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Prediction of Radioactive Half-Lives and Atomic Nucleus Dimensions in a Concentric Shell Model or Flocon Model

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Abstract

Considering only the wave aspect, we determine the energy of a bond between 2 nucleons; this quantified energy is associated with a standing wave. Then, starting from the mass loss corresponding to this energy, we determine the number of bonds in this nucleus. The mass defect value for a link is used to determine a specific length at that link. Fixing a precise distance between nucleons makes it possible to determine a geometry of the nucleus and its dimensions. It makes it possible to understand when this bond is stronger than the electrostatic force and allows deducing a shell model built in a precise order. The calculation on the mass defect will also make it possible to determine that one or more nucleons concerned by the radioactivity will be bound by a single bond to the rest of the nucleus or, on the contrary, bound by several bonds which induce short ½ lives or, on the contrary, very long. The analysis of the bonds on H, He and C make it possible to write formulae which are then applied to the nuclei to find the radioactive ½ lives. To find by equations the radioactive ½ lives does not call into question the standard model since it concerns only the defect of mass of the nuclei with energies that are not used to find the main particles of the standard model. This model, which favours a geometric approach to the detriment of a mathematical approach based on differential equations, can lead to theoretical questions about the possibility of interpreting the structure of the nucleus in a more undulatory way. It is possible to explain radioactivity in a more deterministic way.

Keywords

½ Radioactive Lives, Atomic Nucleus Dimensions, Shell Model

1. Introduction and Theoretical Postulate

For each particle, we will consider only the wave aspect, which will allow studying the binding as interferences or combinations of waves. The calculation is made from the number of proton-neutron bonds δ that will be isolated and counted from the mass defect Δm. (Δm is the difference between the masses of the neutron and the proton and it is considered that this corresponds to the energy of a bond).

1) The nucleons are thus considered as a combination of waves of which we can determine a main or resulting wave whose frequency f is calculated simply by posing $E_p = m_p c^2$ and $E_p = hf_p \Rightarrow f_p = m_p c^2 h^{-1}$ (with E_p proton energy, m_p proton mass, c = light velocity, h = Planck constant, f_p proton associated frequency); Similarly the frequency associated with the neutron will be $f_n = m_n c^2 h^{-1}$

2) The frequency Δf of the resulting interference wave of 2 others waves will be $\Delta f = |f_n - f_p|$

The bonds inside stable nuclei, such as helions, are not taken into account in the calculation of the ½ lives. Nor is there any attempt to find the bond energies of particles such as mesons, bosons or gluons. These particles from the standard model have energies far superior to the mass defect of the binding energies.

This p-n interference wave takes an energy of $\Delta m = 0.001389$u to the neutron, the neutron and the proton vibrate at the same frequency. It is postulated that this induces a standing wave which will favour and thus determine a very precise distance d between the nucleons corresponding to a ½ wavelength λ of the period P_p of proton vibration ($P_p = 0.433 \times 10^{-23}$ s), so $d = 0.65 \times 10^{-15}$ m. The anti-node of this standing wave explains an "attractive force" between 0.65 and 0.97 fm and a "repulsive force" when the distance is less than 0.65 fm. It provides an explanation to a repulsive strong interaction when the distance tends to 0 and attractive at medium distance. In fact, theoretically and thus verifiable, depending on the distance with other anti-nodes, the force would be alternately repulsive or attractive. (Attractive when $n \times 0.65$ fm $< d < n \times 0.97$ fm, $n \in N$). The size of a proton can thus be defined as the distance between 2 anti-nodes or 0.65 fm on average with a maximum size of 0.97 fm. This size assumption is consistent with the estimated radius of the proton (proton radius = 0.831 fm [1]) (see Figure 1).

In fact, it is assumed that the binding between two nucleons consists of standing waves and an interference wave. This postulate with a standing wave therefore induces a precise and necessary distance d for the bond to be established between a proton and a neutron. This precise distance forces the nucleus to have a precise geometry. Thus, if the distance between a proton and a neutron can remain fixed, the bond will be stable. If geometry prevents the nucleon from staying at this ideal distance, the bond will be unstable.

The energy E of a wave is of the form $E = \int \psi^2 \mathrm{d}x$ (ψ = amplitude of the wave), therefore for a wavelength λ, E is of the form $E = \psi^2 \lambda$ or for the standing wave since $d = \lambda/2$, $E = \psi^2 d$. When d increases, the energy or the mass defect

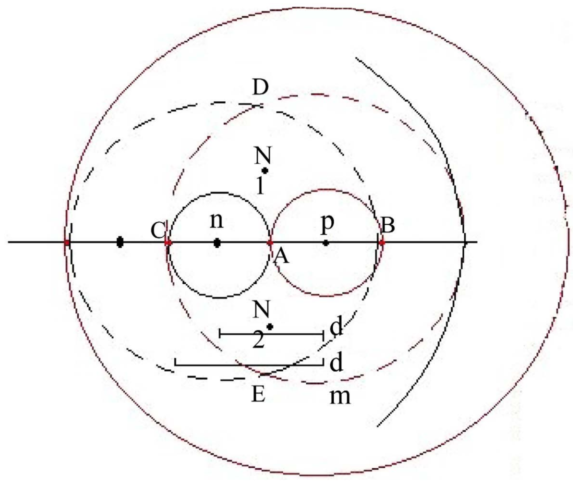

Figure 1. Proton-neutron liaison. The proton p has a period of 4.3 × 10^{24} s or a wavelength of 1.29 × 10^{-15} m. When the neutron n loses 0.00139 u in the p-n bond, standing waves can be established between the 2 nucleons. We take the shortest possible distance d or a ½ wavelength, which means that the nucleons are "in contact". The anti-nodes of the standing wave are at points A, B, C. The centres p and n of the 2 nucleons will tend to remain at the nodes where the vibrations are of lower amplitudes. The maximum distance dm without break will be when the point n reaches C with the point p remaining in place or when the point p reaches B with the point n remaining in place. $d_m = d/2$ = 0.9675 × 10^{-15} m. B and C are points where the amplitudes of the waves from n and p cancel each other out. It is the same beyond B and C. However on the right perpendicular to BC passing by A, there will be maxima of amplitude in D and E and beyond. There will be nodes in N1 and N2 located exactly at the distance d from n and p that will allow 2 other nucleons to be positionned there.

increases. If d corresponds to an energy Δm, then we can write that the total length of the bonds d_t corresponds to a total mass defect Δm_t.

$$d_t = (d/\Delta m) \times \Delta m_t \tag{1}$$

3) It is the P_{pn} periods of the interference bond and the nucleon period that are useful in determining the ½ lifes.

If a bond assumes 2 identical frequencies so that a standing wave can be established, it is necessary that the neutron loses Δm = 0.001389 u to have a vibration frequency identical to the proton; thus, there may be a interference pn in the bond between a proton and a neutron; 2 isolated neutrons will tend to group in pairs with no additional loss of mass. With this rule, nothing prevents a nucleon from interfering with several nucleons or groups of nucleons as long as their vibration frequencies are identical and it is located at a vibration node. When the nucleon is located at one or more distances d, the bond and thus the nucleus is stable.

We do know, however, that for a theory, stationary wave superimposition is a questionable element. Sazdjian [2] writes in his thesis that the superimposition will see "the position of the zero point move over time with a certain pulsation" and will no longer correspond to a fixed point. When the distance d cannot be identical for 2 bonds, there will be superposition of several standing waves of slightly different periods, which will cause instability in the binding with a computable period.

2. Method of Calculation

2.1. Reminder of the Equivalence between Frequencies, Periods and Mass Defect

The interference wave p-n will have a frequency $\Delta f_{pn} = f_n - f_p$ (f_n frequency of neutron vibrations, f_p frequency of proton vibrations). Its period P_{pn} will therefore be $P_{pn} = 1/|f_n - f_p| = 3.19 \times 10^{-21}$ s (This period can be calculated directly by posing $P_{pn} = h/E$ with h = Planck constant, E = energy in J corresponding to 0.00139u which is the mass difference between a neutron and a proton. For the neutron, the period would be 0.44×10^{-23} s and for the proton 0.433×10^{-23} s)

The period P_{pn} of the interference pn will have a larger period than the standing wave of period P_p in a ratio $P = P_{pn}/P_p$. the standing wave and the interference wave will therefore be in phase with this periodicity P.

This periodicity P in the bond L, depending on whether we consider the period of the proton P_p or that of the neutron P_{ne}, will be equal to

$$P = P_{pn} / P_p \tag{2}$$

or

$$P = P_{pn} / P_{ne} . \tag{3}$$

Considering the frequencies, (2) and (3) become:

$$P = f_p / \Delta f_{pn} \tag{4}$$

or

$$P = f_n / \Delta f_{pn} \tag{5}$$

(The frequencies f_n, f_p and Δf_{pn} are all of the form $f_x = m_x c^2 h^{-1}$. There is therefore a simplification that allows to directly calculate the period P from the masses in u)

$$P = m_p / \Delta m \tag{6}$$

or

$$P = m_n / \Delta m \tag{7}$$

(with $\Delta m = m_n - m_p$; $m_n = 1.008665$ u and $m_p = 1.007276$ u)

(The order of magnitude is $P = m_p/\Delta m = 725.18$ s (if the nucleon has lost more mass, e.g. $5\Delta m$, then the bond will have a P period equal to 720.18 s ($P = (m_n - 5\Delta m)/\Delta m$))

2.2. Calculation Methods That Can Be Used to Determine the Number of Isolated Bonds

1) The mass defect Δm_t found for each nucleus, will make it possible to determine how many bonds δ with an energy of 0.000139u ($\delta = \Delta m_t/0.001389$ (8)). We can reasonably assume that when the number of bonds within a group is

very large, the group will be particularly stable: for helium4, we find a mass defect corresponding to 21 bonds p-n ($\delta = 21.07$), which confirms the special role of this grouping. The mass defect for a helium nucleon can so reach $5\Delta m$ (the maximum of isolated bonds does not exceed 9 for the heaviest elements) (See **Table A1** in Appendix 2).

2) The number of bonds corresponding to the number of N helions present in the nucleus (21 bonds per helion) is subtracted and so the number of bonds of the triplets 3H (6 bonds) or 3He (5 bonds), or doublet 2H (1 bond) when they are present. These groupings are formed primarily as shown by the results on how the mass defect increases, the analysis of the elements from H to C, and the consequence that the elements with odd Z are monoisotopic. We thus determine the number of isolated bonds δ' between the helions or with the groups 3H, 3He, 2H starting with the stable elements.

$$\delta' = \delta - 21.07N - 6.41N_1 - 5.17N_2 - N_3 \tag{9}$$

(N_1, N_2, N_3 are respectively the number of ^{3}H, ^{3}He, ^{2}H; N_1, N_2, N_3 are 0 or 1, when one is 1, the other 2 are 0)

3) Finally, for a given isotope Y of greater and generally radioactive mass, the number of additional bonds δ'' in relation to the precedent lower isotope X is determined, taking into account that these additional bonds may be double on shell 2, triple on the 3, etc. (on multiple bonds and shells, see paragraph 3-3-2).

$$\delta'' = \left(\delta_y - \delta_x\right)/n \tag{10}$$

(δ_y = total number of bonds of Y, δ_x = total number of bonds of X, $n = 1$ for a single bond, $n = 2$ from shell 2)

2.3. Half-Life Calculation

Figure 2 shows the ½ radioactive lives of 3337 radioactive isotopes from H to Pb elements from Nubase [3] [4] [5] [6]. Most of the ½ radioactive lives are between 10^{-4} and 10^7 s, a small part around 10^{-7} s; the ½ long lives above 10^{10} s are divided into 4 undulations; a peak of ultrashort lives is around 10^{-22} s. These 3 distribution zones correspond to different mass defects:

Since there are 3 zones and a correlation between the times of ½ lives and the number of bonds δ'' (see **Table A1**), we considered 3 ways of interfering for waves:

- Interferences of several bonds for one nucleon ($\delta'' > 3$) for 1/2 long lives.
- Interference of a bond of one nucleon with another ($0 < \delta'' \leq 3$) for short 1/2 lives.
- Pass time ($\delta'' \leq 0$) for the ultra short 1/2 lives.

