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Research Article

Atomic Nuclei Binding Energy

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Abstract

In 1936 Bethe and Bacher and in 1938 Hafstad and Teller predicted that α-particle structures could be present in atomic nuclei. In the course of developing a theory of nuclear structure based on the assumption of closest packing of clusters of nucleons, Linus Pauling found that the magic numbers have a very simple structural significance. He assumed that in nuclei the nucleons may, as a first approximation, be described as occupying localized 1s orbitals to form small clusters. These small clusters, called spherons, are usually helions (i.e. α-particles), tritons and dineutrons. In nuclei containing an odd number of neutrons, an ^{3}He cluster or a deuteron may serve as a spheron. The close-packed-spheron model differs from the conventional liquid-drop model of the nucleus in having spherons rather than nucleons as the units. This is a simplification: ^{154}Gd, for example, is described in terms of 45 spherons, rather than 154 nucleons. This enables to determine the systematic of binding energy in a much simpler way than the approach based on individual nucleons. The authordeveloped that idea, i.e. having clusters as basic bricks within the nucleus instead of nucleons. So, the authorconsidered the binding energy of α-particle and of Deuterium, Tritium, ^{3}He and the way these spherons are bonded instead of the bonding between individual nucleons. According to that hypothesis the nuclei of the various elements are constituted out of α-particles and other nucleons grouped in order to form sub nuclei bound together by four types of bonds called NN, NP, NNP, and NPP. Nevertheless, my purpose is not about looking for a new 3D model of atomic nucleus structure. It is the reason why the author favored an approach trying to breakdown the binding energy value of each element and its isotopes in several sub values indicated above. So, this process is considering only unidimensional binding energy values. This binding energy distribution approach in the nuclei is essential to the comprehension of LENR process.
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1. Introduction

In line with Pauling's [1] view on the nuclear structure, allowing him to determine some clusters within the nucleus he called spherons, the author tried to organize the binding energy of the nucleus in a similar way. The sub-nuclei The author took into considerations are these spherons particles which are linked together with four types of bonds determined in the following way.

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- Deuterium like bond, called NP with value 2.2246 MeV, linking a neutron of one α-particle with a proton of a second α-particle, or a neutron or proton outside an α-particle to that α-particle.
- Tritium like bond, called NNP with value 8.4818 MeV, linking three nucleons of three different α-particles, or one or two nucleons outside an α-particle to one or two α-particles.
- ^{3}He like bond, called NPP with value 7.718 MeV, having a similar function as NNP.
- A dineutron bond the author called NN, with value 4.9365 MeV and linking two neutrons not being located within the same α-particle. This bond value is deduced from the α-particle binding energy, as it will be shown in the following.
- The α-particle bond with value 28.325 MeV [2].

2. Light Nuclei Binding Energy

With these five bonds: α (actually binding energy of the α-particle) NN, NP, NNP, and NPP the author could determine the binding energy (quoted E_{B}) of the n α nuclei and later of all stable nuclei. When these bonds occur any other time, they are quoted NN/2, NP/2, NNP/2, and NPP/2. Also, as NN and NP are constantly oscillating, the author determined the mean of these two bonds as an "A" (A for average) bond = NN/2 + NP/2.

2.1. Examples of n α nuclei binding energy (E_{B})

E_{B} ^{16}O = 4 E_{B} α+ 4A, i.e. 4 times the binding energy of α-particle + 4 (NN/2 +NP/2) = 127.622 MeV,

E_{B} ^{20}Ne = 5 E_{B} α+ A + 2NPP = 160.6416 MeV,

E_{B} ^{24}Mg = 6 E_{B} α+ 2A + NN + NNP + NPP = 198.2474 MeV,

E_{B} ^{28}S i= 7 E_{B} α+10A + NN/2 = 236.5488 MeV,

E_{B} ^{32}S = 8 E_{B} α+ 4A + 4NPP = 271.7942 MeV,

E_{B} ^{36}Ar = 9 E_{B} α+ 8A + 3NPP = 306.7234 MeV,

E_{B} ^{40}Ca =10 E_{B} α+ 6A + NN + 2NNP + 2NPP = 342.0694 MeV.

Moreover, one can see the kinship between these nuclei, for example:

E_{B} ^{16}O versus E_{B} ^{32}S, E_{B} ^{32}S = 2 E_{B} ^{16}O - 4A + 4 NPP,

E_{B} ^{40}Ca versus E_{B} ^{16}O and E_{B} ^{24}Mg, E_{B} ^{40}Ca = E_{B} ^{16}O + E_{B} ^{24}Mg+ NNP + NPP.

