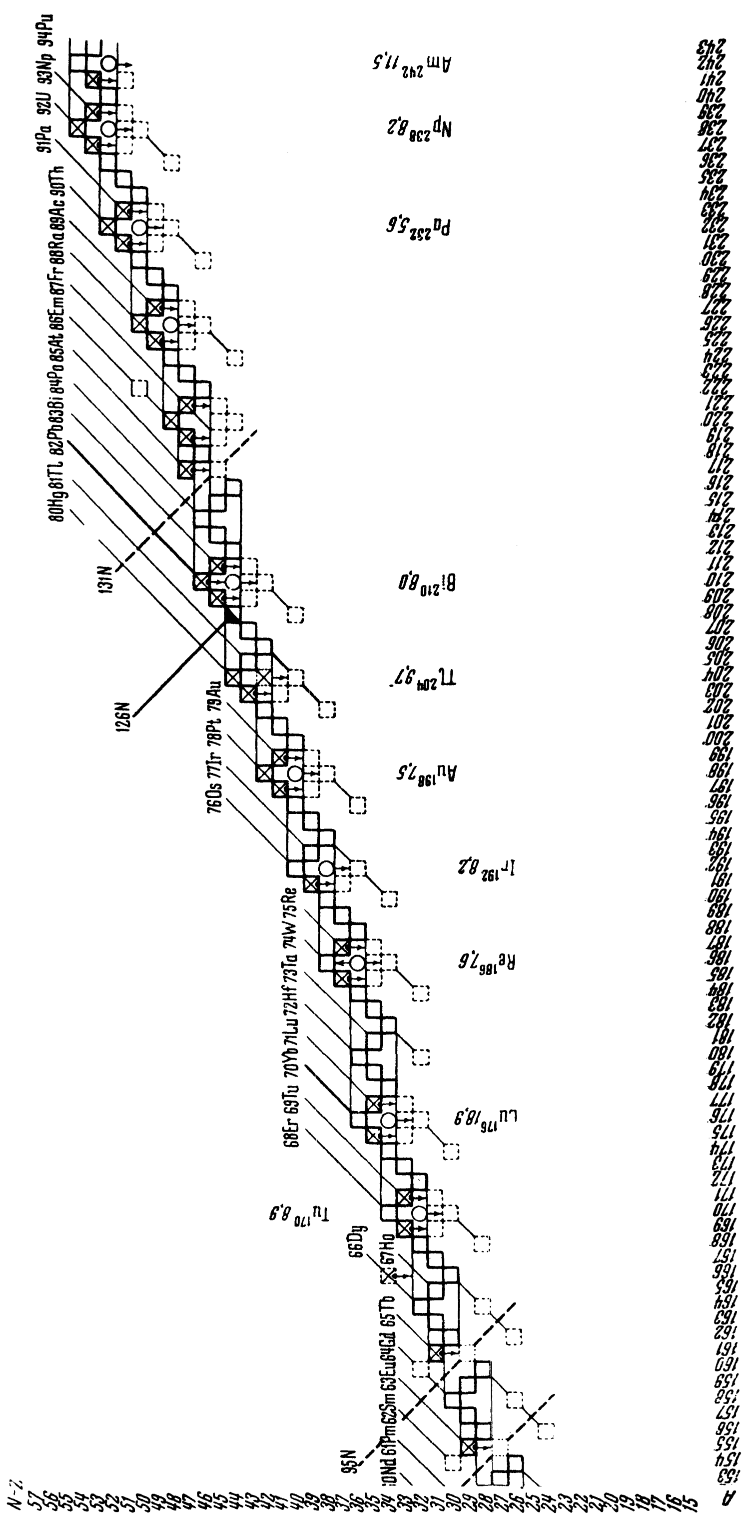

bound β-stable nucleus
bound β⁻-active nucleus with decay energy less than 0.78 MeV
β⁻-active non-bound nucleus with decay energy less than 0.78 MeV
β⁻-stable non-bound nycleus
β-active nucleus, located in the region of bound nuclei
other β⁻, β⁺, and K-active nuclei
doubly-magic nuclei.
N-Z
A


131N
126N
95N
N-Z
A

even Z, no absence of bound nuclei with some odd N will be observed; consequently there will be no two bound isotopes with identical odd Z (for example, the sequence $_{37}Co^{59}_{32}$, $_{28}Ni^{61}_{33}$, $_{28}Ni^{63}_{35}$, and $_{29}Cu^{65}_{36}$). Both possibilities have equal probability, and it can therefore be expected that, in approximately half the cases, the absence of nodal nuclei with an odd number of neutrons will be observed. At the present time this is known to occur for 7 out of 27 possible cases (I_{bound} changes 27 times). Analogous considerations should apply also to β- stable nuclei with odd A (minimum-mass criterion approximating the maximum-binding-energy criterion). In fact, it is because the absence of β- stable nuclei with odd N is always accompanied by the presence of a pair of β- stable isotopes with odd Z.

From our point of view the only things that can be considered anomalies in the distribution are the absence of bound nuclei with $Z = 41$ and 50, and the absence of both bound and β- stable nuclei for $N = 39$. All these anomalies are simultaneous violations of rules 1 and 2 in the vicinity of the peripheral doubly-magic nuclei $_{28}Ni^{68}_{40}$, $_{40}Zr^{90}_{50}$, and $_{58}Ce^{140}_{82}$. The numbers 41 and 59 each exceed by one the magic numbers 40 and 58, while 39 is one less than the magic number 40. In the same region anomalies are also observed in the distribution of the β- stable isotopes -- the absence of stable isotopes of Tc ($Z = 43$) and Pm ($Z = 61$), but the connection of these anomalies with the filling of the nuclear shell is not as pronounced as the anomalies in the distribution of the bound nuclei.

The table lists the values of log ft for β- active bound nuclei[5,12,13]. Similar data are also given on the margin of the diagram for certain β- active nuclei for which the ratio between the number of neutrons and protons should be particularly convenient, starting with the normal course of the bound-nuclei curve. These are odd-odd nuclei, located in the transition regions, where $N - Z$ increases by four for the bound even-even nuclei, and also such β- active nuclei as Sr^{89} and others, which would have been bound were it not for the anomalously excessive binding energy of the doubly-magic nucleus Zr^{90} and of the neighboring nuclei.

All these β-transitions are in most cases rigorously forbidden, and among them are most transitions in the forbidden form of the β - spectrum (except one). This circumstance indicates the dependence of the degree of forbidenness of the beta transition, in addition to all other factors, on the position of the nucleus in the atomic-nuclei diagram.

Thus , attempts to explain the anomalies in the distribution of the β- stable nuclei by the presence of some other special nuclear configurations, other than the known nuclear shells, must be considered to be in error; all the anomalies are due to the filling of the nuclear shells, although this cannot be always established off hand.

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Translated by G. J. Adashko
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