2.3.1. ½ Life When There Is a Nucleon for Several Bonds ($\delta'' > 3$)

The nucleon concerned by radioactivity will have several bonds with different nucleons located at distances d_1, d_2, d_n. Each link will have an average period of 725 s when d is the average distance. The relationship between the period and the distance is given by

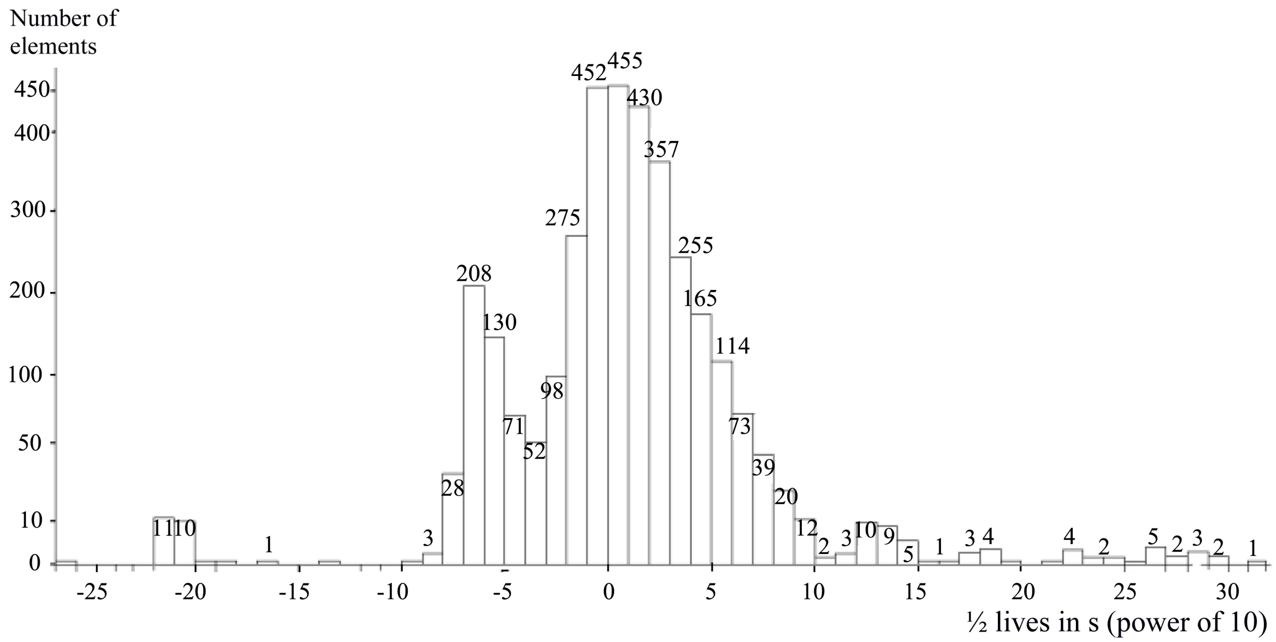

Figure 2. Distribution of radioactive ½ lives of 3337 isotopes: There is: 1) a central zone with a main peak between 10^{-4} and 10^{7} s where most ½ lives are located (median between 10 and 10^{2}). 2) A peak between 10^{-22} and 10^{-20} s. 3) Another peak around 10^{-7} s. 4) Above the central zone, 4 increases in the number of ½ lives are observed from 10^{10} to 10^{15}, from 10^{15} to 10^{20}, from10^{20} to 10^{25}, from 10^{25} to 10^{30} s. These 4 increases could correspond to wave combinations, but the number is statistically small.

$$P = P_{pn} \times c/2d \tag{12}$$

(see calculation Appendix 2). (The distance d varying between a minimum and a maximum, the period P will vary between 363 s and 1088 s) It is assumed that radioactivity will occur when the nucleon or helion has several such bonds in phase. This is a long half-life.

Thus a neutron with k bonds of period P will have a 1/2 life

$$T = P^{k} \tag{17}$$

2.3.2. ½ Life When There Is One or More Nucleons for a Bond ($\delta'' = 1$ or 2)

The nucleon concerned by the radioactivity will have a 1/2 life T due to the difference of periods P_1 and P_2 of 2 waves.

$$T = P_1 - P_2 \tag{15}$$

or

$$T = \left(P_{pn} \times c/2\right) \times \left|d_1 - d_2\right| / d_1 d_2 \tag{16}$$

This formula (calculation in Appendix 2) allows us to find, according to the constraints on distances d1 and d2, the durations of the 1/2 lives for isotopes with ½ lives between 10^{-4} and 10^{7} s.

2.3.3. Ultra Short 1/2 Lives Less Than 10^{-20} s ($\delta'' = 0$ or -1)

For the 1/2 lives of the order of 10^{-20} s, there is no additional bond since there is no additional mass defect and we propose to interpret this time as that of the passage time of a wavelength or a vibration. The additional nucleons, cannot interfere long enough to create bonds with the vibrations of the neighboring nucleons. When the ½ life is of the order of 10^{-21} s (e.g., for 5He) this could correspond to the vibration period of the interference pn of 3.2×10^{-21} s.

When the period is of the order of 10^{-24} s, it could correspond either to the period of vibration of the nucleon (4.33×10^{-24} s), or to the time of passage of an interference in a part of the nucleus since a fm is traversed in 0.33×10^{-24} s.

3. Results in Applying This Method to the Different Isotopes

The results of the number of bonds from the mass defect, and the correlation with the 1/2 lives are reported in Appendix 2 Table A1. This table shows that:

1) There is a substantial increase of δ to $21\Delta m$ from ^{3}He to ^{4}He.

2) Whenever, when Z is even, the number N of neutron reaches Z, then there is an increase of δ allowing the formation of a new helion.

3) When, in addition to helions, there are 1 proton and 2 neutrons, they will form a ^{3}H. Similarly, when 2p and 1n are available, δ' increases by 5 to form a ^{3}He.

4) Stable elements can be spotted; δ'' is highest for stable or very long 1/2 life elements ($\delta'' > 3$). For short 1/2 lives: $0 < \delta'' \leq 3$ and for 1/2 ultra short lives: $\delta'' \leq 0$.

3.1. H and He (Nucleon-Nucleon Interaction)

- ^{2}H-total mass defect $\Delta m_t = 0.001848$, (8) $\Rightarrow$ $\delta = 1$ (1.3) There is only one bond that cannot interfere with others; the distance d between the centres of neutron n and proton p can remain constant around an average value; the nucleus is therefore stable.

(The total length of the deuterium will therefore be $2d$ or 1.3 fm)

- ^{2}He cannot exist since there is no pn interference to put the 2 protons at the distance d $^{\text{and}}$ the repulsive electrostatic force dominates at this distance d. The energy of the bond corresponding to 0.00139u is $E_{pn} = 2.0711 \times 10^{-13}$ J. Since there is a distance $d = 0.645$ fm between the centres of 2 nucleons, the energy E_e of the electrostatic force of Coulomb between 2 protons can be calculated and is 3.567×10^{-13} J ($E_e = K_c \times q^2/d$ with K_c constant of Coulomb $= 8.987 \times 10^{-9}$, q charge of a proton). Between 2 protons, energy E_e decreases to $E_{pn} = 2.0711 \times 10^{-13}$ J at a distance $d_p = 1.111 \times 10^{-15}$ m which is greater than the maximum distance dm of 0.9675×10^{-15} m (see Figure 1). So the bond cannot be made.
- ^{3}H have a mass defect. $\Delta m_t = 0.00891$ u or $\delta = 6.41$. The total mass defect corresponds to 6 bonds. (The additional mass defect δ'' compared to ^{2}H corresponds to 5 proton-neutron bonds). Each neutron being equivalent, we can say that there are 3 bonds per neutron ($k = 3$). As shown in Figure 1, the positioning of a 2nd nucleon seems possible in N3 or N4, which requires the proton and the 1st neutron to be positioned at a wavelength that is a distance

$2d$ (see **Figure 3**). N3 is located exactly $2.24d$ from the centre of the 2 other nucleons. The total of the bonds is of $6.48d$ allowing to predict an energy corresponding to $6.48\Delta m$ according to Equation (1). The observed mass defect is $6.41\Delta m$. The value of the radioactive 1/2 life (3.88×10^8 s) will be perfectly recovered by the calculation ((17) $\Rightarrow$ $T = 3.83 \times 10^8$ s) since, spatially without interference, the 3 nucleons can be placed at an ideal distance multiple of d.

- ^{3}He The mass defect Δm_t corresponds to the energy of 5.17 bonds (or $5.17\Delta m$). As for ^{3}H, we can imagine a geometric configuration allowing to find the defect of mass: the 2nd proton binds with the neutron. The electrostatic force brings proton and neutrons to the maximum distance of $1.5d$. The protons will be on a node of the bond between the neutron and the other proton. The total distance between the 3 nucleons is then $5.12d$ (see **Figure 4**).

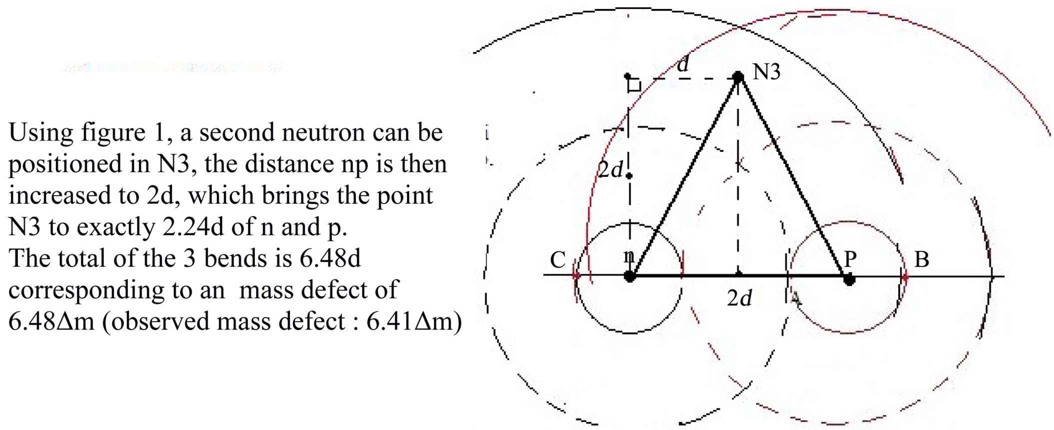

Figure 3. Possible geometry of the nucleus ^{3}H.

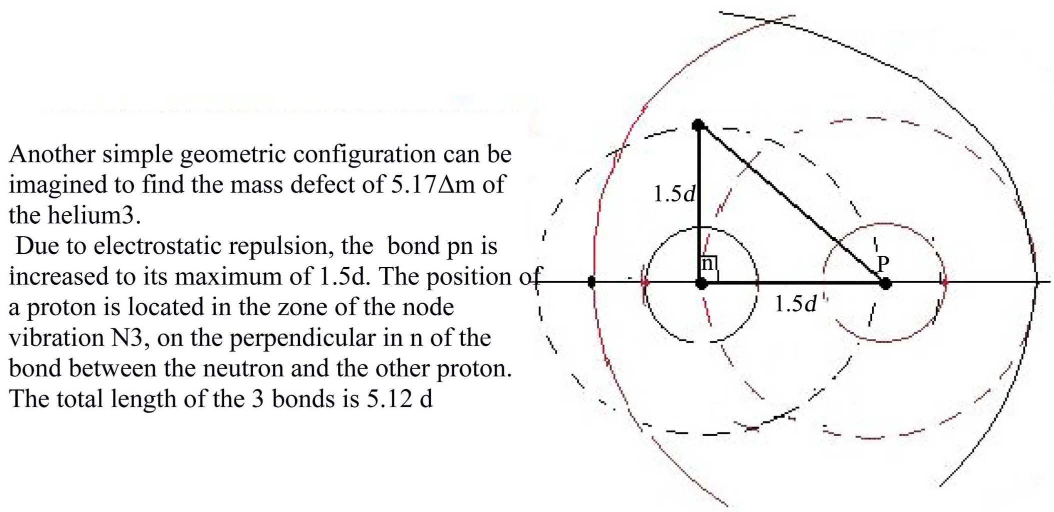

Figure 4. Possible geometry of ^{3}He. This configuration of ^{3}He where the nucleons have only one antinode of vibration instead of two with a distance between them does not vary is a hypothesis that would explain why ^{3}He which contains yet 2 protons is more stable than ^{3}H.

- ^{4}He has a significant mass defect $\Delta m_t = \Delta f_a = 0.02930$ corresponding to $\delta = 21.07$ bonds L. This significant mass defect Δf_a with many bonds involves a very stable nucleus and makes it possible to say that nucleons first form helions or particles alpha; these mass defects are found whenever 2 protons and 2 neutrons can be grouped by 4. We can imagine many geometric solutions to explain this mass defect of $21.07\Delta m$ and it would be very risky, because of the lack of precise dimensions of the nucleus, to say which one is the right one. We give an example (see **Figure 5**) simply to say that the hypothesis of a precise geometry with standing waves makes it possible to find the defect of mass. The total d_t of the bonds ($d_t = 21.07d$) makes it possible to find a maximum diameter of the nucleus at 3.379 fm in accordance with the measured diameter of the ^{4}He nucleus at 3.35648 fm [7].
- ^{5}He with an atomic mass M_a of 5.0123 u will have: $\Delta m = 2\text{p} + 3\text{n} - \Delta f_a - M_a = -0.00085\text{u}$, $\delta' = 0$ therefore no additional bond ($\delta'' = 0$) for the 3rd neutron. It is a neutron emission decay with a 1/2 life of 0.7×10^{-21} s, which could correspond to the period of one vibration or to the passage time of a part of the path of the interference pn which has a period of 3.2×10^{-21} s. (1/4 of the wavelength beats in 0.8×10^{-21} s and is 0.25×10^{-14} m, length of the order of magnitude of the nucleus). So, it could be interpreted as a nucleon that passes at the level of the nucleus and that interferes only the time of its passage.
- ^{6}He has a 1/2 life of 806 ms and with $\Delta m = 0.00136$ u has a single additional bond compared to ^{4}He ($\delta' = 1$) for 2 neutrons that form a halo.

Since $\delta'' = 1$ (a single additional bond compared to ^{5}He, the precedent lower isotope), the 1/2-life T will be calculated from the difference between 2 adjacent periods P_1 and P_2 according to Equation (16). A 1/2 life of $T = 0.806$ s corresponds to a variation of length Δd of only 0.007 fm.

