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PATTERN IN THE DIFFERENCE OF MASS NUMBERS

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Abstract

This paper includes the findings of empirical research. In the case of stable isotopes of an element (with even number of Z), the heaviest stable isotope possesses the maximum number of neutrons (the N/Z ratio remains high). Such nuclides of elements and the longest-lived nuclides (in the case Z > 82) are taken. The two nearest elements (with even-even atomic numbers) are taken, and the difference of Mass numbers of nuclides is determined. Up to naturally occurring uranium, such values are recorded. It is found that the maximum number of nucleons increased from one element to another element remains 6 normally (if don't include the case found near the Magic numbers). And thus, the maximum number of neutrons increased remains 4. Then, the trends near the first unbound proton-rich nuclides and the first unbound neutron-rich nuclides of elements are identified, and a comparison is made. The remarkable result is found. The pattern in the difference of Mass numbers helps predict the one-neutron drip lines for the elements.

Key Words: *Mass number, Magic number, Neutron drip line*

1.Introduction

Mass number (also known as Nucleon number) is used to organize the nuclide chart. Unlike the nuclear mass, the Mass number is an integer. It is not easy to predict the exact values of nuclear mass. Even a small error in the value of nuclear mass causes the large deviation in the value of neutron separation energy. And thus, the location of neutron drip line changes by several units. But this problem can be avoided if one thinks differently. The pattern in the difference of Mass numbers helps predict the one-neutron drip lines of the elements. In this paper, the one-neutron drip lines are predicted with the help of trends found.

From the different regions of the valley of stability, the nuclides are taken for making comparison. The heaviest stable nuclides, the first unbound proton-rich nuclides and the neutron-rich nuclides just before first unbound nuclides are considered. The two nearest elements (with even-even, or odd-odd atomic numbers) are taken, and the difference of Mass numbers of nuclides is determined.

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2. Heaviest Stable Nuclide of the Element

Take the heaviest stable nuclides of the elements **[1, 2, 3]**. In the case of elements with Atomic number (Z) greater than 82, the longest-lived isotopes are considered.

^{46}Ca , ^{50}Ti , ^{54}Cr , ^{58}Fe , ^{64}Ni , ^{70}Zn , ^{74}Ge , ^{80}Se , ^{86}Kr , ^{88}Sr , ^{94}Zr , ^{98}Mo , ^{104}Ru , ^{110}Pd , ^{114}Cd , ^{124}Sn , ^{126}Te , ^{134}Xe , ^{138}Ba , ^{142}Ce , ^{148}Nd , ^{154}Sm , ^{160}Gd , ^{164}Dy , ^{170}Er , ^{176}Yb , ^{180}Hf , ^{186}W , ^{192}Os , ^{198}Pt , ^{204}Hg , ^{208}Pb , ^{209}Po , ^{222}Rn , ^{226}Ra , ^{232}Th , ^{238}U.

(The elements lighter than calcium can be added)

2.1. Now, determine the difference of Atomic numbers (ΔZ) of the nearest elements. For example;

ΔZ = 2, $_{22}$Ti, $_{20}$Ca; similarly, ΔZ = 2, $_{24}$Cr, $_{22}$Ti; ΔZ = 2, $_{26}$Fe, $_{24}$Cr; ΔZ = 2, $_{92}$U, $_{90}$Th; and so on.

2.2. Take the Mass number (A) of each nuclide. And then determine the difference of Mass numbers (ΔA), taking the two nearest elements. The two nearest elements form a set. See the following sets and the values of ΔA;

Set	ΔA	Elements
1	**4**	^{50}Ti, ^{46}Ca
2	**4**	^{54}Cr, ^{50}Ti
3	**4**	^{58}Fe, ^{54}Cr
4	**6**	^{64}Ni, ^{58}Fe
5	**6**	^{70}Zn, ^{64}Ni
6	**4**	^{74}Ge, ^{70}Zn
7	**6**	^{80}Se, ^{74}Ge
8	**6**	^{86}Kr, ^{80}Se
9	**2**	^{88}Sr, ^{86}Kr
10	**6**	^{94}Zr, ^{88}Sr
11	**4**	^{98}Mo, ^{94}Zr
12	**6**	^{104}Ru, ^{98}Mo
13	**6**	^{110}Pd, ^{104}Ru

