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Research Article

Cold Nuclear Transmutations. Distribution of Binding Energy within Nuclei

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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 He^3 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: Gd^{154}, for example, is described in terms of 45 spherons, rather than 154 nucleons. This enables to determine the binding energies in a much simpler way than the approach based on individual nucleons. I developed that idea, i.e. having clusters as basic bricks within the nucleus instead of nucleons. These clusters are the same than Pauling's ones, i.e. α particles and deuterium, tritium, He^3 and dineutrons like clusters. Nevertheless, on the method, my approach differs from that one of Pauling. I tried a simple method of mind experiments, approaching the problem step by step, nucleus after nucleus, isotope after isotope, looking each time at the preceding nucleus or isotope binding energy to compare with the next nucleus binding energy. My purpose is about LENR, i.e. looking for differences of binding energies between elements at the beginning and the end of the LENR process in order to determine the energy release. Indeed, my approach is looking for the distribution of binding energy within each element and each isotope, comparing their values, rather than researching for an internal structure of these elements. So, my approach is not about 3D structure of the nuclei but is rather based on an unidimensional value of their binding energy, looking for the internal distribution of that energy and trying to find distribution similarities between elements and isotopes. As a result, I could determine in a coherent way the binding energy of all stable nuclei and their isotopes on basis of the five clusters mentioned above and which are the same as those retained by Pauling. Indeed, I do not care about the geometrical structure of the packing of spherons, but rather about the organization of these spherons in order to determine for each element and isotope the binding energy characterizing it.
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1. Introduction

In 1936 Bethe and Bacher [1] and in 1938 Hafstad and Teller [2] predicted that α particle structures could be present in atomic nuclei. In line with Pauling [3] view on the nuclear structure, allowing him to determine some clusters within the nucleus he called spherons, I tried to organize the nucleus in a similar way. The sub nuclei I took into consideration are the α particles. These particles are linked together with four types of bonds determined in the following way.

- 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.
- He^3 like bond, called NPP with value 7.718 MeV, having a similar function as NNP.
- A dineutron bond, I called NN, with value 4.9365 MeV and linking two neutrons not being located within the same α particle. This bond and its value are deduced from the α particle binding energy (for details see www.philippehatt.com).

So, the binding energy (E_B) of an element is composed with E_B of α particles (28.325 MeV each) together with the E_B's of the various four bonds determined above.

With Pauling's model, the difficulty was the arbitrary decisions he made about which structures are "real nuclei" and which are not. I was confronted with the same problem. It is the reason why I studied first the n α nuclei as certain authors predict that α particle structures could be present in atomic nuclei. This could be in particular the case of the light nuclei like O^{16}, Ne^{20}, Mg^{24}, Si^{28}, S^{32}, Ar^{36}, and Ca^{40}. This is my first assumption or hypothesis. So, everything considered, I made that choice which could be seen as arbitrary. In the frame of that hypothesis, there are by definition only α particles within the nucleus. The problem to solve is then how they are bound together. For instance, Be^8 is not stable as there is no room for bonds between the two α particles, the E_B of that element being more or less equal to the E_B of its two α particles. It is not the case of O^{16} containing four α particles and having a global E_B superior to the E_B of these four α particles together. This difference represents the E_B between the four α particles.

2. Composition of Inter Alpha Binding Energy

I assumed that the bonds between α particles should link one α to another α in case of NN and NP involving only two nucleons, and three α in case of NNP and NPP. I eliminated the bonds of type NNN and PPP as non "realistic" and accepted NP, NNP, and NPP because they are equivalent to deuterium, tritium and He^3 bonds already existing before the α particle is constituted.

As far as NN and PP are concerned, these constituting the α particle binding energy, I accepted only NN for the following reasons.

- With exception of He^3 there is no stable element or stable isotope containing more protons than neutrons. So, outside the α particles there is only one proton possible and not more in a given nucleus. There could of course be more neutrons. This excludes proton–proton bonds outside α particle.
- Coming back to O^{16} and to the binding energy in excess to that one of the α, I noticed the following. The four α could be linked by minimum three bonds between each time two α or by one NNP or NPP bond and one NN or one NP bond. The only suitable values were two NP's together with the neutron–neutron binding energy within α particle. Actually, four $E_B\alpha$, two NP and the "neutronic" part of α particle E_B is equal to E_B of O^{16}.

These are the assumptions concerning the four bonds NN, NP, NNP, and NPP. To simplify I merged NP and NN in one bond called A = NN/2+NP/2.