- ^{7}He ($\Delta m = 0.00057$ u so $\delta'' = 0$ additional bond compared to ^{6}He. It is a disintegration by neutron emission as for ^{5}He. The 1/2 life will also correspond to the passage time of a wavelength (we can try the ad hoc explanation that this 1/2 life of 2.9×10^{-21} s corresponds to the time that passes 3/4 of the wave pn, that is 2.4×10^{-21} s).

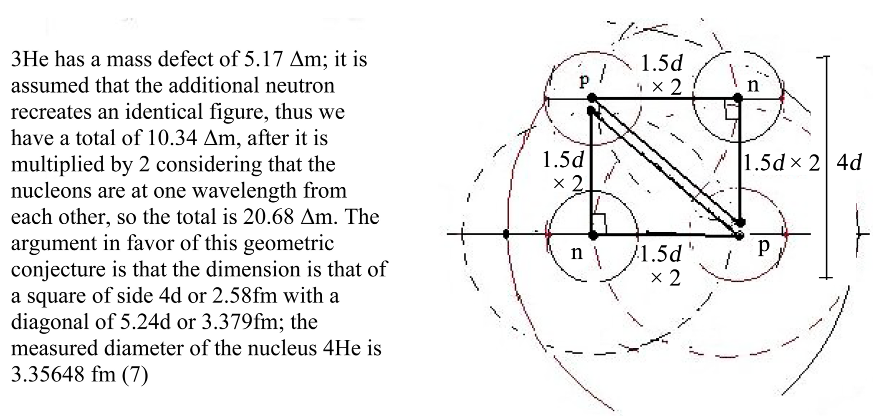

Figure 5. Hypothetical example on the geometry of ^{4}He. If we consider the atomic mass of ^{4}He, the vibration period is 1.1×10^{-24} s.

- ^{8}He (½ vie = 119 ms) will have two bonds ($\delta' = 2.40$) for the four neutrons in halo. The spatial configuration is a hypothesis that would make it possible to better explain the different daughter isotopes (see **Figure 6**).

3.2. From Li to C

- ^{4}Li ^{and} ^{5}Li release a p and have ½ lives of 0.09×10^{-21} s and 0.37×10^{-21} s.
- ^{6}Li, $\delta = 23.5$, there are $21\Delta m$ to form a helion, $1\Delta m$ for a bond p-n and $1.5\Delta m$ for 2 bonds between the group pn and the helion.
- ^{7}Li, $\delta'' = 6$, the group pn is replaced by a group ^{3}H with its 6 internal bonds.

^{8}Li, $\delta'' = 1.5$, which suggests a bond of $1.5d$ for the last neutron and that the group ^{3}H of the ^{7}Li is not modified. Therefore, the halo should be non-symmetrical since it consists of a neutron and of a group ^{3}H and not 1p + 3n.

^{9}Li, $\delta'' = 3.1$ there are 3 bonds more than the ^{8}Li; a bond will unite the new neutron to the previous; the group will be bound to the central nucleus by a double bond $2d$. So, ^{9}Li will have an elongated shape. When this neutron becomes a proton, there will be formation of 2 ^{4}He and depending on whether the remaining neutron will have its 2 bonds straddling the 2 He or on a single one, we will have the 2 modes of decay at 50% (see **Figure 7**).

^{10}Li releases a neutron and has a 1/2 life of 1.35 to 3.7×10^{-21} s that can be conjectured to correspond to a passage time proportional to the diameter of the nucleus variable according to the isomer.

^{11}Li has an additional bond to ^{10}Li or ^{9}Li. The pair of neutron attaches to a distance $1d$. The long length of ^{11}Li would thus reach about $9d$.

^{12}Li emits a neutron and we find an ultrashort 1/2life.

- ^{8}Be ($M_a = 8.0053$ u) $4p + 4n - 2\Delta f_a - M_a = -0.00006$. $\delta' = 0$, there is no bond, so this element exists only the time of a wave passage.
- ^{9}Be (9.01218u): $\delta'' = 1.34$. This element is interesting: it is stable despite a small δ'' allowing for the neutron a bond with each of the helions at a short distance ($0.67d$). The stability, with the idea of standing waves, would be due

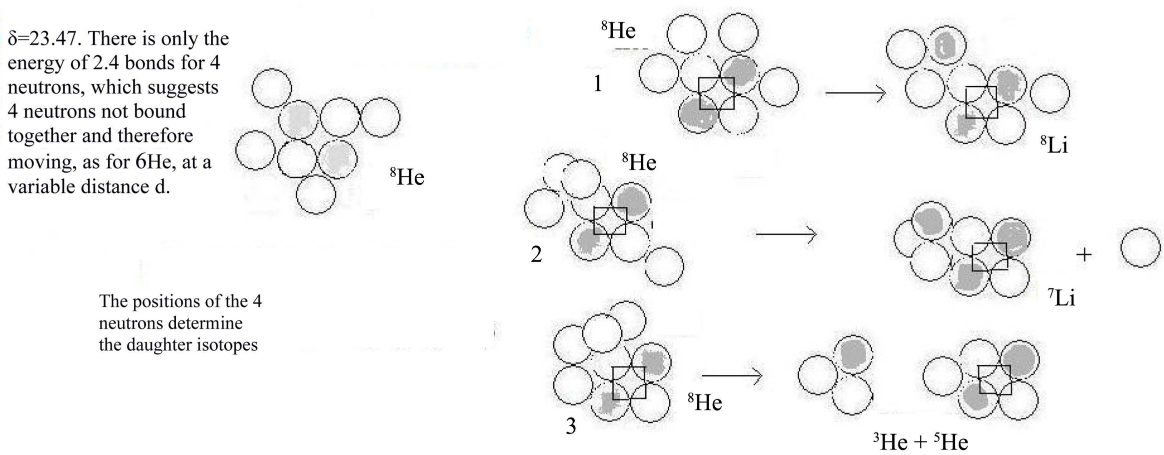

Figure 6. Spatial configuration and ^{8}He daughter isotopes. The configuration 1 where neutrons are dispersed is the most common (83.1%); 1) in 2, 3 nucleons are grouped together (16%); 2) in 3, the 4 nucleons are grouped together (0.09%).

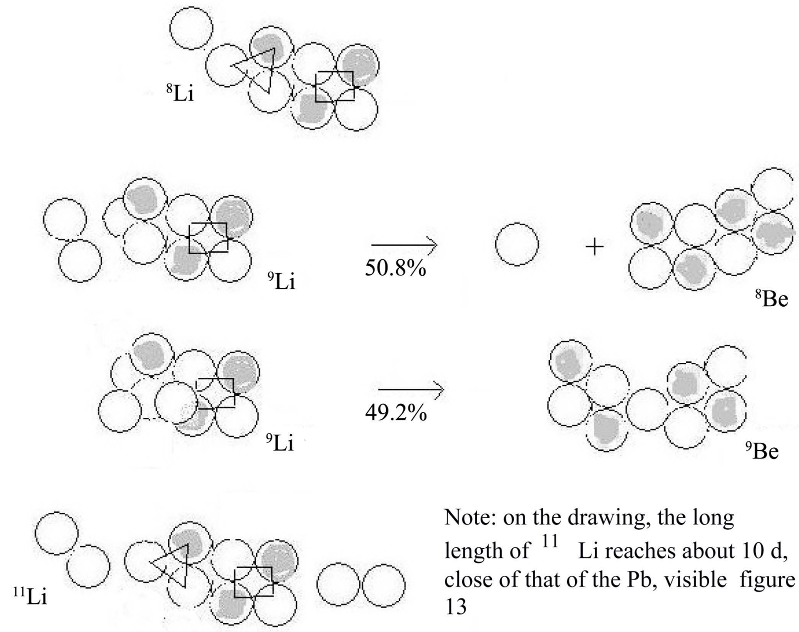

Figure 7. Possible configurations of lithium and berylium. 8Li has 10 bonds in addition to the helion, that is 6 bonds to make a group ^3H and 4 bonds to unite at a distance $2d$ the group ^3H and the nucleon to the helion. ^9Li has 3 additional bonds. The 2 n can grouped together in pair. The position of the 2 n relative to the group ^3H at the time of decay could explain the daughter isotopes. ^{11}Li: The peripheral neutrons could be grouped by two because the isolated neutron of the ^{10}Li remains only 2×10^{-21} s.

to the fact that the geometry allows the 2 bonds to have identical distances and therefore frequencies of vibrations without phase shift (**Figure 7**). The shape of the ^9Be that can be deduced is consistent with that described by Ebran, *et al.* [8].

- The carbon atom ^{12}C: it will be composed of 3 helions; subtraction of 3 times the mass defect of one helion makes it possible to find 6 bonds L (we can suppose that each proton of one helion interferes with one of the six neutrons of another helion):

$6p + 6n - 3\Delta f_a - 6\Delta f_{pn} = 12.09714 - 3 \times 0.0297 - 6 \times 0.00138 = 11.99971$. We find the exact mass of the ^{12}C, which makes it possible to assume that all 6 bonds have the ideal distance d and that this nucleus is particularly stable.

For ^{13}C, the mass defect ($\delta'' = 3.82$) makes it possible to find 4 additional bonds p-n, which makes it possible to imagine that the additional neutron is fixed by 2 double bonds (bonds of length $2d$ as for ^3H) (see **Figure 8**).

For ^{14}C, there are 6 additional bonds compared to ^{13}C, the last neutron can be linked by 4 bonds (2 doubles and 2 singles).

3.3. Above C, It Is Possible to Construct the Hypothesis of a Model in Shells or Corona

3.3.1. Starting from C, We Start from the Findings from Table A1

1) Helions are primarily constituted. Systematically, for all isotopes, when the number of neutrons reaches the even number of protons Z, there is a loss of

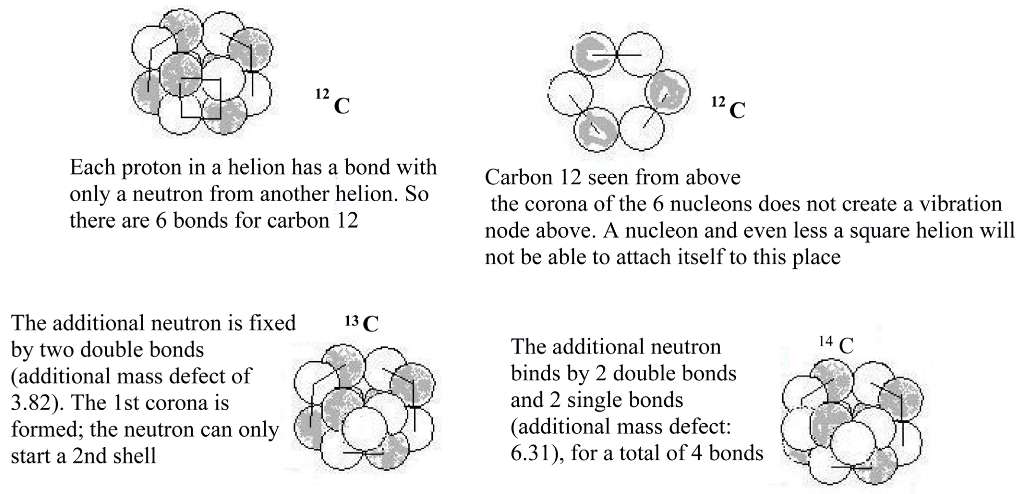

Figure 8. The atom of carbon.

additional mass of at least 21Δm allowing to constitute a new helion. If a helion cannot be formed, it can be seen that then, first of all, the triplets ^{3}H or ^{3}He are formed (there is a defect of additional mass of 6 or 5Δm).

2) Table A2 (Appendix 2) recalls that, above C, the number of stable nuclei is greater when Z is even. For elements where Z odd, an additional neutron added to the stable isotope will be converted by radioactivity β^- into a proton to form a new helion (When Z odd, the lower-mass stable element above nitrogen is always made up of helions with or without neutron pairs and a group ^{3}H (see paragraph 3-3-3)).

3.3.2. A Model of the Nucleus Will Be Able to Be Drawn from Stable Nuclei Which, Like C, Have a Number of Helions Multiple of 3 (see Figure 9)

We note that for the ^{12}C, there are 6 bonds (6Δm) between the 3 helions, or 2 bonds by helion.

To interpret the large number (12Δm) of additional bonds of $^{24}_{12}$Mg for the 3 new helions compared to the ^{12}C:

1) Or we imagine a very large number of connections between the 3 new helions and then, the bigger the nucleus would be the more stable it would be. The nucleus being less stable when it grows, this hypothesis must be rejected.

2) The other hypothesis to explain the large number of additional bonds (the important mass defect) is to say that the distance between the new helions is 2d (2 nodes on the standing wave forming the bond) and not d (distance between 2 nodes). (This is the hypothesis we made for ^{3}H and resumed for ^{4}He, ^{13}C and ^{14}C). Each link at a 2d distance that we will now call double bond corresponds to an average mass defect of 2Δm.

This hypothesis also has the advantage of being able to describe an excited nucleus. An excited nucleus could be a nucleus where the nucleons are placed at distances of 2, 3 or 4d. This is consistent with the representations of excited nuclei [8].