14	**4**	^{114}Cd, ^{110}Pd
15	**10**	^{124}Sn, ^{114}Cd
16	**2**	^{126}Te, ^{124}Sn
17	**8**	^{134}Xe, ^{126}Te
18	**4**	^{138}Ba, ^{134}Xe
19	**4**	^{142}Ce, ^{138}Ba
20	**6**	^{148}Nd, ^{142}Ce
21	**6**	^{154}Sm, ^{148}Nd
22	**6**	^{160}Gd, ^{154}Sm
23	**4**	^{164}Dy, ^{160}Gd
24	**6**	^{170}Er, ^{164}Dy
25	**6**	^{176}Yb, ^{170}Er
26	**4**	^{180}Hf, ^{176}Yb
27	**6**	^{186}W, ^{180}Hf
28	**6**	^{192}Os, ^{186}W
29	**6**	^{198}Pt, ^{192}Os
30	**6**	^{204}Hg, ^{198}Pt
31	**4**	^{208}Pb, ^{204}Hg
32	**1**	^{209}Po, ^{208}Pb
33	**13**	^{222}Rn, ^{209}Po
34	**4**	^{226}Ra, ^{222}Rn
35	**6**	^{232}Th, ^{226}Ra
36	**6**	^{238}U, ^{232}Th

Table A. 1, The exceptional values are noticed.

2.3. Now, make a chart taking the values of ΔA.

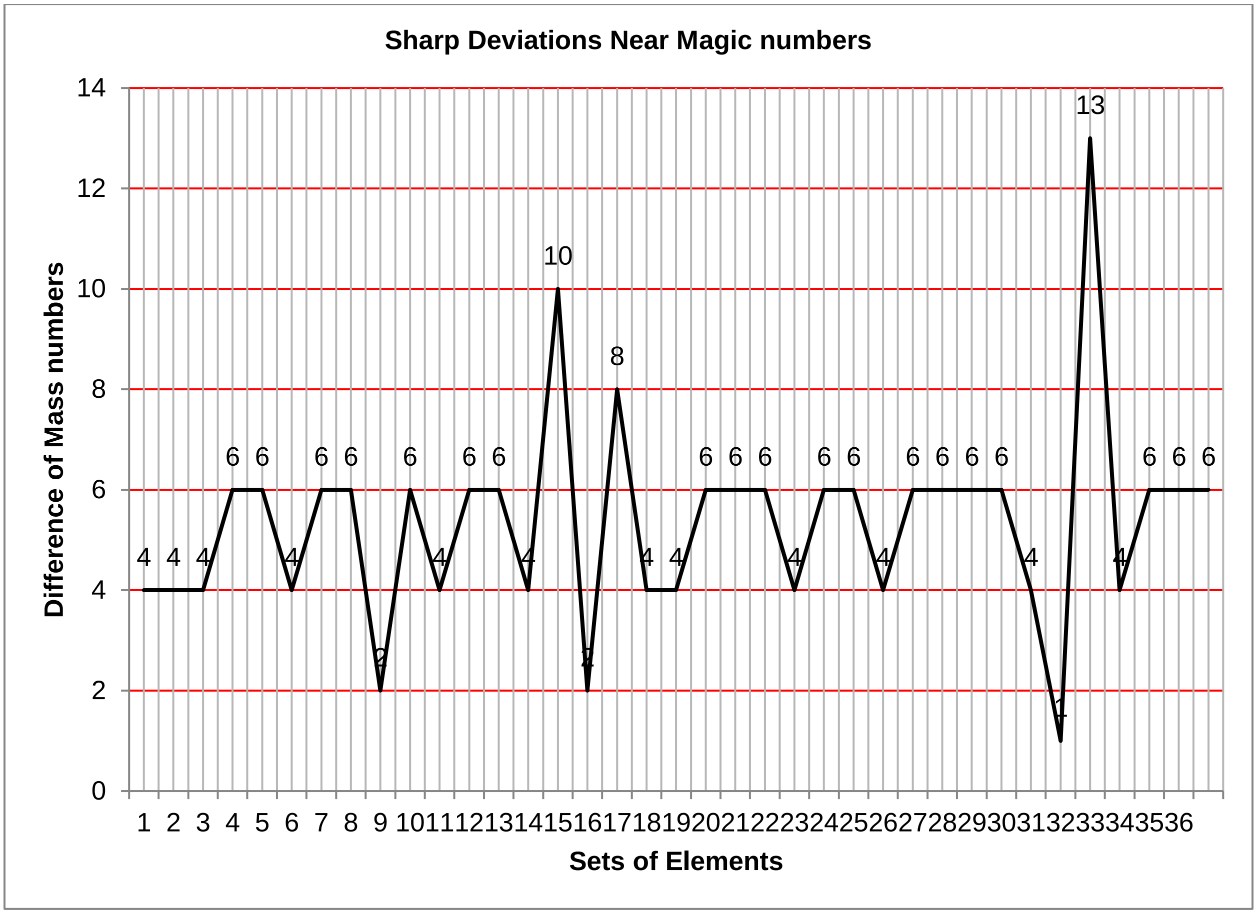

Fig. A. 1, The trends in the case of heaviest stable nuclides of elements.