3. Examples of Nuclei Binding Energy

With these five bonds: α, NN, NP, NNP, and NPP, I could determine the binding energy of the $n\alpha$ nuclei mentioned above, and later of all stable nuclei.

Examples:

E_B of O^{16} $= 4\ E_B\ \alpha + 4A$,

E_B of Ne^{20} $= 5\ E_B\ \alpha + 5A + NP/2$ (or $A + 2NPP$),

E_B of $Mg^{24} = 6\ E_B\ \alpha + 2A + NN + NNP + NPP$,

E_B of $Si^{28} = 7\ E_B\ \alpha + 10A + NN/2$,

E_B of $S^{32} = 8\ E_B\ \alpha + 4A + 4NPP$,

E_B of $Ar^{36} = 9\ E_B\ \alpha + 8A + 3NPP$,

E_B of $Ca^{40} = 10\ E_B\ \alpha + 6A + NN + 2NNP + 2NPP$.

Moreover, one can see the kinship between these nuclei, for example, see Figs. 1–3:

E_B O^{16} versus E_B S^{32}

E_B Ca^{40} versus E_B O^{16} and E_B Mg^{24}.

$^{32}_{16}S$		8α	E_B in MeV = 271.7801
	E_B	8α	226.6000 MeV
		2NN	9.8730
		2 NP	4.4492
		4 NPP	30.8720
			271.7942 MeV
			$+0.014$

$E_B = 8\ E_B\ \alpha + 4A + 4NPP = 271.7942$ MeV $(+0.014)$.

The core of this structure is the same than that one of O^{16}. Four NPP bonds linking each time three α particles are completing this core structure. The S^{32} contains eight α particles, the double of O^{16}. Nevertheless, the bonds of S^{32}

supplementary to O^{16} have a higher value: 4 NPP = 8A + NP instead of 4A. The excess value is then equal to 4A + NP. A tentative transmutation process between two O^{16} nuclei with outcome S^{32} is shown in Fig. 2. 4A bonds of second O^{16} structure interact with the four α particles of first O^{16} structure.

Result: 4NPP bonds are created as there are four interactions between each time three α particles.

Total: eight α particles, 4A bonds and 4NPP bonds, i.e. the structure of S^{32} (see Fig. 1).

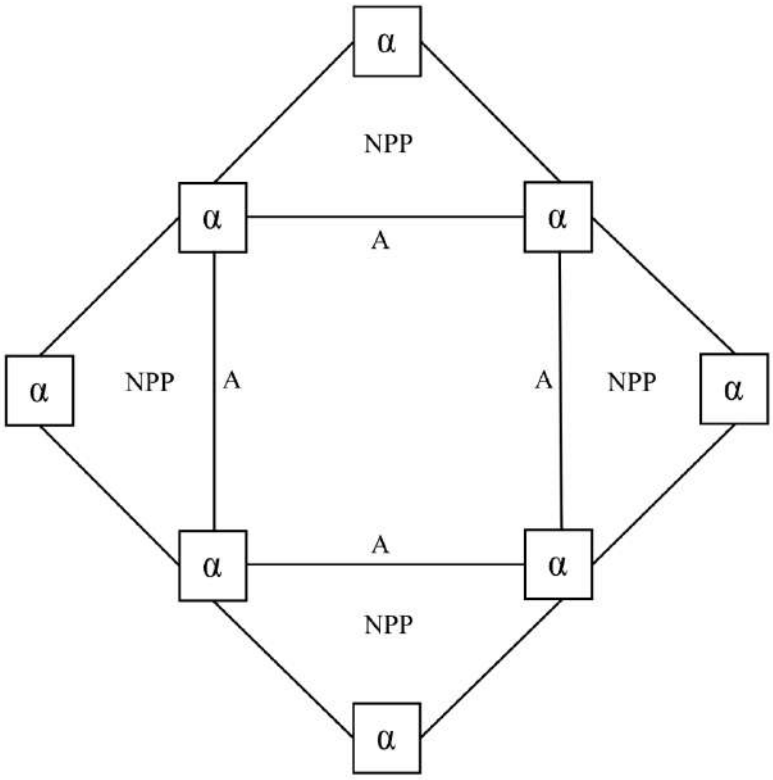

Figure 1. Distribution. of E_B $^{32}_{16}$S between α particles.

$^{40}_{20}$Ca 10 αE_B in MeV = 342.0522.

E_B	10	α	283.2500	MeV
	4	NN	19.7460	
	3	NP	6.6738	
	2	NNP	16.9636	
	2	NPP	15.4360	
			342.0694	MeV
			+0.017	

E_B = 10 E_B α+ 6A + NN + 2NNP + 2NPP = 342.0694 MeV (+ 0.017).