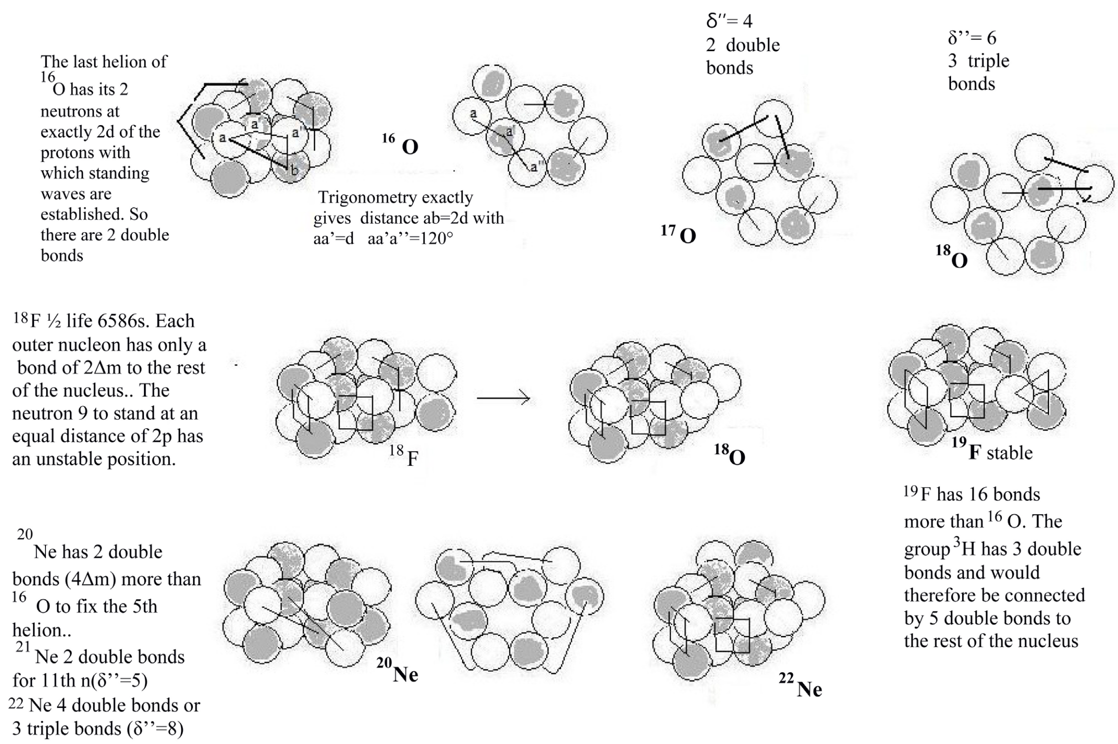

Figure 9. Formation of a 2nd shell.

- So for ^{16}O, if there are still 2 bonds by helion, with a loss of mass of 5.53 Δm, the additional helion will attach itself to the outer part of the ^{12}C corona starting a second shell. Trigonometry makes it possible to verify that the distance between a neutron of this helion and a proton of the 1st shell is exactly $2d$. The geometry does not allow it to attach itself to the top of the corona because the square shape of the new helion does not correspond to the hexagonal shape of the ^{12}C. Placing the new helion above would not keep the nucleons at a distance d and protons would be in contact (see Figure 9).
- It is the same for ^{20}Ne where 4 additional Δm allow to link a new helion on the second shell by 2 double bonds.

For $^{24}_{12}Mg$, there is a mass defect allowing two double bonds to connect the 3rd helion on shell 2. This hypothesis where the distance increases with the size of the nucleus could explain an increasing instability and goes in the direction of the model of the nucleus in shells. Thus, most of the mass defect of $^{36}_{18}Ar$ is explained if the 3 additional helions are connected on a 3rd shell by 6 triple bonds. Similarly, 6 quadruple bonds are obtained for ^{50}Cr and 6 quintuple bonds for ^{64}Zn (Figure 10).

- This principle of connecting as soon as possible the last 3 helions per n times 6 bonds allows, from the mass defect (and more precisely the additional mass defect δ_s compared to the previous element multiple of 3 helions), to determine on which shell n are the last 3 helions and to define a fill order. $n = \delta_s/6$ with $\delta_s < 25$ (18). This empirical formula is valid until neutrons are needed to stabilize the nucleus. Neutrons use a variable number of bonds depending on

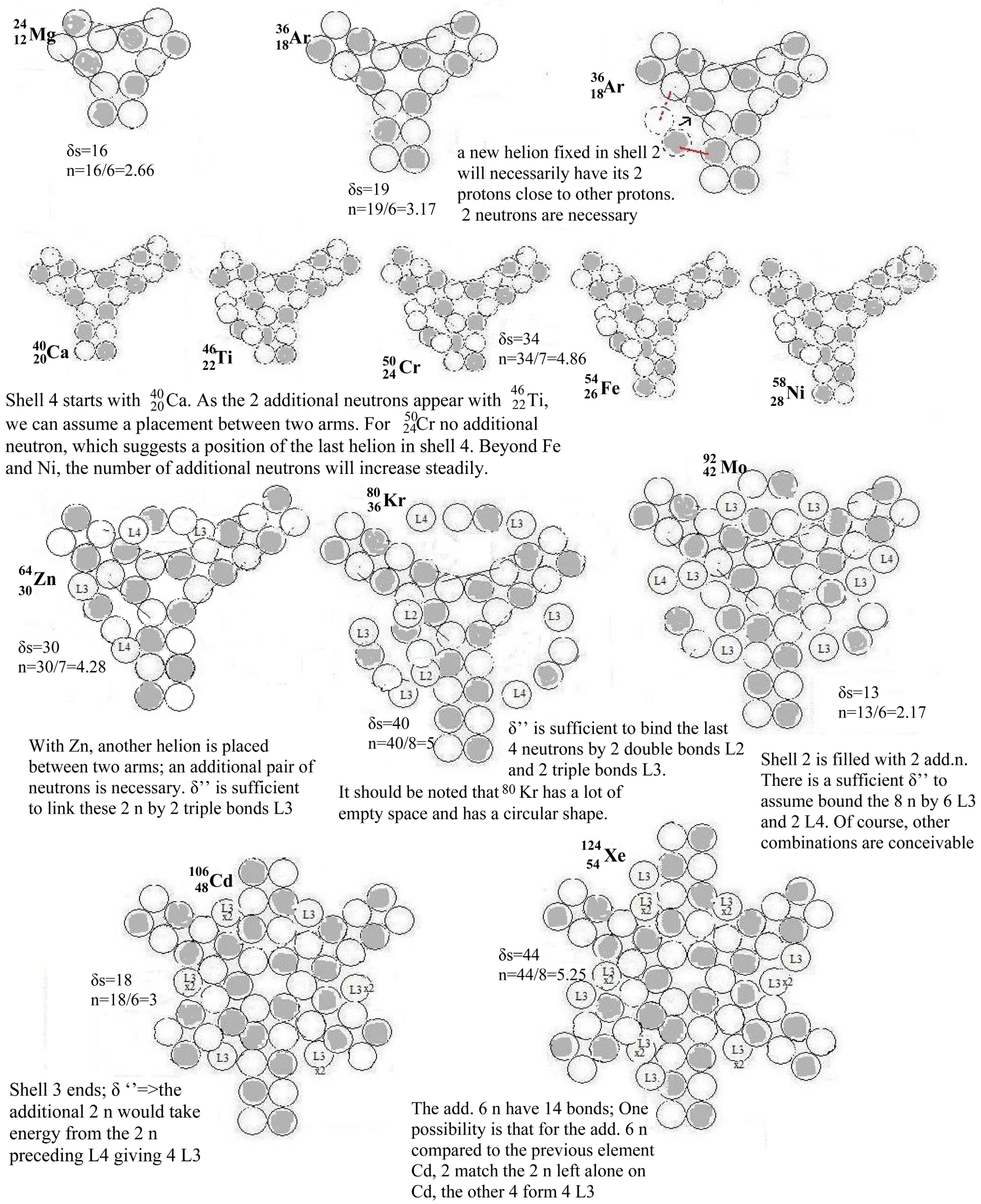

Figure 10. Formation of shells 3 to 5. The shell number n is given by $n = \delta_s/6$ when there is no neutron in addition to the helions. δ_s is the additional mass defect for an element with helions multiple of 3 compared to the previous element, multiple of 3 helions. n will become $\delta_s/7$ then $\delta_s/8$ depending on the number of additional neutrons. δ'' (number of new bonds in relation to the next lower isotope) is indicative of the number of bonds between the new neutrons and the new helion. (nuclei are seen from above, so only half of each helion is seen).

the shell in which they are fixed and this must be taken into account. So, when 35 > δ_s > 25, (18) becomes $n = \delta_s/7$ (19), when δ_s > 35, (18) becomes $n = \delta_s/8$ (20). For the other multiple elements of 3 helions, ${}^{50}_{24}\text{Cr}$ will have 4 shells (n = 4.85), ${}^{64}_{30}\text{Zn}$ will fill the rest of the shell 4 (n = 4.28), ${}^{80}_{36}\text{Kr}$ will have 5 shells (n = 5.00). ${}^{92}_{42}\text{Mb}$ will fill the rest of shell 2 (n = 2.17), ${}^{106}_{48}\text{Cd}$ will fill the rest of shell 3 (n = 3.00), ${}^{124}_{54}\text{Xe}$ part of shell 5 (n = 5.5) as ${}^{142}_{60}\text{Nd}$ (n = 5.25) (see Figure 10 and Table A4).

- This filling helps to understand the role of additional neutrons and how they stabilize the nucleus. The filling brings, after the ${}^{40}_{20}\text{Ca}$, helions to have their protons in contact with other protons. Two pairs of protons will be in contact (at a distance of 0.645 fm where the electrostatic repulsive force is stronger), which will bring each helion in this position to need two neutrons to be stable. For the construction of the nucleus, this leads to say that a helion that does not need 2 neutrons is fixed on one of the three branches; a helion that needs 2 neutrons is fixed between two branches. Thus, above the ${}^{40}_{20}\text{Ca}$, it can be assumed that the last helion of ${}^{46}_{22}\text{Ti}$ is fixed between 2 branches, that the last helions of ${}^{54}_{26}\text{Fe}$ and ${}^{56}_{28}\text{Ni}$ are fixed on the branches. From ${}^{64}_{30}\text{Zn}$, there is a steady increase in the number of neutrons. It is tempting to interpret the decrease in mean energy per nucleon from the Fe and Ni by this neutron augmentation mechanism; this is in agreement with the Aston curve. It can be verified on Table A4 and Table A5 in the Appendix 2 that the increase of neutrons for the stable elements is 2 in 2. We can see that, when Z is even, the number of neutrons in addition to those of the helions is even and that, for each element, the stable isotopes of lower mass between Ca and Pb, 32 elements, all have stability for $2n$ neutrons then $2n + 2$ neutrons (e.g. ${}^{54}\text{Fe}$ and ${}^{56}\text{Fe}$, ${}^{64}\text{Zn}$ and ${}^{66}\text{Zn}$) (exception of ${}^{46}_{22}\text{Ti}$ and ${}^{47}_{22}\text{Ti}$ which are stable, ${}^{90}\text{Zr}$ with ${}^{91}\text{Zr}$ and ${}^{142}\text{Nd}$ with ${}^{143}\text{Nd}$) It can however be noted that this does not explain why, almost systematically, there is a stable isotope with an odd number of neutrons $2n + 3$ (e.g.; ${}^{57}\text{Fe}$, ${}^{67}\text{Zn}$, …).

From ${}^{124}_{54}\text{Xe}$, the order in which the shells are filled and how the additional neutrons are placed is easier to understand by taking the excess of mass loss for each additional helion (see Table A5). The increase in the loss of mass from one nucleus to another to uranium is variable but remains in a narrow range correlated with the number of neutrons required for the stability of the nucleus.

This filling can be followed on the geometry of the nucleus and is more understandable on a graphical representation. The geometric form in trifide corona by growing creates spaces that are then occupied (see Figure 11).