2.4. See the chart carefully. Near the electron Magic numbers (36, 54 and 86) **[4]** or the proton Magic numbers (50 and 82) **[4]**, the remarkable deviations are achieved. Near the Magic numbers, the values 10, 8 and 13 can be seen. These values seem infrequent and exceptional. Take the most frequent and higher value of ΔA. This is found 6. Determine the value of ΔA/ΔZ ratio. Such value remains 3.0.

3. Comparison and Assessment

Now, the first unbound proton-rich nuclides of elements (with odd numbers of Z) are taken to identify the trends. The elements with odd numbers of Z show the known or confirmed values.

Take these elements **[1, 3]**. The two nearest elements form a set. See the following sets and the values of ΔA:

Set	ΔA	Elements
1	**3**	^{42}V, ^{39}Sc
2	**3**	^{45}Mn, ^{42}V
3	**5**	^{50}Co, ^{45}Mn
4	**5**	^{55}Cu, ^{50}Co
5	**4**	^{59}Ga, ^{55}Cu
6	**6**	^{65}As, ^{59}Ga
7	**4**	^{69}Br, ^{65}As
8	**4**	^{73}Rb, ^{69}Br
9	**4**	^{77}Y, ^{73}Rb
10	**4**	^{81}Nb, ^{77}Y
11	**4**	^{85}Tc, ^{81}Nb
12	**4**	^{89}Rh, ^{85}Tc
13	**4**	^{93}Ag, ^{89}Rh
14	**4**	^{97}In, ^{93}Ag
15	**8**	^{105}Sb, ^{97}In
16	**5**	^{110}I, ^{105}Sb
17	**5**	^{115}Cs, ^{110}I
18	**4**	^{119}La, ^{115}Cs
19	**4**	^{123}Pr, ^{119}La
20	**5**	^{128}Pm, ^{123}Pr
21	**6**	^{134}Eu, ^{128}Pm
22	**5**	^{139}Tb, ^{134}Eu
23	**6**	^{145}Ho, ^{139}Tb
24	**4**	^{149}Tm, ^{145}Ho

25	**6**	^{155}Lu, ^{149}Tm
26	**4**	^{159}Ta, ^{155}Lu
27	**6**	^{165}Re, ^{159}Ta
28	**6**	^{171}Ir, ^{165}Re
29	**6**	^{177}Au, ^{171}Ir
30	**4**	^{181}Tl, ^{177}Au
31	**8**	^{189}Bi, ^{181}Tl
32	**6**	^{195}At, ^{189}Bi
33	**6**	^{201}Fr, ^{195}At
34	**6**	^{207}Ac, ^{201}Fr
35	**7**	^{214}Pa, ^{207}Ac

Table A.2, The values 8, 8 and 7 seem exceptional.

(The elements lighter than scandium can be added)