2.2. Examples of n α nuclei isotopes binding energy

E_{B} ^{12}C = 3 E_{B} α+ NN + NP = 92.136 MeV,

E_{B} ^{13}C = 3 E_{B} α+ NN + NP + NP/2 + NPP/2 = 97.107 MeV,

E_{B} ^{14}C = 3 E_{B} α+ 1.5 NP + 2NNP = 105.274 MeV,

E_{B} ^{15}C = 3 E_{B} α+ NP + 2.5 NPP = 106.495 MeV,

E_{B} ^{16}C = 3 E_{B} α+ NP + 2.5 NPP + NNP/2 = 110.735 MeV.

E_{B} ^{14}N = 3 E_{B} α+ NNP/2 + 2 NPP = 104.652 MeV,

E_{B} ^{15}N = 3 E_{B} α+ 2NN + 2NP + NNP + NPP = 115.497 MeV,

$E_{\mathrm{B}}\ ^{16}\mathrm{N} = 3\ E_{\mathrm{B}}\ \alpha + 1.5\mathrm{NN} + 2.5\mathrm{NP} + \mathrm{NNP} + 1.5\mathrm{NPP} = 118.000$ MeV.

$E_{\mathrm{B}}\ ^{16}\mathrm{O} = 4\ E_{\mathrm{B}}\ \alpha + 2\mathrm{NN} + 2\mathrm{NP} = 127.622$ MeV

$E_{\mathrm{B}}\ ^{17}\mathrm{O} = 4\ E_{\mathrm{B}}\ \alpha + 1.5\mathrm{NN} + 1.5\mathrm{NP} + \mathrm{NPP} = 131.760$ MeV

$E_{\mathrm{B}}\ ^{18}\mathrm{O} = 4\ E_{\mathrm{B}}\ \alpha + 2\mathrm{NN} + 4\mathrm{NP} + \mathrm{NPP} = 139.789$ MeV

Remark: for all these results the differences between experimental and calculated values are less than 0.030 MeV (Basis: "The Ame 2012 atomic mass evaluation").

3. Theoretical Basis for These Calculations

3.1. Definition of lines

On my website (www.philippehatt.com) the author propose a structure for the neutron based on the following:

- A core constituted with 1800 electron masses divided into 18 × 100 masses, i.e a mass of 1800 × 0.5109989461 MeV = 919.798103 MeV.
- Some adjacent structures having a total mass of 38.637343 electron masses which are constituted with the following "lines":

18 + 1800 + 18,
18 + 1800 + 17.

So, there are 71 lines (18 + 18 + 18 +17). These lines are alternating two by two so that there are 18 + 1800 + 17.5, i.e 35.5 lines at each time. This number of 35.5 lines (71/2) corresponds to 38.637343 electron masses. Each line has a mass of 1.088375859 electron masses (38.637343 electron masses / 35.5) or 0.5561589 MeV. This is the standard unit of bond mass in MeV. So, 38.637343 electron masses × 0.5109989461 MeV = 19.7436415 MeV. The average mass per line in MeV is

19.7436415 /35.5 = 0.5561589 MeV.

The value of the binding energy of Deuterium, Tritium and He3 is determined on basis of these lines:

- E_{B} deuterium = NP = 4 lines: 4 × 0.5561589 = 2.2246 MeV,
- E_{B} tritium = NNP = 15.25 lines: 15.25 × 0.5561589 = 8.4814 MeV,
- $E_{\mathrm{B}}\ ^{3}\mathrm{He}$ = NPP = 13.875 lines: 13.875 × 0.5561589 = 7.7167 MeV,
- 2NN = 17.75 lines = 9.871821 MeV, i.e. 19.7436415/2 MeV.

The value of α-particle binding energy is 28.29566 MeV according to "The Ame 2012 atomic mass evaluation". In adding the four values determined above one obtains:

E_{B} deuterium	2.2246 MeV,
E_{B} tritium	8.4814 MeV,
$E_{\mathrm{B}}\ ^{3}\mathrm{He}$	7.7167 MeV,
2NN	9.8718 MeV,
$E_{\mathrm{B}}\ \alpha$	28.2945 MeV.

The difference between the two values (Ame value versus calculated value according to my theory) is about 1 keV. So, the addition of these four bonds values determine the value of the α-particle binding energy. These bonds values

are the following converted into lines values:

2NN = 17.75 lines,
NP = 4 lines,
NNP = 15.25 lines,
NPP = 13.875 lines.

These values are correlated:
1.25 NP + NN = 13.875 = NPP,
5 NN = 44.375 = 2 NNP + NPP,
2 NN - 1.25 /2 NP = 15.25 = NNP.

NP = 4 × 0.5561589 = 2.224636 MeV, difference with CODATA value is 0.00007 MeV.
NNP = 15.25 × 0.5561589 = 8.48142347, difference with CODATA value is 0.0004 MeV.
NPP = 13.875 × 0.5561589 = 7.716705, difference with CODATA value is 0.00134 MeV.