The existence of empty spaces within the nucleus is one hypothesis that has already been made by several studies speaking of a "bubble structure" [9] [10]

The nucleus gradually takes the form of a 6-pointed star with 5 levels or shells. (at no time is there a mass defect sufficient to form a 6th shell and bind the new neutrons) Between the branches, spaces are available and we note that the filling of shell 5 which can contain 14 He ends with the Pb (Figure 12) (NB: On the figure, at shell 5, there are 2 times between 2 branches of the star, 2 He instead of

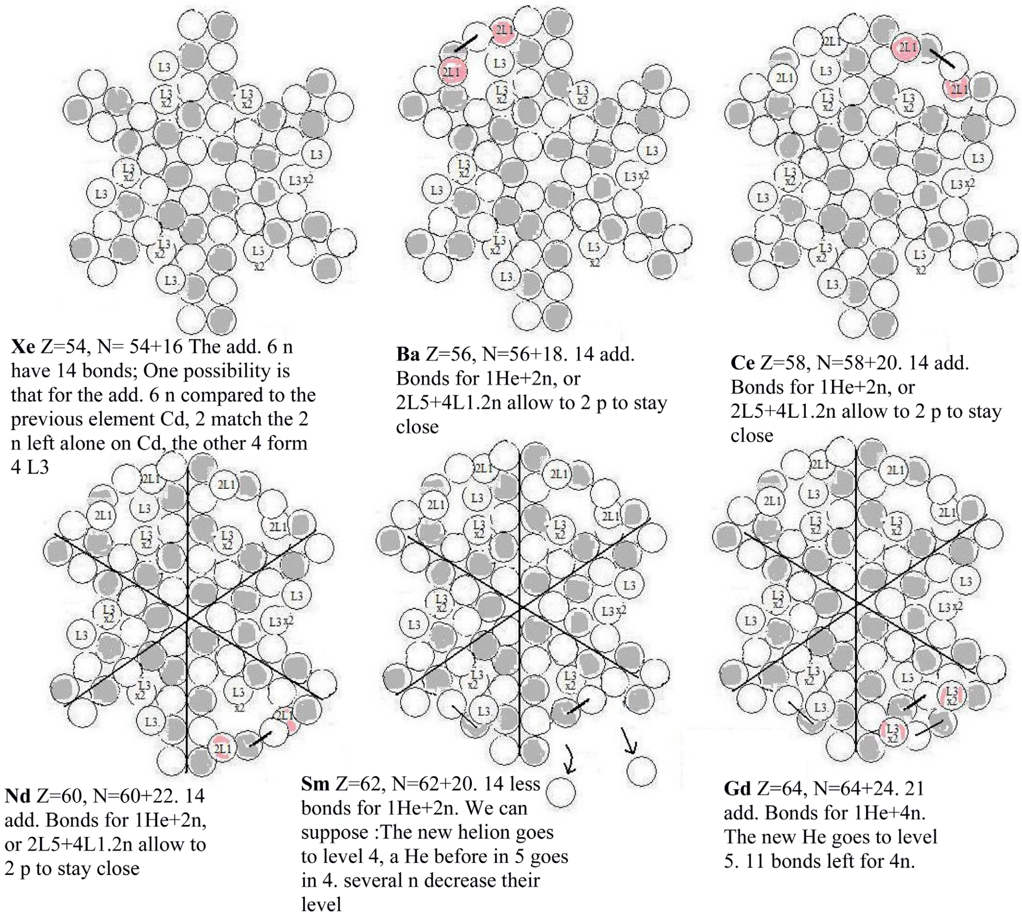

Figure 11. Filling of the spaces of the nucleus and hexagon shape.

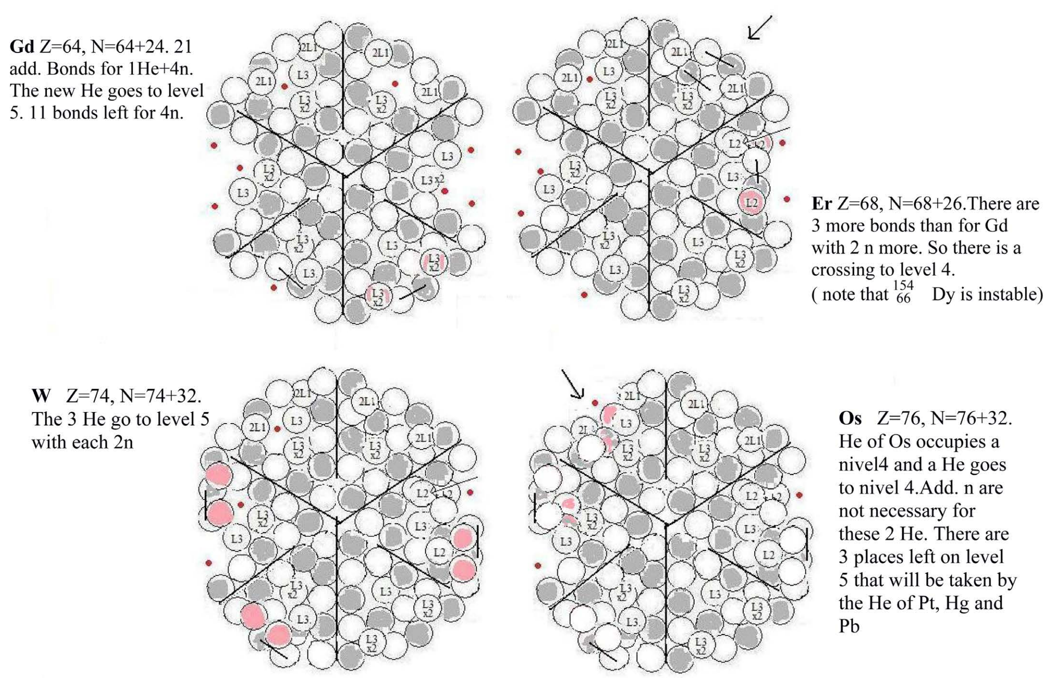

Figure 12. End of filling of shell 5 with Pb.

one, which is logical since with a diameter of 9*d*, the outer limit of the 4th shell can contain exactly 14.01 He of dimension 2*d*). As part of a corona model, it is happy to see that this filling based on geometry could give us an explanation: and the principle of quantum numbers associated with shells and sub-shells, and to an exclusion principle since each helion having a specific place, there cannot be 2 helions in the same place. It should be noted, however, that our 5 shells do not correspond to quantum shells and that we do not systematically find a correlation with magic numbers.

- Between Pb and U, there is always an average increase of 2 neutrons for each additional helion with only an average of 3.2 bonds for a helion with 2 neutrons. This excess mass defect of 3.2 is small and comparable to that of lighter elements below C. Also, instead of considering a sixth shell, this small increase in the number of bonds makes us think that helions, as for the C, will group by 3 with one or two helions of the shell 5 and that these latter helions will have weaker links with the rest of the nucleus. This is a hypothesis that could explain the fissions of heavy elements where Ra gives Pb + C, Th becomes O + Pb or Yb + Ne + Ne or Hg + Ne, U becomes Pb + Ne or Hg + Mg or Hf + Ne + Ne. This suggests for our model that the magnification of the nucleus above the Pb is done by fixing an extension having the shape of a C, a O, a Ne or a Mg (see **Figure 13**).

Our model suggests that there is no super-heavy stable element. The magnification of the nucleus above Pb is done by fixing an extension in the form of a C, O, Ne or Mg. It then seems logical to think that the larger this extension, the more unstable the nucleus.

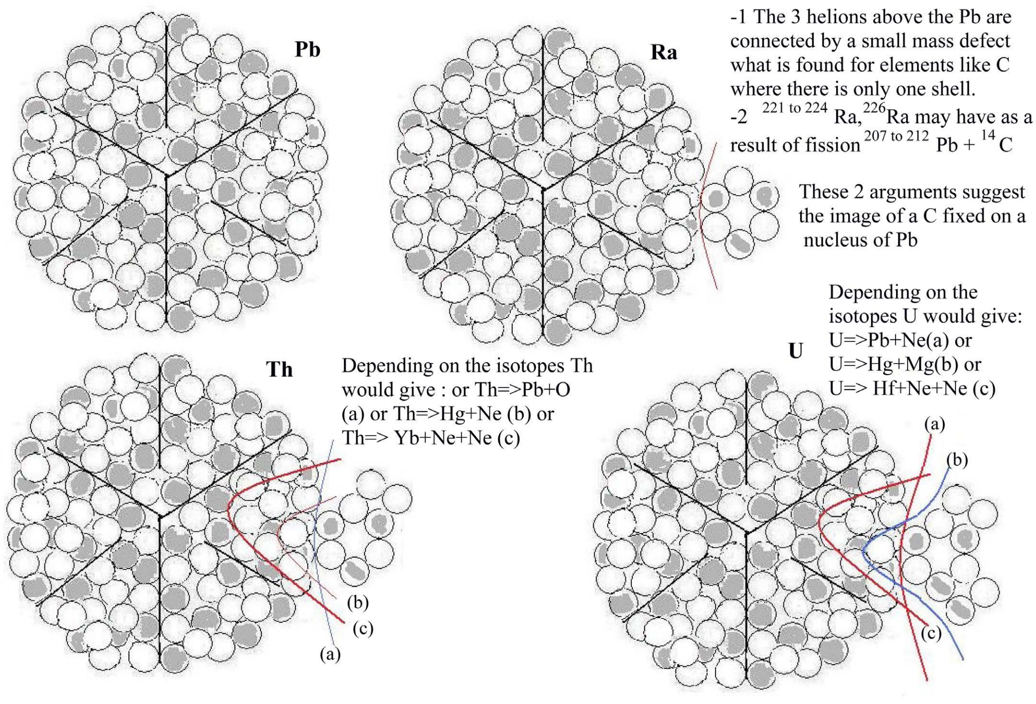

Figure 13. From Lead to Uranium.

(One could also imagine a sixth shell consisting of 14 helions which would be placed in front of the 14 helions of the shell 5 of the Pb. But it is difficult to see why there would appear an additional defect of $12\Delta m$ per helion necessary to constitute this shell when there is only $3.2\Delta m$ by helion from Po to U). It should be noted that knowing the mass defect of these stable elements, it is easy to verify that the immediately superior radioactive isotopes have a small number of bonds to retain their additional neutrons. The number of bonds can give us an idea of their position within the nucleus and will allow us to choose the formula to use to determine their ½ life. This geometric position would induce by what wave interferences they are bound and thus their radioactive ½ life.

3.3.3. Consequences of This Model on Stable Monoisotopic Nuclei (Odd *Z*)

The fact that they are monoisotopic is logical for our model since helion formation is a priority as soon as a neutron is added. We can predict which monoisotopic element will be stable: we take the stable isotope X of the element with the lowest mass A with Z even, or ${}^{A}_{Z}\mathrm{X}$, and we add a ${}^{3}\mathrm{H}$ group with 0 or 1 or 2 pairs of neutrons depending on the shell reached by the previous element with even Z.

- Thus, for even elements ${}^{A}_{Z}\mathrm{X}$ from ${}^{16}_{8}\mathrm{O}$ to ${}^{40}_{20}\mathrm{Ca}$ stable without neutron in addition to helions, elements Y with a stable number of odd protons will all be of the form:

$$\mathrm{Y} = {}^{A+3}_{Z+1}\mathrm{X} \quad (Z \text{ even}, \ 6 < Z < 20) \tag{21}$$

- Between ${}^{40}_{20}\mathrm{Ca}$ and ${}^{90}_{40}\mathrm{Zr}$, the stable element Y, with number of odd protons will have a mass number of: $A + 3 + 2$.

$$\mathrm{Y} = {}^{A+3+2}_{Z+1}\mathrm{X} \quad (Z \text{ even}, \ 18 < Z < 40) \tag{22}$$

- Between ${}^{90}_{40}\mathrm{Zr}$ and ${}^{142}_{60}\mathrm{Nd}$, the stable odd element is obtained by adding to group ${}^{3}\mathrm{H}$ either a pair of neutrons (Ag, Pr),or 2 pairs (Rh, In, I), or 3 pairs (Sb, Cs, La), or no pair (Nb). For our model it can be interpreted by the progressive filling of shells 4 to 2.
- Between ${}^{144}_{62}\mathrm{Sm}$ and ${}^{204}_{82}\mathrm{Pb}$, the stable element Y with number of odd protons will have a mass number of: $A + 3 + 4$ (except ${}^{165}_{67}\mathrm{Ho}$ which has 6n more instead of 4).

$$\mathrm{Y} = {}^{A+3+4}_{Z+1}\mathrm{X} \quad (Z \text{ even}, \ 60 < Z < 82) \tag{23}$$

For our model, this stability in the addition rule could be explained by filling only of shell 5.

In the few cases where there are two stable isotopes, (Cu, Ga, Br, Ag, Sb, Ir, Tl), the second stable isotope is obtained by adding a pair of neutrons.

As soon as an additional neutron is added to this group in addition to the pairs of neutrons needed to stabilize the nucleus, a neutron will most often be transformed into a proton (β-decay) to form a new helion. This is the possible explanation for the low number of stable isotopes for elements with odd Z.

3.4. Results on ½ Lives

It is the number of δ'' and therefore the geometry that will make us choose one of the formulas below to use to determine the ½ lives.

3.4.1. ½ Life When There Is a Nucleon for Several Bonds ($\delta'' > 3$)

The ½ life will be calculated from the formula $T = P^k$ (17).

In **Table A3** in the Appendix 2, we reproduce all isotopes of masses greater than stable elements (Radioactivity α and β) of ½ long lives (>10 years) from the classification (64 isotopes) and find a very good correlation between the observed½ lives and what our calculation provides (only 4 heavy isotopes come out of our calculation). The deviation that often exists from the mean value could be explained by the variation in the distance of the nucleon or helion bonds concerned by the radioactivity. The ½ life is then a way to calculate the distance d of the bonds. ((12) (17) $\Rightarrow \quad d = P_{pn} \times c/2 \times T^{1/k}$) (24)

It is also interesting to note that for all these elements at ½ long life, from the lightest to the heaviest, δ'' is always greater than 3 and between 5 and 8.

3.4.2. ½ Life When There Is One or More Nucleons for a Bond ($0 < \delta'' \leq 3$)

- The first thing is to note that there is a total correlation for isotopes between their ½ lives between 10^{-4} s and 10^{7} s and their δ'' between 0 and 3.
- The formula $T = \left(P_{pn} \times c/2\right) \times \left|d_1 - d_2\right| / d_1 d_2$ (16) allows to find the exact durations of ½ lives. This is done from distances d_1 and d_2 below the maximum that we have set to remain within the framework of standing waves. The knowledge of the 1/2 life allowing to predict the distances, the validation of this formula could come from such measures.
- For some periods, for example around 10^{-9} s halfway between ultra short and short periods, the existence of a peak might suggest a different type of interaction than described for short periods. The combination of 2 waves T_1 and T_2 from the formula (16) with periods around 10^{-4} s would allow to find the periods T of the peak at 10^{-9} s according to a formula $T = T_1 \times T_2$, but in the absence of any observation, this is only a conjecture.