This structure has a core equal to that one of O16.The rest is similar to Mg^{24}. Actually, the addition of O^{16} bonds and Mg^{24} bonds is the following:

O^{16}	4A			
Mg^{24}	2A	NN	NNP	NPP
	6A	NN	NNP	NPP

The bonding of Ca^{40} is the following: Ca^{40} 6A NN 2NNP 2NPP. Ca^{40} bonds represent the O^{16} bonds plus the Mg^{24} bonds with addition of one NNP and one NPP bonds (see Fig. 3).

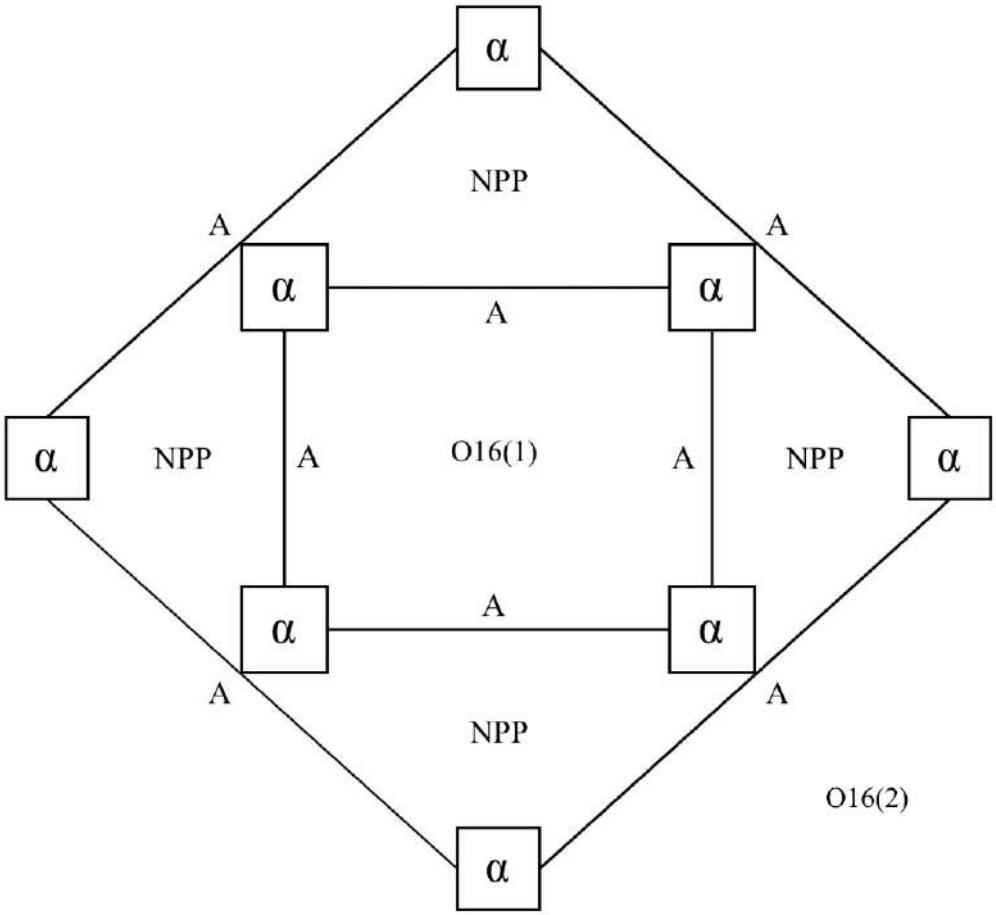

Figure 2. Tentative transmutation process. Basis: Two structures of O^{16} with each 4A bonds.