The last difference is more significant than the two others, nevertheless acceptable.
So, the binding energy of α-particle according to my theory is calculated as follows:

50.875 (=17.75 + 4 +15.25 + 13.875) × 0.5561589 MeV (value of 1 line) = 28.29458 MeV, the difference between CODATA value being 0.00108 MeV, mainly due to the NPP difference. These values (E_{B} α, NP, NNP, and NPP) are constituting the basic values for calculating the binding energy of all the nuclei elements.

3.2. Hypothesis for the nucleosynthesis

In order to determine the binding energy of the different light nuclei it was relied on the following hypothesis: each nucleus (starting from $^{4}_{2}$He) has a substructure made up of α-particls. The N and P supplementary to α-particls can create $^{2}_{1}$H, $^{3}_{1}$H and $^{3}_{2}$He substructures or clusters. Thus, once the nucleus consists of 2N and 2P, its structure is that of the α-particle one, and when it consists of $x\alpha$ + 2N + 2P, its structures become x + 1) α. According to that hypothesis the nucleus can be conformed to in the following ways:

$x\alpha$+ 1N	$x\alpha$+ 1P				In case of one nucleon supplementary to $x\alpha$
$x\alpha$+ 2N	$x\alpha$+ 1N + 1P	$x\alpha$+ 2P			In case of two nucleons supplementary to $x\alpha$
$x\alpha$+ 3N	$x\alpha$+ 2N + 1P	$x\alpha$+ 1N + 2P	$x\alpha$+ 3P		In case of three nucleons supplementary to $x\alpha$
$x\alpha$+ 4N	$x\alpha$+ 3N + 1P	$x\alpha$+ 2N + 2P	$x\alpha$+ 1N + 3P	$x\alpha$+ 4P	In case of four nucleons supplementary to $x\alpha$

This conforms to the Ikeda diagram [3] showing how the structure of light-α conjugate nuclei can be considered as comprised of α-clusters.

The stability of the atomic nucleus depends on its composition. The stability is maximum if it is entirely composed with α-particles, insofar as these particles have stable bonds among them.

When the structure of the nucleus is formed by x particles α to which nucleons are added, this structure is stable as long as the parity between N and P remains stable. Anyway, there is a tendency to respect this symmetry by transformation of N in P or P in N, usually with the emission of particles $\beta-$ and $\beta+$. If the nucleons supplementary

to the α-particles have an odd number as a value, N prevails over P and the substructure or cluster at issue is N or 2N + P in case of a stable structure. When the number of nucleons supplementary to $x\alpha$ is equal to or more than 4 (e.g. 3N + P), the nucleus has a tendency of creating a supplementary α-particle through the transformation of N into P or vice versa. The stable light nuclei are therefore formed mainly by α-particles.

This hypothesis could be confirmed for the lightest nuclei for which one can verify a parity or nearly parity between N and P. For the heaviest nuclei, one should consider another hypothesis.

3.3. Binding energy for each nucleus

According to the hypothesis developed in the former points the binding energy of every nucleus is the sum of the binding energy of its different substructures and the binding energy among these substructures.

3.4. The proton binding energy

On my website the author propose a structure of proton which is similar to that one of neutron. This structure is based on a core constituted with 1800 electron masses as for the neutron and some adjacent structures having a total mass of 36.11216 electron masses (called PP bond for proton–proton bond).

The mass values of neutron and proton which are correlated between themselves (see my website www.philippehatt.com), are the following:

N = 1838.637343 electron masses,
P = 1836.11216 electron masses.

So, the binding energy of α-particle according to that hypothesis is:

(38.637343/2 + 36.11216) × 0.5109989461= 28.3250964 MeV = 2NN + PP.

The difference between 28.3250964 MeV (E_{B} α = 2 NN + PP) and 28.29458 MeV (value of α-particle binding energy based on the lines, i.e 50.875 lines, see Section 3.1) is equal to 0.03052 MeV. So, my hypothesis is that the NP, NNP, NPP bonds of α-particle rearrange themselves to produce the PP bond of value 36.11216 electron masses within a given α-particle in a nucleus including more than one α-particle. In other terms the "free" α-particle binding energy has a value of 2NN + NP + NNP + NPP bonds and the "bound" α-particle binding energy has a value of 2NN + PP bonds.