3.4.3. Ultra Short ½ Lives (<10^{-20} s)

Similarly, for these ½ lives, we can verify that all radioactive elements have a $\delta'' \leq 0$.

4. Discussions and Conclusion

The model we propose remains valid from the H to the heaviest elements.

4.1. On Characteristics of the Bond

The initial postulate is that the bonds between the nucleons start from the two-body interaction between a proton and a neutron; the energy of the bond then corresponds to the difference in mass between this neutron and this proton. Since the neutron has lost 0.00139u, neutron and proton then vibrate at the same frequency; it is then postulated the existence of standing waves whose periods will interfere with that of the energy corresponding to the difference in mass between a neutron and a proton. The period will be $P = P_{pn}/P_p$ (2).

- This model based on standing waves makes it possible to set a precise distance of 0.65 fm between the nucleons. The maximum length of the bond will be at the level of the antinode of the wave which will give a maximum length of dm = 0.975×10^{-15} m and a minimum length of 0.325×10^{-15} m. This variation in the distance d between 2 nodes induces a variation in the period P, $P = P_{pn} \times c/2d$ (12) which will give a period between 363 s and 1088 s with an average of 726 s. This principle of a standing wave where the nucleons stabilize at the vibration nodes would allow us to understand that the strong interaction is repulsive below 0.65 fm, attractive between 0.65 fm and 0.975 fm and weaker or absent beyond.

Considering superpositions for standing waves is not theoretically impossible. When, for a geometric reason, the distance cannot be identical for 2 bonds involving a nucleon, the difference in the periods of the 2 standing waves will cause instability responsible for the radioactivity. This hypothesis makes the fission mechanisms understandable but is less satisfactory for radioactivity β.

- The energy of the bond allows to calculate the precise distance of 1.11 fm (greater than the maximum distance of 0.975 fm) where the energy of the electrostatic force of Coulomb equals the force of the bond. This allows us to understand how a neutron allows 2 protons to remain neighbours.

4.2. The Helions Are Constituted in Priority

The increase of the mass defect as the masses increase is used to verify that the nucleons are first grouped to form helions since each time 2 protons and 2 neutrons appear, either by addition or following a decay β, an additional mass defect of about $21\Delta m$ is immediately observed corresponding to the number of bonds constituting a helion. Similarly, each time a neutron and two protons or a proton and two neutrons are added, there is a mass defect supplement of 5 or 6 Δm corresponding to the bonds contained in the groups ^{3}He or ^{3}H. The 3 added free nucleons form these 2 triplets in priority. When in addition to helions, a neutron proton pair is added, the additional loss of $1\Delta m$ suggests that this proton and neutron bind. This observation that helions are formed in priority explains why stable nuclei with even Z are more numerous than those with odd Z.

4.3. Model of the Nucleus in Concentric Shells or Corona

Starting from the idea that helion is the basic element for constructing the nuclei, it is possible to represent the geometry of the nuclei from 3 criteria:

1) The neutrons inserted between the helions have the role of allowing protons to remain nearby but up to the Ca, to be stable the nuclei do not need additional neutrons which indicates that the protons are not neighboring.

2) For stable elements, the additional mass defect for each new helion and new neutrons necessary to keep protons close together, makes it possible to make the hypothesis of a positioning of the helions in shells, The additional mass defect

makes it possible to specify what this shell is. (a) It is a minimum of $2\Delta m \times n$ (n = shell number) for each additional helion. b) The shell n is determined from the empirical formulae $n = \delta_s/6$ with $\delta_s < 25$ (18) or $n = \delta_s/7$ when $25 < \delta_s < 35$ (19) or $n = \delta_s/8$ when $\delta_s > 35$ (20), δ_s = additional mass defect of the last 3 helions compared to the previous element multiple of 3 helions).

3) When helions begin to bind, starting from 3, so from ^{12}C (consisting of 3 helions bound by 6 simple bonds making necessary a ring shape), the standing waves will have nodes of vibration in the plane of the corona. The waves will be "destructive" above or below this plane, hence the choice of a corona or snowflake model and not a ball model.

These 3 criteria lead to the hypothesis of a nucleus where helions are arranged in concentric shells.

In order for the nucleus to remain stable without additional neutrons until Ca, we have tried to show that the nucleus, from ^{12}C, begins to be built into a 3-pointed star. Up to Ca, helions can be added without the protons being in "contact" since the nuclei are stable without the addition of neutrons. This mechanism continues until Fe and Ni after the addition of 2 neutrons with Ti. The installation of helions or ^3H groups between these 3 branches then requires the presence of neutrons from ${}^{45}_{21}Sc$ and ${}^{46}_{22}Ti$. Indeed, when a helion is placed between existing helions its 2 protons will necessarily be close to 2 protons. Neutrons, in addition to helions or ^3H groups, are therefore in even numbers and this hypothesis explains why between C and Pb when Z even, the first 2 stable isotopes have $2n$ then $2n + 2$ neutrons.

Similarly, when the number of protons is odd, we can verify that the stable nucleus has, in addition to helions and the ^3H group, a number of null or even neutrons depending on the shell, according to a formula: $Y = {}^{A+3}_{Z+1}X$ (even Z, $6 < Z < 20$) (21) or $Y = {}^{A+3+2}_{Z+1}X$ (even Z, $18 < Z < 40$) (22) or $Y = {}^{A+3+4}_{Z+1}X$ (even Z, $60 < Z < 82$) (23) (${}^{A}_{Z}X$ = stable element of lower mass immediately below Y)

The 5th shell finishes filling with Pb. Above, the small increase in mass defect and the type of fission decay suggest that the nucleus grows by fixing an element between C and Mg on a nucleus of Pb.

This corona model has a large diameter (6.45 fm when 5 shells) but its thickness remains relatively constant (1.2 fm).

Nucleon periods and distances within the nucleus are correlated according to equation $P = P_{pn} \times c/2d$ (12) for the short ½ lives or $d = P_{pn} \times c/2 \times T^{1/k}$ (24) for some isotope bonds with long ½ lives. This means that, starting from ½ life, it should be possible to specify some of the dimensions of a nucleus and the distances between the nucleons within it. The ½ life is so a way of calculating distances. In addition, if an ultra-short ½ life of the order of 10^{-20} s corresponds to a time of passage of a wave through all or part of the nucleus, then the time of the ½ life allows to determine a dimension of the nucleus.

Therefore, one way to confirm or invalidate our model would be to make very accurate measurements of the dimensions in the nucleus.

Of course, it is not said that there cannot be other possible configurations meeting these 3 criteria. This corona model is identical to shells models where we start from interactions with 2 bodies; the geometry allows to define locations that could explain the "boxes" defined by the quantum numbers. (with the difference that we finish filling the 5th and last shell with the Pb). The shells that we define are different from those from previous shells models and we do not find all the magic numbers.

4.4. The ½ Lives

The fact that this model is based on standing waves and their superpositions could explain that the radioactive periods are not randomly distributed but have preferential zones around 10^{-22} s, around 10^{-7} s, between 10^{-4} and 10^{7} s, then in 4 waves between 10^{10} and 10^{30} s.

The number of bonds concerned by radioactivity and the number of nucleons are deduced from the mass defect resulting from the experimental observation. The number of additional bonds in relation to the immediately below isotope, almost without exception, makes it possible to deduce for all the elements if the radioactive ½ life is short or long and induces the use of the corresponding formula. These formulas, $T = P^k$ (17) for the long ½ lives, $T = \left(P_{pn} \times c/2\right) \times \left|d_1 - d_2\right| / d_1 d_2$ (16) for the short ½ lives and to match a passage time of a wave for the ultra short ½ lives, allow to find the radioactive ½ lives. However, these formulas have limits: the ultra short ½ lives are found starting from a distance travelled but this distance is not a fact of observation. For the short ½ lives, it is necessary to set a precise distance between nucleons; this distance is likely and possible, but has not been measured. (For some periods, for example around 10^{-9} s halfway between ultra-short and short periods, the existence of a peak could conjecture another type of interaction than that described for short periods; the combination of 2 waves from the formula. (16) with periods around 10^{-4} s would allow to find the periods of the peak at 10^{-9} s). For long ½ lives the number k of bonds involved in radioactivity is not calculated from the number of new bonds δ''. k could only be deduced from a geometry that we do not know.

However, the fact that we can find the radioactive ½ lives of all the elements by a theoretical calculation that requires experimental verifications could be a step forward. This raises a question since the only postulate we have put is to associate a wave to a nucleon and then study the interferences between the nucleons.

4.5. Limits to This Theory

Our theory does not call into question the standard model but we must ask ourselves if, for the nucleus in the part we studied, it would not be better to use what was first put forward at the beginning of quantum mechanics by Bohr, namely wave mechanics rather than the probabilistic mechanics introduced by Bohm. Indeed, the model is in agreement with only part of the fundamental hypotheses of quantum mechanics: the nucleons interact according to a 2-body interaction, the nucleus is an N-body system, it is not relativistic. But nucleons are not pointed objects and there is no correspondence for our shell with quantum numbers that assume a number of shells and sub-shells.

Radioactivity is explained by superpositions of waves that we imagine being in phase at an interval of time, but even if there are arguments, other solutions could be imagined. To say that the link is due to interference is an assumption. The element of verification of our theory is a more accurate measurement of distances and mass defects which could make it possible to precise our model especially for elements of significant mass where the uncertainty does not allow to place with precision the pairs of neutrons ensuring the stability of the nucleus.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix 1

Calculation of the vibration periods of the standing wave forming the bond as a function of the distance d and of the period of the wave coming from 2 standing waves.

- The distance d between the centres of 2 nucleons will correspond to the ½ wavelength λ of the standing wave that is established between the 2 nucleons. When the standing wave has the period of vibration of the proton P_p (P_p = 4.33×10^{-24} s), the frequency P of the bond will be $P = P_{pn}/P_p$ (2) = 725.18 s and $d = \lambda/2 = P_p \times c/2$ (11) $d = 0.645 \times 10^{-15}$ m (c = speed of light, $P_{pn} = 3.19 \times 10^{-21}$ s).

(when the mass loss is more important, for example $6\Delta m$ for the neutron in a helion, the period P may decrease to 720.18 s and the distance d will be 0.6455 fm, a decrease of only about 0.05 fm)

(2) and (11) make it possible to express the period P according to the distance.

(2), (11) $\Rightarrow$ $P = P_{pn} \times c/2d$ (12).

- This distance d is the distance between 2 nodes of vibration and we will consider that this bond does not break if the centre of a nucleon does not vibrate beyond an anti-node. The maximum distance dm between the 2 nucleon centres will therefore be $d_m = \lambda/2 + \lambda/4$ or $d_m = (3/2)d$ (13). Or $d_m = 0.9675 \times 10^{-15}$m. The minimum distance d_{mi} will be $d_{mi} = (1/2)d$ (14).
- When the geometry of the nucleus imposes a distance dm between 2 nucleons the minimum period P' of the bond will become: (12) (13) $\Rightarrow$ $P' = P_{pn} \times c/3d$ or $P' = P \times (2/3)$ or $P' = 483.45$ s.
- In the case of periods in the order of the second up to several minutes it is assumed that the ½ life T is explained by the difference between two neighboring periods P_1 and P_2 of two bonds (there is only one Δm for two bonds), $T = P_1 - P_2$ (15); (12) (15) $\Rightarrow$ $T = P_{pn} \times c/2d_1 - P_{pn} \times c/2d_2$ or $T = \left(P_{pn} \times c/2\right) \times \left|d_1 - d_2\right| / d_1 d_2$ (16).

Theoretically, a very small difference in distance between d_1 and d_2 makes it possible to find T between 0 and 1 s. Ex: for ^{8}Li, T = 840 ms, (16) $\Rightarrow$ $d_1 - d_2 = 0.73 \times 10^{-3}$ fm or (1) $\Rightarrow$ $\Delta m = 1.56 \times 10^{-6}$ u.

If one of the two bonds has the maximum distance, the ½ life can reach (16) $\Rightarrow$ T = 159.5 s with $d_1 = 1.5d$ and $d_2 = d = 0.65$ fm.

If one of the two bonds has the maximum distance and the other the minimum length ($d_1 = 1.5 \times 0.65$ fm and $d_2 = 0.5 \times 0.65$ fm), then (16) $\Rightarrow$ T = 981.5 s which is the maximum ½ life in the assumption of a ½ life explained by a difference between two neighboring periods.

Appendix 2

Table A1. Number of bonds of some isotopes from NUBASE (3, 4, 5, 6), as examples.