3.1. Now, make a chart taking the values of ΔA.

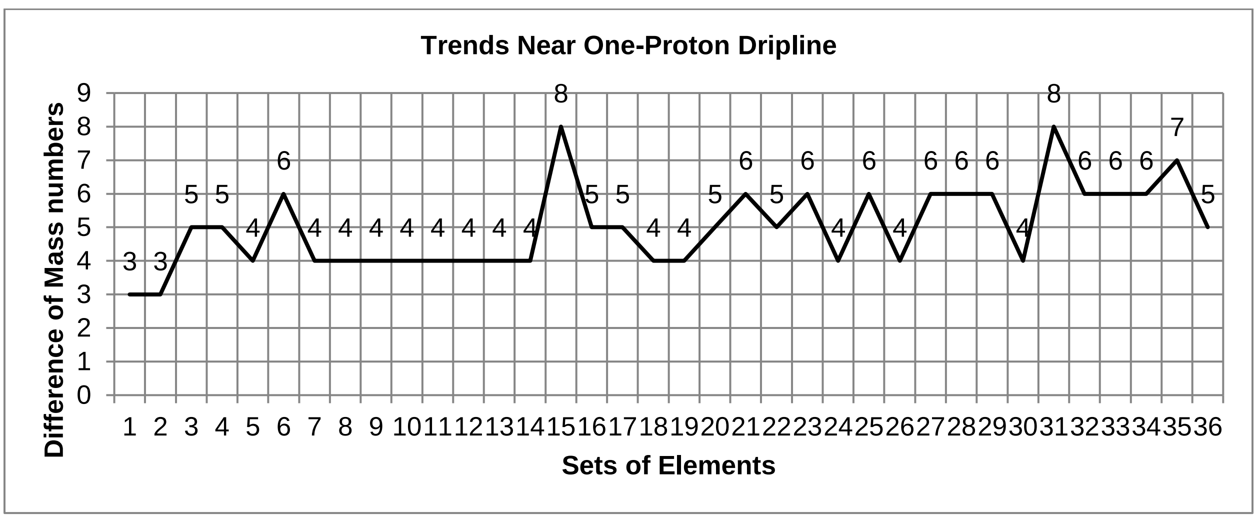

Fig. A. 2, Near Magic numbers the exceptional values are noticed.

3.2. See that in the set of elements, the maximum number of nucleons increased from one element to another element remains 6 normally (if don't include the case found near the Magic numbers, or some exception).

Near the electron Magic numbers (86) **[4]** or the proton Magic numbers (50 and 82) **[4]**, the values 7, 8 and 8 can be seen. These values seem infrequent and exceptional.

4. Isotopes Near the First Unbound Neutron-rich Nuclides

Then the trends near the first unbound neutron-rich nuclides of elements are identified.

The neutron rich isotopes found just before the first unbound nuclides or very short-lived radioactive nuclides of the elements **[1, 3, 5, 6]** are taken. The two nearest elements form a set. See the following sets and the values of ΔA:

Set	1	2	3	4	5	6	7	8	9
ΔA	8	8	4	8	6			6	4
Elements	^{12}Be, ^{4}He	^{20}C, ^{12}Be	^{24}O, ^{20}C	^{32}Ne, ^{24}O	^{38}Mg, ^{32}Ne			^{56}Ar, ^{50}S	^{60}Ca, ^{56}Ar
Set	1	2	3	4	5	6	7	8	9
ΔA	6	6	8	4	8			6	4
Elements	^{9}Li, ^{3}H	^{15}B, ^{9}Li	^{23}N, ^{15}B	^{27}F, ^{23}N	^{35}Na, ^{27}F			^{53}Cl, ^{47}P	^{57}K, ^{53}Cl

Table A. 3, Elements with even-even or odd-odd numbers of Z.

4.1. In the above Table, near the electron Magic numbers (2 and 10) **[4]** or the proton Magic numbers (2 and 8) **[4]** the value 8 can be seen.

Once again in the set of elements, the maximum number of nucleons increased from one element to another element remains 6 (if don't include the case found near the Magic numbers, or some exception). The value of ΔA/ΔZ ratio remains 3.0.

5. Conclusion

After taking data from the different regions of the valley of stability and analyzing them, it is found that the maximum number of nucleons increased from one element to another element remains the same, normally. And it remains 6 (six).

Now think again about the neutron-rich nuclides noticed just before the first unbound nuclides or very short-lived radioactive nuclides of the elements **[1, 3, 5, 6]**. The value of A remains about 3Z (except in the case of Z = 2, a Magic number). The value of A/Z ratio remains not far from the value of ΔA/ΔZ ratio (i.e., 3.0). This slight difference seems the result of Magic numbers' effect.

With the help of identified trends, the one-neutron drip lines for some elements are predicted:

Z	A	A/Z
1	3 (equal to 3Z, or 3Z + 0)	3.0
2	4 (2Z + 0)	2.0
3	9 (3Z + 0)	3.0
4	12 (3Z + 0)	3.0
5	15 (3Z + 0)	3.0
6	20 (3Z + 2)	3.33
7	23 (3Z + 2)	3.28
8	24 (3Z + 0)	3.0
9	27 (3Z + 0)	3.0
10	32 (3Z + 2)	3.2
11	35 (3Z + 2)	3.18
12	38 (3Z + 2)	3.16
15	47 (3Z + 2)	3.13
16	50 (3Z + 2)	3.12
17	53 (3Z + 2)	3.17
18	56 (3Z + 2)	3.11
19	57 (3Z + 0)	3.0
20	60 (3Z + 0)	3.0
21	63 or 65 (predicted)	3.0 or 3.09
22	66 or 68 (predicted)	3.0 or 3.09
23	69 or 71 (predicted)	3.0 or 3.09
24	72 (predicted)	3.0
25	75 (predicted)	3.0

Table A. 4, A pattern emerges near the first unbound neutron-rich nuclides.

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