3.5. Values used for the present calculations

This is the reason why the author used the following data in his theory:

28.325 MeV for binding energy of α-particle,

4.9365 MeV for NN binding energy (in fact the half of 2 NN),

2.2246 MeV for NP (deuterium like) binding energy,

8.4818 MeV for NNP (tritium like) binding energy,

7.7180 MeV for NPP (^{3}He like) binding energy.

The three last ones are the values of Ame 2012 atomic mass evaluation. They are very close to the author's own values (see Section 3.1). This choice avoids discussions on "values". On choosing the value of 28.325 MeV as binding energy

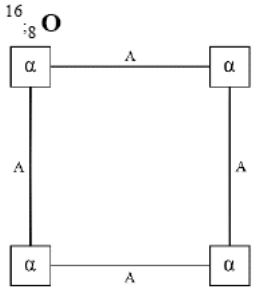
of α-particle the author gave my reasons (see Section 3.4), as well as for NN bond which is part of α-particle bond. All these values are good approximations of the "real" values and are enough precise to determine the binding energy of every nucleus to be compared with the values given in the Ame 2012 atomic mass evaluation. The author am able to determine each nucleus binding energy with less than 30 keV difference only. Moreover, and far more important as the precision of the data, is the demonstration of the kinship between the nuclei and between the isotopes of each element.

One can notice that kinship in the following, showing some examples of nuclei binding energy values.

Remark: the NN value (4.9365 MeV) is comparable to the mass of quark down (4.8 MeV) and the NP value (2.2246 Mev) is comparable to the mass of quark up (2.4 MeV).

4. Examples of Binding Energy Distribution

4.1. Oxygen 16 $\left({}^{16}_{8}\mathrm{O}\right)$

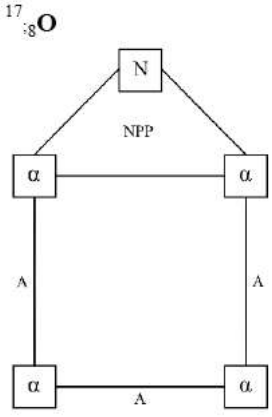


$E_{\mathrm{B}} = 4\ E_{\mathrm{B}}\ \alpha + 4\mathrm{A} =$ 127.6222 MeV+ 0.003

$\mathrm{A} = \mathrm{NN}/2 + \mathrm{NP}/2$

Four α-particles are linked with four A bonds. An A bond is equal to (NN/2+NP/2) bonds. Within an A bond the NN bond and the NP bond are constantly alternating, oscillating.
This alternative movement creates the most solid bonds in a nucleus. So, having only A bonds is the most favorable condition for nucleus stability

4.2. Figure 2 – Oxygen 17 $\left({}^{17}_{8}\mathrm{O}\right)$



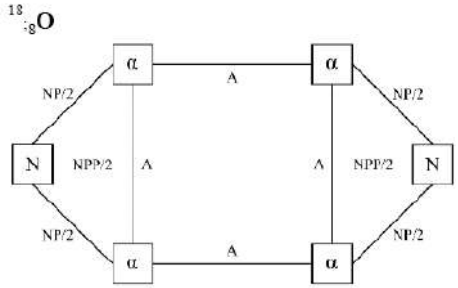
$E_{\mathrm{B}} = 4\ E_{\mathrm{B}}\ \alpha + 3\mathrm{A} +$ NPP = 131.7596 MeV - 0.003

${}^{17}_{8}\mathrm{O} = {}^{16}_{8}\mathrm{O} - \mathrm{A} + \mathrm{NPP}$

^{17}O has a supplementary neutron in its structure. This induces the replacement of one A bond by a NPP bond linking the neutron to two protons located in two different α-particles.

${}^{17}_{8}\mathrm{O} = {}^{16}_{8}\mathrm{O} - \mathrm{A} + \mathrm{NPP}$

4.3. Figure 3 – Oxygen 18 $\left({}^{18}_{8}\mathrm{O}\right)$



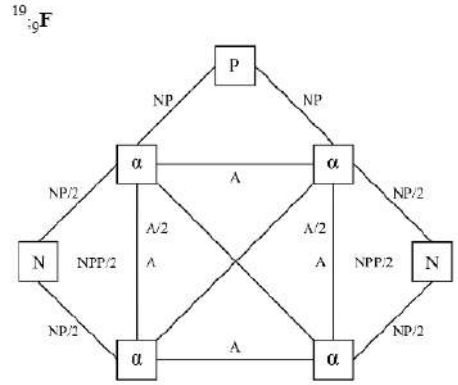
$E_{\mathrm{B}} = 4\ E_{\mathrm{B}}\ \alpha + 4\mathrm{A} + 2\mathrm{NP} + \mathrm{NPP} = 139.7894$ MeV

^{18}O has two supplementary neutrons attached to the ^{16}O structure by one NPP bond and two NP bonds.