Symbol	Z	N	atomic mass (u)	½ life	Decay	daughter-isotope (s)	δ	δ’	δ”	Comment
^{1}H	1	0	1.00782503207		Stable					
^{2}H	1	1	2.0141017778		Stable		1		1	
^{3}H	1	2	3.0160492777	12.32 (2) an	β^-	^{3}He	6.41		5	The group ^{3}H was formed
^{4}H	1	3	4.02781 (11)	1.39 (10) × 10^{-22} s	n	^{3}H				
^{5}H	1	4	5.03531 (11)	>9.1 × 10^{-22} s?	n	^{4}H				
^{6}H	1	5	6.04494 (28)	2.90 (70) × 10^{-22} s	3n, 4n	^{3}H,^{2}H				
^{7}H	1	6	7.05275 (108)	2.3 (6) × 10^{-27} s	4n	^{3}H				
^{3}He	2	1	3.0160293191		Stable		5.17		/	^{3}He was formed
^{4}He	2	2	4.00260325415		Stable		21.07	0	/	^{4}He (α) was formed
^{5}He	2	3	5.01222 (5)	700 (30) × 10^{-24} s	n	^{4}He	20.37	0	0	
^{6}He	2	4	6.0188891 (8)	806.7 (15) ms	β^- (99.99%)	**^{6}Li**	21.82	1	1	
^{7}He	2	5	7.028021 (18)	2.9 (5) × 10^{-21} s	n	^{6}He	21.48	1	0	
^{8}He	2	6	8.033922 (7)	119.0 (15) ms	β^- 83.1%; β^- n	^{8}Li, **^{7}Li,**	23.47	2	1	
					16%; β^- fis 0.09%	^{5}He ^{3}H				
^{9}He	2	7	9.04395 (3)	7 (4) × 10^{-21} s	n	^{8}He	22.49	1	−1	
^{10}He	2	8	10.05240 (8)	2.7 (18) × 10^{-21} s	2n	^{8}He	22.64	1-2	0	
^{4}Li	3	1	4.027 19 (23)	91 (9) × 10^{-24} s	p	^{3}He	2.37			No group formed except ^{2}H
^{5}Li	3	2	5.012 54 (5)	370 (30) × 10^{-24} s	p	^{4}He	19.15	0	/	
^{6}Li	3	3	6.015122795 (16)	**Stable**			23.53	2	4	Δm > 21. the nucleus α was formed
^{7}Li	3	4	7.016 00455 (8)	**Stable**			29.12	2	6	One group ^{3}H was formed

Continued

^{8}Li	3	5	8.022 48736 (10)	840.3 (9) ms	β^--fission	2 ^{4}**He**	30.69	3	2	
^{9}Li	3	6	9.026 789 5 (21)	178.3 (4) ms	β^- n (50.8%)	^{8}Be	33.83	6	3	
					β^- (49.2%)	^{9}**Be**				
^{10}Li	3	7	10.035 481 (16)	2.0 (5) × 10^{-21} s	n	^{9}Li	33.81	6	0	
^{10m1}Li			200 (40) keV	3.7 (15) × 10^{-21} s						
^{10m2}Li			480 (40) keV	1.35 (24) × 10^{-21} s						
^{11}Li	3	8	11.043 798 (21)	8.75 (14) ms	β^- n 84.9%, β^- 8.07%	^{10}Be, ^{11}Be	34.06	7	1	
					β^- 2n 4.1%, β^- 3n 1.9%	^{9}Be, ^{8}Be				
					β^- fiss. (1.0%)	^{7}He + ^{4}**He**				
					β^-, fi (0.014%)	^{8}Li + ^{3}H				
^{12}Li	3	9	12.053 78 (107)	<10 ns	n	^{11}Li	33.12	12	−1	
^{5}Be	4	1	5.04079 (429)		p	^{4}Li	-2.17			
^{6}Be	4	2	6.019726 (6)	5.0 (3) × 10^{-21} s	2p	^{4}**He**	19.21	0	/	The difference with 5Be is 21.38. One nucleus of He4 was formed
^{7}Be	4	3	7.01692983 (11)	53.22 (6)j = 4.6 × 10^{6} s	CE	^{7}**Li**	27.46	6	/	α (21) + ^{3}He (5) = 26. One 3He was formed
^{8}Be	4	4	8.00530510 (4)	6.7 (17) × 10^{-17} s	fission	2 ^{4}**He**	42.05	0	/	A second α was formed
^{9}Be	4	5	9.0121822 (4)	**Stable**			43.34	1	1	Stable despite a single bond. It is necessary to imagine that the neutron 5 is at the same distance of the 2 α
^{10}Be	4	6	10.0135338 (4)	1.39 Ma = 8.16 × 10^{13} s	β^-	^{10}**B**	48.60	7	5	The n has 5 bonds (13) => T = 726^5 = 4.76 × 10^{13} s
^{11}Be	4	7	11.021658 (7)	13.81 (8) s	B^- 97.1 β^-, α 2.9%	^{11}**B**, ^{7}**Li**	48.99	7	1/2	
^{12}Be	4	8	12.026921 (16)	21.49 (3) ms	β^- (99.48%)	^{12}B	51.44	9	2	
					β^-, n (0.52%)	^{11}**B**				
^{13}Be	4	9	13.03569 (8)	0.5 (1) ns	n	^{12}Be	51.37	9	0	

Continued

^{14}Be	4	10	14.04289 (14)	4.84 (10) ms	β^-, n (81.0%)	^{13}B	52.42	10	1	
					β^- 14.0%, β^- 2n 5.0%	^{14}B, ^{12}B				
^{15}Be	4	11	15.05346 (54)#	<200 ns			51.04	9	−1	
^{16}Be	4	12	16.06192 (54)#	<200 ns			51.20	9	0	
^{7}B	5	2	7.02992 (8)	350 (50) × 10^{-24} s	p	^{6}Be	17.12			<21, The nucleus of ’He4 is not formed
^{8}B	5	3	8.0246072 (11)	770 (3) ms	β^+ fission	2 (**^{4}He**)	27.17	1	/	Formed with 1He (21) + ^{3}He (5); stay 1bond
^{9}B	5	4	9.0133288 (11)	800 (300) × 10^{-21} s	p	^{8}Be	41.52	0	0	
^{10}B	5	5	10.0129370 (4)	**Stable**			48.03	6	6	
^{11}B	5	6	11.0093054 (4)	**Stable**			56.88	9	9	One 3H was formed
^{12}B	5	7	12.0143521 (15)	20.20 (2) ms	β^- 98.4%, β^-, α 1.6%	**^{12}C**, ^{6}Be	59.48	12	3	
^{13}B	5	8	13.0177802 (12)	17.33 (17) ms	β^- 99.72%, β^- n 0.28%	**^{13}C, ^{12}C**	63.25	15	3	
^{14}B	5	9	14.025404 (23)	12.5 (5) ms	β^- (93.96%)	^{14}C	64.00	16	1	
					β^-, n (6.04%)	**^{13}C**				
^{15}B	5	10	15.031103 (24)	9.87 (7) ms	β^-, n (93.6%)	^{14}C	66.13	18	2	
					β^- (6.0%)	^{15}C				
					β^-, 2n (0.40%)	**^{13}C**				
^{16}B	5	11	16.03981 (6)	<190 × 10^{-12} s	n	^{14}B	66.10	18	0	
^{17}B	5	12	17.04699 (18)	5.08 (5) ms	β^-, n (63.0%)	^{16}C	67.17	19	1	
					β^- (22.1%)	^{17}C				
					β^-, 2n (11.0%)	^{15}C				
					β^-, 3n (3.5%)	^{14}C				
					β^-, 4n (0.40%)	**^{13}C**				
^{18}B	5	13	18.05617 (86)	<26 ns	n	^{17}B	66.80	19	0	

Continued

^{19}B	5	14	19.06373 (43)	2.92 (13) ms	β^-	^{19}C	67.60	20	1	
^{8}C	6	2	8.037675 (25)	2.0 (4) × 10^{-21} s	2p	^{6}Be	16.77			<21 so helion no formed
^{9}C	6	3	9.0310367 (23)	126.5 (9) ms	β^+ 60%	^{9}B	27.78	2	/	1 hélion + ^3He = 26; stay 2
					β^+, p (23%)	^{8}Be				
					β^+, α (17%)	^{5}Li				
^{10}C	6	4	10.0168532 (4)	19.290 (12) s	β^+	^{10}**B**	44.21	2	/	2 α formed
^{11}C	6	5	11.0114336 (10)	20.334 (24) min	β^+ (99.79%)	^{11}**B**	54.35	7	/	two α + one ^3He = 47
					K⁻ CE (0.21%)	^{11}**B**				
^{12}C	6	6	12 exactement	**Stable**			68.81	6	/	3 helions (63) + 6 internal bonds
^{13}C	6	7	13.0033548378 (10)	**Stable**			72.63	10	4	
^{14}C	6	8	14.003241989 (4)	5.73 × 10^3 ans	β^-	^{14}**N**	78.94	16	6	
^{15}C	6	9	15.0105993 (9)	2.449 (5) s	β^-	^{15}**N**	79.89	17	1	
^{16}C	6	10	16.014701 (4)	0.747 (8) s	β^-, n (97.9%)	^{15}**N**	83.17	20	3	
					β^- (2.1%)	^{16}N				
^{17}C	6	11	17.022586 (19)	193 (5) ms	β^- (71.59%)	^{17}N	83.73	21	1	
					β^-, n (28.41%)	^{16}N				
^{18}C	6	12	18.02676 (3)	92 (2) ms	β^- (68.5%)	^{18}N	86.96	24	3	
					β^-, n (31.5%)	^{17}N				
^{19}C	6	13	19.03481 (11)	46.2 (23) ms	β^-, n (47.0%)	^{18}N	87.40	24	0	
					β^- (46.0%)	^{19}N				
					β^-, 2n (7%)	^{17}N				
^{20}C	6	14	20.04032 (26)	16 (3) ms	β^-, n (72.0%)	^{19}N	89.67	27	3	
					β^- (28.0%)	^{20}N				
^{21}C	6	15	21.04934 (54)	<30 ns	n	^{20}C	89.42	26	−1	

Continued

^{22}C	6	16	22.05720 (97)	6.2 (13) ms	β^-	^{22}N	90.00	28	2	
^{10}N	7	3	10.04165 (43)	200 (140) × 10^{-24} s	p	^{9}C	25.38			
^{11}N	7	4	11.02609 (5)	590 (210) × 10^{-24} s	p	^{10}C	42.81	1	/	2 α formed
^{12}N	7	5	12.0186132 (11)	11.000 (16) ms	β^+ 96.5%	^{12}C	54.42	7	/	+ one ^{3}He formed
					β^+, α (3.5%)	^{8}Be				
^{13}N	7	6	13.00573861 (29)	9.965 (4) min	β^+	^{13}C	69.92	7 (1)	/	3α (63) + 6 = ^{12}C, stay 1
^{14}N	7	7	14.0030740048 (6)	**Stable**			78.11	14 (8)	8	^{12}C (69) + ^{2}H (1) = 70, stay 8
^{15}N	7	8	15.0001088982 (7)	**Stable**			86.43	17 (11)	8	^{12}C (69) + ^{3}H (6) = 75, stay 11
^{16}N	7	9	16.0061017 (28)	7.13 (2) s	β^- (99.99%	^{16}O	88.36	19	1	Reminder: above stable nuclei after C, the additional groups or neutrons will be on a second shell
					β^-. α (0.001%)	^{12}C				bonds are double. δ'' is calculated by dividing the difference of the δ' by 2
^{17}N	7	10	17.008450 (16)	4.173 (4) s	β^-. n (95.0%)	^{16}O	92.90	24	2.5	
					β^- (4.99%)	^{17}O				
					β^-. α 0.0025%	^{13}C				
^{18}N	7	11	18.014079 (20)	622 (9) ms	β^- (76.9%)	^{18}O	95.08	26	1	
					β^-, α 12.2%	^{14}C				
					β^-, n (10.9%)	^{17}O				
^{19}N	7	12	19.017029 (18)	271 (8) ms	β^-, n 54.6%	^{18}O	99.20	30	2	
					β^- (45.4%)	^{19}O				
^{20}N	7	13	20.02337 (6)	130 (7) ms	β^- n 56.99%	^{19}O	100.87	32	1	
					β^- (43.00%)	^{20}O				
^{21}N	7	14	21.02711 (10)	87 (6) ms	B^-, n 80%	^{20}O	104.41	35	1.5	
					β^- 20.0%	^{21}O				

Continued

^{22}N	7	15	22.03439 (21)	13.9 (14) ms	β^- 65%, β^-, n (35%)	^{22}O ^{21}O	105.41	36	1/2	
^{23}N	7	16	23.04122 (32)	14.5 (24) ms	β^- 20.0%	^{21}O	106.72	38	1	
^{24}N	7	17	24.05104 (43)	<52 ns	n	^{23}N	105.90	37	−1/2	
^{25}N	7	18	25.06066 (54)	<260 ns			105.21	36	−1/2	
^{12}O	8	4	12.034405 (20)	580 (30) × 10^{-24} s	2p (60%)	^{10}C	42.06			
					p (40.0%)	^{11}N				
^{13}O	8	5	13.024812 (10)	8.58 (5) ms	β^+ (89.1%)	^{13}N	55.20			
					β^+, p (10.9%)	**^{12}C**				
^{14}O	8	6	14.00859625 (12)	70.598 (18) s	β^+	**^{14}N**	73.10			
^{15}O	8	7	15.0030656 (5)	122.24 (16) s	β^+	**^{15}N**				
^{16}O	8	8	15.99491461956	**Stable**			95.41	11	/	4 α formed
^{17}O	8	9	16.99913170 (12)	**Stable**			98.61	15	4	
^{18}O	8	10	17.9991610 (7)	**Stable**			104.82	21	6	
^{19}O	8	11	19.003580 (3)	26.464 (9) s	β^-	**^{19}F**	107.87	24	1.5	
^{20}O	8	12	20.0040767 (12)	13.51 (5) s	β^-	^{20}F	113.75	30	3	
^{21}O	8	13	21.008656 (13)	3.42 (10) s	β^-	^{21}F	116.69	33	1.5	
^{22}O	8	14	22.00997 (6)	2.25 (15) s	β^- (78.0%)	^{22}F	121.98	38	2.5	
					β^-, n (22.0%)	^{21}F				
^{23}O	8	15	23.01569 (13)	82 (37) ms	β^-, n (57.99%)	^{22}F	124.10	40	1	
					β^- (42.0%)	^{21}F				
^{24}O	8	16	24.02047 (25)	65 (5) ms	β^-, n (57.99%)	^{23}F	126.89	43	1.5	
					β^- (42.01%)	^{24}F				
^{25}O	8	17	25.02946 (28)	5.2 × 10^{-8} s	n	^{24}O	126.66	43	0	