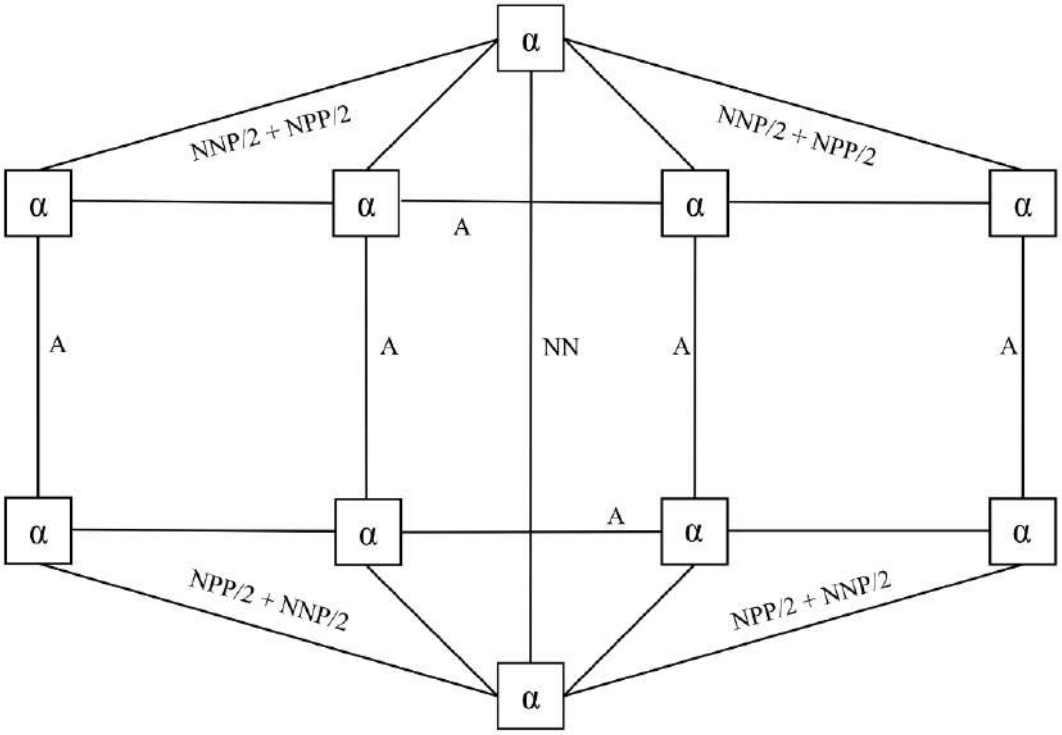

Figure 3. Distribution of E_{B} Ca^{40} between α particles.

4. Discussion

The key idea of my theory is to find a common distribution of binding energy within the various nuclei which could in turn help to understand the LENR process. It is about finding a kinship between the various nuclei. According to my theory there is the following sequence in binding energy:

NP | bonds pre-existing
NNP ⇒ NPP | to α particle bond
α particle

So, in case of two α and more, it is assumed that the binding energy between these α is based on binding energy between their nucleons and that the value of these bonds is related to the values of NP, NNP, NPP and on the value of NN which part of α binding energy is.

4.1. Progression of binding energy

4.1.1. *Basic values*

NP = 2.2246 MeV,

NNP = 8.4818 MeV,
NPP = 7.7180 MeV. Difference between NNP and NPP = 0.7638 MeV,
α particle = 28.325 MeV = 2NN + PP = 9.873 MeV + 18.452 MeV (for details see www.philippehatt.com).

4.1.2. *Determination of binding energy values based on preceding values*

He^5 = He^4+ neutron (N),
$E_B = E_B\ \alpha -$ NNP + NPP = 28.325 − 0.7638 = 27.5612 MeV,
Li^6 = He^4+ N + P (proton),
$E_B = E_B\ \alpha -$ NNP + NPP + 2NP = 28.325 − 0.7638 + 4.4492 = 32.01 MeV,
Li^7 = He^4+ 2N + P,
$E_B = E_B\ \alpha +$ 3NP + NNP/2 = 28.325 + 6.6738 + 4.2409 = 39.2397 MeV,
Be^9 = 2 He^4+ N,
$E_B = 2\ E_B\ \alpha +$ 1.5/2 NN + 1.5/2 NP − NPP/2 = 56.65 + 3.7024 +1.6685 − 3.859 = 58.162 MeV,
B^{10} = 2 He^4+ N + P,
$E_B = 2\ E_B\ \alpha +$ NNP/2 + NPP/2 = 56.65 + 4.2409 + 3.859 = 64.7499 MeV,
B^{11} = 2 He^4+ 2N + P,
$E_B = 2\ E_B\ \alpha +$ 1.5 NN +2 NP + NPP = 76.222 MeV.

4.2. Other examples of nuclei binding energy

E_B C^{12} =3 $E_B\ \alpha +$ NN + NP = 92.136 MeV,
E_B C^{13} =3 $E_B\ \alpha +$ NN + NP + NP/2 + NPP/2 = 97.107 MeV,
E_B C^{14} =3 $E_B\ \alpha +$ 1.5 NP + 2NNP = 105.274 MeV,
E_B C^{15} =3 $E_B\ \alpha +$ NP + 2.5 NPP = 106.495 MeV,
E_B C^{16} =3 $E_B\ \alpha +$ NP + 2.5 NPP + NNP/2 = 110.735 MeV.