${}^{18}_{8}\mathrm{O} = {}^{17}_{8}\mathrm{O} + \mathrm{A} + 2\mathrm{NP} = {}^{16}_{8}\mathrm{O} + \mathrm{NPP} + 2\mathrm{NP}$

$^{18}\mathrm{O} = {}^{17}\mathrm{O} + \mathrm{A} + 2\mathrm{NP} = {}^{16}\mathrm{O} + \mathrm{NPP} + 2\mathrm{NP}$

4.4. Figure 4 – Fluorine 19 $\left({}^{19}_{9}\mathrm{F}\right)$



$E_{\mathrm{B}} = 4\ E_{\mathrm{B}}\ \alpha + 5\mathrm{A} + 4\mathrm{NP} + \mathrm{NPP} = 147.8192$ MeV $+ 0.018$

${}^{19}_{9}\mathrm{F} = {}^{18}_{8}\mathrm{O} + \mathrm{A} + 2\ \mathrm{NP}$

^{19}F has a proton in excess of ^{18}O. One A and 2NP bonds are added to ^{18}O structure. $^{18}\mathrm{O} + \mathrm{A} + 2\mathrm{NP}$.
${}^{19}_{9}\mathrm{F} = {}^{16}\mathrm{O} + \mathrm{A} + 4\mathrm{NP} + \mathrm{NPP}$.
Compared with ^{16}O one A bond is added to the core structure, the other bonds are linking the two N (NP + NPP/2) and the P (2NP) with that core structure.

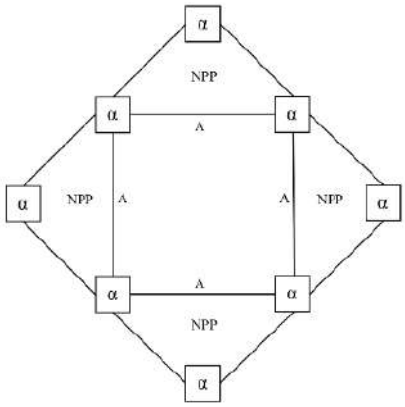
5. Examples of Other Nuclei Binding Energies

One can now start the study of all other nuclei. It will be seen that the bonds of α type, as well as ${}^{2}_{1}\mathrm{H}$, ${}^{3}_{1}\mathrm{H}$, ${}^{3}_{2}\mathrm{He}$ and NN are sufficient to explain the binding energy of all nuclei, which pleads for predominance of α-particles in the nuclei. The atomic nuclei are therefore constituted of sub-nuclei, essentially ${}^{4}_{2}\mathrm{He}$ but also ${}^{2}_{1}\mathrm{H}$, ${}^{3}_{2}\mathrm{He}$ and ${}^{3}_{1}\mathrm{H}$ or simply of N or P, somewhat like molecules, being understood that the bonds can be more or less strong.

More examples are to be found in the book on Atomic Nuclei Binding Energy [5].

5.1. ^{32}S binding energy distribution

^{32}S is composed with two ^{16}O



E_B =8 E_B α+ 4A + 4NPP = 271.7942 MeV+ 0.014

$^{32}S = 2 \times 016 - 4A + 4NPP$

The two ^{16}O structures combine in the following way: one ^{16}O structure stays unchanged; the second ^{16}O structure bonds the first one like shown in the figure. As a consequence, three α-particles are at stake and the A bonds are changed in NPP bonds.

Remark: Up to ^{40}Ca the author uses the notation from nuclide to nuclide as seen above, i.e. boxes to represent the α-particles. As the number of α-particle is growing, it is better to use a different system in the diagrams (see below for Cu diagrams) for a practical reason of saving space.

5.2. ^{63}Cu binding energy distribution among ^{63}Cu

$^{63}_{29}Cu$	14α, 6N, 1P supplementary			E_B in MeV = 551.3847
Stable				
Nat. abundance: 69.2 %				
	14	x	28.325	396.5500 MeV
	7	x	4.9365	34.5555
	7	x	2.2246	15.5722
	0	x	8.4818	0
	7	x	7.7180	54.0260
				29.6190
	6	x	4.9365	13.3476
	6	x	2.2246	0
	0	x	8.4818	7.7180
	1	x	7.7180	551.3883 MeV
				+ 0.004

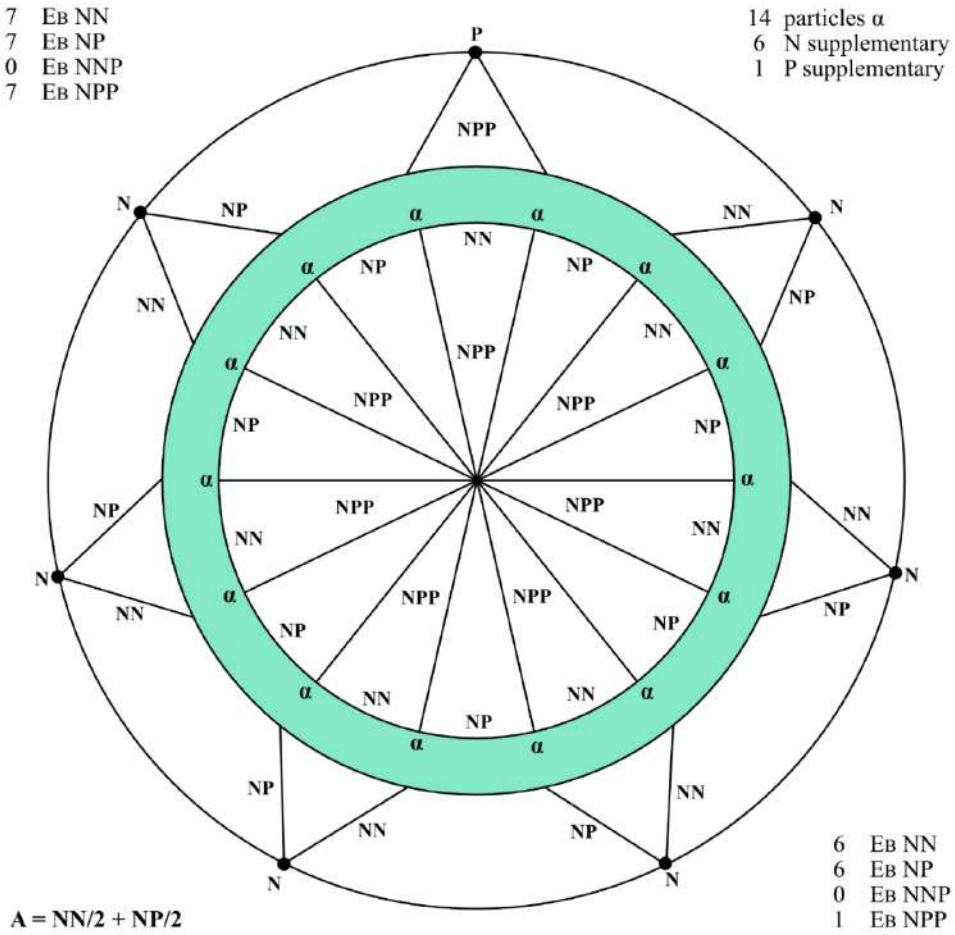


Figure 1. Binding energy distribution among ^{63}Cu.

The α-particles are directly bonded with NN and NP bonds and cross bonded with NPP bonds. The 6 N supplementary are linked to α-particles with NN and NP bonds.

NN and NP are oscillating so that each bond equals NN/2 + NP/2 = A.

The P supplementary is linked with one NPP bond to α-particles.

5.3. ^{64}Cu binding energy distribution

The ^{64}Cu bonds differ from ^{63}Cu ones by one NNP cross bond replacing one NPP cross bond.

The 7 N supplementary are linked to α-particles with 7 (NN+NP) bonds.

$^{64}_{29}$Cu	14α, 7N, 1P supplementary	E_{B} in MeV = 559.3008
Lifetime: 12.9 h	$\left\{\begin{array}{ll} 14 & \times 28.325 \\ 7 & \times 4.9365 \\ 7 & \times 2.2246 \\ 1 & \times 8.4818 \\ 6 & \times 7.7180 \end{array}\right\}$	396.5500 MeV 34.5555 15.5722 8.4818 46.3080
	$\left\{\begin{array}{ll} 7 & \times 4.9365 \\ 7 & \times 2.2246 \\ 0 & \times 8.4818 \\ 1 & \times 7.7180 \end{array}\right\}$	34.5555 15.5722 0 7.7180 559.3132 MeV+0.012