E_B N^{14} =3 $E_B\ \alpha +$ NNP/2 + 2 NPP = 104.652 MeV,
E_B N^{15} =3 $E_B\ \alpha +$ 2NN + 2NP + NNP + NPP = 115.497 MeV,
E_B N^{16} =3 $E_B\ \alpha +$ 1.5NN + 2.5NP + NNP + 1.5NPP = 118.000 MeV.

E_B O^{16} =4 $E_B\ \alpha +$ 2NN + 2NP = 127.622 MeV,
E_B O^{17} =4 $E_B\ \alpha +$ 1.5NN + 1.5NP + NPP = 131.760 MeV,
E_B O^{18} =4 $E_B\ \alpha +$ 2NN + 4NP + NPP = 139.789 MeV.

Remark: for all these results the differences between experimental and calculated values are less than 0.026 MeV (source: "The AME 2012 atomic mass evaluation").

5. Conclusion

5.1. Determining the binding energy

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 was also broken down in 2 NN and PP values. Only NN is active 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 elements and their isotopes. One should also consider that the mass differences in binding energy values could be positive or negative, the negative values showing a mass recreation. Having this in mind one can determine the binding energy value of every element or its isotopes. See the figures displayed in www.philippehatt.com.

My geometrical schemas are not designed to build a structure of nucleons 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 O^{16} the figure is based on four α particles bound by four equal bonds I call "A", actually a simplification for NN/2 + NP/2. If a neutron is added it becomes O^{17}. So, I look for a bond implying the new neutron and two nucleons located within two α particles. This is the state the closest to O^{16}. I have the choice between NNP and NPP. It is NPP which fits, so I take that one arbitrarily. I am 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, I use three bonds which pre-exist to the α bond, i.e. NP, NNP, NPP, and a fourth one deducted from α bond, i.e. NN.

So, my method is not based on a theory. Instead, I make mind experiments. As said above I have the choice to use a few bonds each time a new neutron or proton is entering a nucleus. I choose 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, I am looking at the compliance of the solution for one nucleus with the solution for another nucleus in order to avoid discrepancies, especially between isotopes. I am 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 I am 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. My work is trying to explain the LENR processes where energy release is a direct consequence of nuclear transmutations, i.e. modification of binding energy values between elements present at the beginning and at the end of the LENR reaction.

So, in my approach to the problem the 2D drawings just illustrate the bonds between α particles and nucleons or between nucleons, and not the 3D structure of the nuclei.

5.2. Calculation of binding energy

As seen, my system for determining the binding energy of the nuclei is based only on calculations.

I found that E_B α is equal to E_B of NP + NNP + NPP + 2 NN, where NP = E_B of Deuterium, NNP = E_B of Tritium, NPP = E_B of He^3 and 2NN being a dineutron of mass value = (mass of neutron − mass of 1800 electrons)/2. The whole is equal to 28.296 MeV.

This is for a free α particle. In a nucleus the NP, NNP, NPP bonds are replaced by a PP bond equal to the mass of proton − mass of 1800 electrons. The whole is equal to 28.325 MeV. So, I tried to determine the E_B of all the nuclei. I could find them for all the stable nuclei and have issued a book on that discovery (see www.philippehatt.com).

Example of calculation: E_B of Be^8 versus E_B of Be^9:

Be^8	$2 \times 28.325 = 56.6500$	$2 \times 28.325 = 56.6500$
	NN/2 = 2.4683	−NNP/2 = −3.8590
	NP/2= 1.1123	
	60.2306 MeV	52.7910 MeV

Average: 60.2306/2 + 52.7910/2 = 56.511 MeV (+0.011 MeV compared with AME 2012 value)

Explanation: the balance between (NN/2 + NP/2) and NNP/2 is negative ($2.4683 + 1.1123 - 3.8590 = -0.2784$ MeV). As a consequence, there is no bond between the two α particles and the nucleus is instable.

Be^9	$2 \times 28.325 = 56.6500$	$2 \times 28.325 = 56.6500$
	3 NN/2 = 7.4048	$-$NPP $= -7.7180$
	3 NP/2 $= 3.3369$	
	67.3917 MeV	48.9320 MeV

Average: 67.3917/2 + 48.9320/2 = 58.1640 (+0.002 MeV compared with AME 2012 value).

Explanation: the introduction of one neutron has occurred two more A bonds and also a negative NPP bond double as for Be^8. Nevertheless, the balance is positive ($7.4048 + 3.3369 - 7.7180 = 3.0237$ Mev). The nucleus is stable.

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