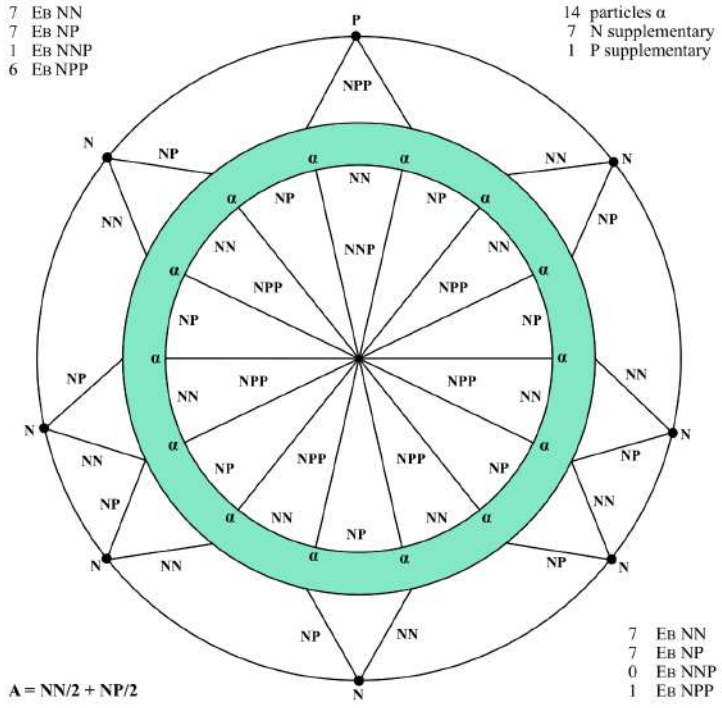


Figure 2. Binding energy distribution among ^{64}Cu.

5.4. ^{65}Cu binding energy distribution

^{65}Cu bonds structure is similar to ^{63}Cu one.

Nevertheless 7 NNP cross bonds are replacing the 7 NPP cross bonds of ^{63}Cu.

Also, the P is linked on one time to two α-particles by one NPP bond as normally (first case), and on another time to two N, forming as such one NNP bond (second case). Therefore, the two NP bonds linking the two N to the two α-particles are not "allowed", hence two NP/2 bonds for the normal binding (first case).

$^{65}_{29}$Cu	14α, 8N, 1P supplementary	E_{B} in MeV = 569.2112
Stable Nat. abundance: 30.8 %	$\left\{\begin{array}{l}14 \times 28.325\\7 \times 4.9365\\7 \times 2.2246\\7 \times 8.4818\\0 \times 7.7180\end{array}\right\}$	396.5500 MeV 34.5555 15.5722
	$\left\{\begin{array}{l}8 \times 4.9365\\7 \times 2.2246\\0.5 \times 8.4818\\0.5 \times 7.7180\end{array}\right\}$	8.4818 59.3726 0 39.4920 15.5722 4.2409 3.8590
		569.2144 MeV + 0.003

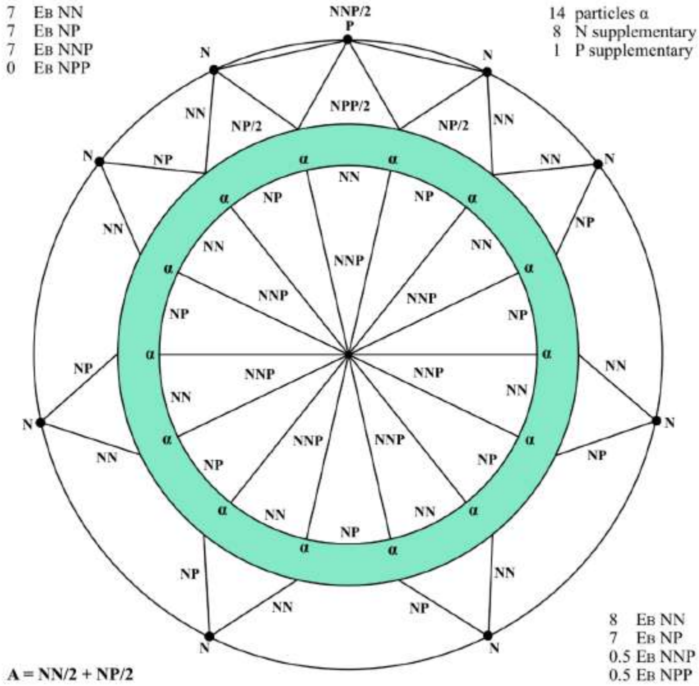


Figure 3. Binding energy distribution among ^{65}Cu.

6. Binding Energy Distribution Among ^{55}Mn to ^{68}Zn Stable Nuclei

See above a summary of binding energy values of ^{55}Mn to ^{68}Zn stable nuclei. ^{63}Cu and ^{65}Cu values correspond to that ones of Figs. 1–3. Table 1 is to read according to these examples. Table 2 shows the corresponding values of binding energies.

7. Summary

(1) These results are obtained by comparing binding energy values of several nuclei, especially isotopes of the same element and by breaking down these values in NP, NNP, NPP and α-particle binding energy values. The α-particle binding energy value is also broken down in 2 NN and PP values. Actually, NN is active inside and outside α-particle, PP being active only within α-particle. One single process is used, i.e. looking step by step, isotope element after isotope element, for binding energy differences between the various isotopes. So, one can determine the binding energy value of every element or its isotopes.

(2) My geometrical schemas are not designed to build a structure of nuclei but are destined to be a visual support for my research, especially to see the kinship between the binding energy distribution within the various nuclei. For instance, in case of ^{16}O (see Sections 4.1–4.4) the figure is based on four α-particles bound by four equal bonds the author calls "A", actually a simplification for NN/2 + NP/2. If a neutron is added it becomes ^{17}O. So, the author looks for a bond linking the new neutron and two nucleons located within two α-particles. This is the state the closest to ^{16}O. The author has the choice between NNP and NPP. It is NPP which fits, so the

Table 1. Binding energy distribution among ^{55}Mn to ^{68}Zn stable nuclei.

		E_B Core				E_B supplementary N, P			
Nucleus	Structure	NN	NP	NNP	NPP	NN	NP	NNP	NPP
$^{55}_{25}$Mn	12 α	6	6						
		2	2		4				
	6 N, 1 P								7
$^{54}_{26}$Fe	13 α	6.5	6.5						
		5.5	3.5		1				
	2 N					2	2		
$^{56}_{26}$Fe	13 α	6.5	6.5						
		6	5	0.5	0.5				
	4 N					4	4		
$^{57}_{26}$Fe	13 α	6.5	6.5						
		6.5	6.5						
	5 N								5
$^{59}_{27}$Co	13 α	6.5	6.5						
			1		6				
	6 N, 1 P								7
$^{58}_{28}$Ni	14 α	7	7						
		5.5	6.5		0.5				
	2 N					2	2		
$^{60}_{28}$Ni	14 α	7	7						
		4.5	4.5		2.5				
	4 N					4	4		
$^{61}_{28}$Ni	14 α	7	7						
		4	4	0.5	2.5				
	5 N					5	5		
$^{62}_{28}$Ni	14 α	7	7						
		4.5	4.5	1	1.5				
	6 N								6
$^{63}_{29}$Cu	14 α	7	7						
					7				
	6 N, 1 P					6	6		1
$^{65}_{29}$Cu	14 α	7	7						
				7					
	8 N, 1 P					8	7	0.5	0.5
$^{64}_{30}$Zn	15 α	7.5	7.5						
		6	9						
	4 N								4
$^{66}_{30}$Zn	15 α	7.5	7.5						
		3	3	0.5	4				
	6 N					6	6		
$^{68}_{30}$Zn	15 α	7.5	7.5						
		8	7						
	8 N								8

Table 2. Binding energy values for ^{55}Mn to ^{68}Zn in MeV.

Binding Energy	Nucleus	E_{B} value (MeV)	Difference with exp. Value (MeV) [4]
E_{B}	^{55}Mn	482.087	$+0.011$
E_{B}	^{54}Fe	471.749	– 0.015
E_{B}	^{56}Fe	492.258	– 0.001
E_{B}	^{57}Fe	499.909	$+0.004$
E_{B}	^{59}Co	517.331	$+0.017$
E_{B}	^{58}Ni	506.470	$+0.011$
E_{B}	^{60}Ni	526.842	– 0.004
E_{B}	^{61}Ni	534.663	– 0.003
E_{B}	^{62}Ni	545.270	$+0.008$
E_{B}	^{63}Cu	551.388	$+0.004$
E_{B}	^{65}Cu	569.214	$+0.003$
E_{B}	^{64}Zn	559.096	– 0.002
E_{B}	^{66}Zn	578.146	$+0.010$
E_{B}	^{68}Zn	595.392	$+0.006$

author takes that one arbitrarily. The author is aware of that "theoretical failure", my purpose being not to build a theory on strong nuclear force but rather to find simplicity in the "jungle" of hundreds of nuclear bonds in order to explain better the LENR process. Actually, the author uses three bonds which pre-exist to the α-bond, i.e. NP, NNP, NPP, and a fourth one deduced from α-bond, i.e. NN.

(3) On my method: it is not based on a theory. Instead, the author made mind experiments. As said above the author has the choice to use a few bonds each time a new neutron or proton is entering a nucleus. The author chooses that one which "fits". This unconventional way is comparable to the work of a chemist looking for several solutions in his experiments and validating that one which fits best. Moreover, the author is looking at the compliance of the solution for one nucleus with the solution for another nucleus in order to avoid discrepancies, especially between isotopes. The author is also taking care of symmetry within a given nucleus and between nuclei. Indeed, my work is not addressing the three-dimensional model of nuclei in the sense that the author is not looking for a structure of these nuclei but rather for the distribution of binding energy within them. Nevertheless, my work could be complementary to those dealing with this topic. A comparison with 3D nuclei models could be relevant.

8. Conclusion

The distribution of binding energy in each nucleus and each isotope as shown above is fundamental for understanding the LENR process, and especially the transmutation process. It allows to determine how the binding energy evolves,

nucleus after nucleus, isotope after isotope. This is essential for LENR process comprehension as the difference in the distribution of binding energy between the elements present at the beginning of the reaction and at the final stage is directly related to the energy released. Many more examples are displayed in my book on Atomic Nuclei Binding Energy [5].

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