Continued

^{26}O	8	18	26.03834 (28)	4.0×10^{-8} s	β^-	^{26}F	126.50	43	0
					n	^{25}O			
^{27}O	8	19	27.04826 (54)	<260 ns	n	^{26}O	125.60	42	−1/2
^{28}O	8	20	28.05781 (64)	<260 ns	n	^{27}O	124.96	42	−1/2

1) There is a sharp increase of δ to 21Δm from ^3He to ^4He (δ''= 16 is the highest value for all the classification, δ'' usually does not exceed 6, exceptionally 9 (^{11}B)). 2) Every time, when Z even, the number N of neutron reaches Z, then there is an increase of δ allowing the formation of a new helion (ex: passage from ^7Be to ^8Be, ^{11}C to ^{12}C, ^{15}O to ^{16}O, ^{19}Ne to ^{20}Ne). 3) When, in addition to helions, there are 1p and 2n, they will form a ^3H (δ' increases at least 6 between ^6Li and ^7Li, ^{10}B and ^{11}B). Similarly, when 2p and 1n are available, δ' increases by at least 5 to form a ^3He (between ^8C and ^9C, ^{11}N and ^{12}N, ^{12}O and ^{13}O). 4) Stable elements can be detected; δ'' is highest for the elements stable or with a very long ½ life ($\delta''> 3$). Taking into account the shell, $0 < \delta'' \leq 3$ for short ½ lives, $\delta'' \leq 0$ for ultra-short ½ lives. δ = total number of bonds. δ' = number of bonds reduced to the unit, above helions and groups ^3H, ^3He or pair p-n (according to Equation (9) δ'' = additional bonds, whether single or multiple, relative to the immediately below isotope (δ'' is not noted when it corresponds to the creation of a ^4He (α), ^3H or ^3He). For elements having several shells, δ'' is obtained according to Equation (10) $\delta'' = (\delta_y - \delta_x)/n$ with $n = 2$ since it is assumed that the additional neutrons are fixed by double bonds. We made the same table for F, Ne, Ar, Kr, Fe and Pb. δ' always follows the same rule: when $\delta''> 3$, the elements are stable or with a long ½ life, when $\delta'' \leq 3$ ½ lives are short. For, F, Ne, Ar, Kr and Fe, as for N and O, δ'' is found assuming that neutrons have double bonds ($n = 2$ in Equation (10)). For Pb, δ'' is obtained without dividing by 2, suggesting simple bonds for additional neutrons.

Table A2. Number N of stable nuclei for each element.

Z	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
N	**2**	**2**	**2**	**1***	**2**	**2***	**2**	**3**	**1**	**3**	**1**	**3**	**1**	**3**	**1**	**4**	**2**	**3**	**2***	**5***	**1**	**5**	**1***	**4**	**1**	**4**	**1**	**5**	**2**	**5**
Z	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
N	**2**	**4***	**1**	**5***	**2**	**5**	**1***	**4**	**1**	**4***	**1**	**6***	**0***	**7**	**1**	**6***	**2**	**6***	**1**	**10**	**2**	**6***	**1**	**7***	**1**	**6***	**1***	**4**	**1**	**5***
Z	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82								
N	**0**	**5***	**1**	**6***	**1**	**7***	**1**	**6**	**1**	**7**	**1**	**5**	**1**	**4***	**1**	**6***	**2**	**5***	**1**	**7**	**2**	**3***								

The * indicates one or two additional isotopes with a very long ½ life. From $Z > 6$, without any exception, when Z odd, $N \leq 2$, when Z even, $N \geq 3$. Beyond $Z = 82$ (Pb), all elements are unstable. Elements where Z is odd are more unstable because an additional neutron added to the stable isotope will be converted by radioactivity β^- into a proton to form a new helion.

Table A3. Radioactive isotopes with a $\delta''> 3$.

k	**Calculated ½ life (17)**	**isotope**	**nber bonds δ'' cal. For isot.**	**Observed ½ life**	**decay**	**% dev. from mean value (0% = mean value; 100% = possible limite value)**
1	(726 s)					
2	(5.27×10^5 s)					
3	0.48 to 12.88×10^8 s (3.83×10^8 s)	$^{228}_{90}Th$	5.49	0.60×10^8 s	α	−92.2%
		^{85}Kr	6	3.4×10^8 s	β^-	−4.75%
		^3H	5.49	3.88×10^8 s	β^-	0.5%

Continued

		^{154}Eu	5.49	5.04×10^8 s	β^-	13.4%
		$^{227}_{89}$Ac	5.04	6.8×10^8 s	β^- (98.6%)	32.8%
		^{210}Pb	4	7.03×10^8 s	β^-	35.4%
		$_{90}$Sr	6	9.07×10^8 s	β^-	58%
		$^{232}_{92}$U	5.61	22×10^8 s	α	201%
		$^{209}_{84}$Po	5.38	32.5×10^8 s	α (99.5%)	317%
4	0.17 to 14.01×10^{11} s (2.78×10^{11} s)	$^{226}_{88}$Ra	4.94	0.51×10^{11} s	α or $\beta^-\beta^-$	−69%
		^{14}C	6	1.8×10^{11} s	β^-	−37.5%
		$^{229}_{90}$Th	4.06	2.32×10^{11} s	α	−8.80%
		$^{231}_{91}$Pa	5.27	10.34×10^{11} s	α	67%
		$^{230}_{90}$Th	5.25	23.8×10^{11} s	α	187%
5	0.63 to 152×10^{13} s (20.17×10^{13} s)	$^{233}_{92}$U	4.45	0.5×10^{13} s	α	−1.04
		^{99}Tc	7	0.66×10^{13} s	β^-	−99%
		$^{126}_{50}$Sn	6.32	0.73×10^{13} s	β^-	−97%
		$^{234}_{92}$U	5.29	0.77×10^{13} s	α	−96%
		^{36}Cl	7	0.95×10^{13} s	β^-	−91%
		^{79}Se	5.38	1.03×10^{13} s	β^-	−89.7%
		$^{208}_{83}$Bi	5.32	1.16×10^{13} s	β^+	−87%
		^{10}Be	5	4.76×10^{13} s	β^-	−50%
		^{93}Zr	5.20	4.82×10^{13} s	β^-	−49.7%
		$^{150}_{64}$Gd	6.72	5.64×10^{13} s	α ($\beta^-\beta^-$ rare)	−45%
		^{135}Cs	6.77	7.25×10^{13} s	β^-	−37%
		$^{154}_{66}$Dy	7.20	9.45×10^{13} s	α ($\beta^-\beta^-$ rare)	−28%
		^{98}Tc	5.6	14.7×10^{13} s	β^-	−12.3%
		$^{107}_{46}$Pd	5.05	20.48×10^{13} s	β^-	0.24%
		$^{182}_{72}$Hf	5.19	28×10^{13} s	β^-	5.9%
		$^{129}_{43}$I	6.82	49.4×10^{13} s	β^-	22.2%
		$^{236}_{92}$U	5.06	73.9×10^{13} s	α	40.7%
		$^{92}_{41}$Nb	6.09	109.3×10^{13} s	β^+ (99%)	67.6%
6	0.23 to 166×10^{16} s (14.64×10^{16} s)	^{146}Sm	6.50	0.32×10^{16} s	α	−94%
		$^{235}_{92}$U	4.09	2.22×10^{16} s	α	−54%
		^{40}K	6	4.02×10^{16} s	β^-	−38.7%
		$^{238}_{92}$U	4.75	20.41×10^{16} s	α	3.8%
		$^{232}_{90}$Th	4.97	44.2×10^{16} s	α	19.5%
		$^{176}_{71}$Lu	4.86	121×10^{16} s	β^-	70% overlap
		$^{187}_{75}$Re	5.68	130×10^{16} s	β^- (99%)	76% overlap

Continued

7	83×10^{16} to 180×10^{19} s (10.6×10^{19} s)	$^{87}_{37}$Rb	7.6	151×10^{16} s	β^- overlap	−91% if k = 7 or +90%if k = 8
		$^{138}_{57}$La	5.79	3.2×10^{18} s	$\beta^+\beta^-$	−78%
		^{147}Sm	4.90	0.5×10^{19} s	α	−71%
		^{190}Pt	6.88	20.48×10^{18} s	α	−42%
8	30×10^{19} to 196×10^{22} s (7.71×10^{22} s)	$^{152}_{64}$Gd	6.63	0.34×10^{22} s	α	−64.6%
		^{115}In	7	1.39×10^{22} s	β^-	−38.6%
		^{59}Co	8	1.61×10^{22} s	stable	−35.6%
		$^{186}_{76}$Os	6.38	6.30×10^{22} s	α	−5%
		$^{174}_{72}$Hf	6.57	6.3×10^{22} s	α	−5%
		$^{44}_{60}$Nd	6.04	7.21×10^{22} s	α	−1.7%
		$^{113}_{48}$Cd	5.05	24.26×10^{22} s	β^-	8.8%: overl. with k = 9
		^{148}Sm	6.29	25.2×10^{22} s	α	9.3%: overl. With k = 9
9	11×10^{22} to 214×10^{25} s (5.60×10^{25} s)	^{50}V	7.2	0.44×10^{25} s	β^+ (83%) β^- (17%)	−7.8%
		$^{180}_{74}$W	6.50	5.65×10^{25} s	α	0.02% overlap
		^{151}Eu	6.13	15.2×10^{25} s	α	3.8% for these 7
		$^{150}_{60}$Nd	5.7	21.1×10^{25} s	$\beta^-\beta^-$	6.2% elements
		$^{100}_{42}$Mo	6.4	26.78×10^{25} s	$\beta^-\beta^-$	8.5% with k = 10
		$^{209}_{83}$Bi	5.76	60.0×10^{25} s	α	21.7%
		^{96}Zr	6.06	63×10^{25} s	$\beta^-\beta^-$	23%
		$^{116}_{48}$Cd	6.72	97.7×10^{25} s	$\beta^-\beta^-$	36%
10	4×10^{25} to 232×10^{28} s (4.06×10^{28} s)	^{48}Ca	7.68	0.13×10^{28} s	$\beta^-\beta^-$	−58%
		^{82}Se	7.16	0.306×10^{28} s	$\beta^-\beta^-$	−45.6%
		^{130}Te	6.50	2.48×10^{28} s	$\beta^-\beta^-$	−0.7% overlap
		^{136}Xe	6.24	6.62×10^{28} s	$\beta^-\beta^-$	1.1% with k = 11
11	1.4×10^{28} to 253×10^{31} s (2.95×10^{31} s)	^{128}Te	6.78	6.93×10^{31} s	$\beta^-\beta^-$	1.6%

We took back all isotopes with a long ½ life (>10 years) from NUBASE (3, 4, 5, 6) with a radioactivity β or α, or 64 isotopes. The number of bonds δ'' refers to the last neutron added and is usually indicative of the number of bonds k concerning the decay. (e.g.: ^{3}H has 5 bonds more than ^{2}H which has one bond, so each neutron has 3 bonds). The ½ life is $T = P^k$ (17) and P varies between 363 s and 1088 s with an average value of 726 s according to Equation (12) depending on the distance d which is between 0.325 and 0.967 fm. ("ideal" average distance: 0.65 fm). It is found that for all isotopes except 4 heavy elements, the observed ½ life is included in the area provided by the calculation. Note that, from $k = 7$, the areas provided by the calculation overlap. It is only for the ^{87}Rb that it is not possible to know whether $k = 6$ or 7 (90% deviation from the mean values for $k = 6$ or 7), the 25 elements with $k > 6$ have a ½ life that can deviate by more than 90% from the mean value; the 11 elements with $k > 7$ where there is overlap are close to a maximum of less than 36% of the mean value. It can therefore also be considered that for all the elements with $k \geq 7$, the observed ½ life is most probably included in the area provided by the calculation. The deviation that often exists from the mean value can be explained by the variation in the distance of the bonds of the nucleon or helion concerned by the radioactivity. The ½ life is then a way to calculate distances. ((12) (17) $\Rightarrow$ $d = P_{pn} \times c/2 \times T^{1/k}$) (24). Another hypothesis to find the exact value would be to imagine a different number of bonds. For example, for the ^{209}Po, to find the value of 32.5×10^8 s, we would have 88.33% of atoms with 3 bonds and 11.67% with 4 bonds). It is an "ad hoc" explanation that allows to find precisely the observed value but which may have the disadvantage of implying that the geometry is different from one nucleus to another for the same isotope (ratio isotopes in state of lower energy/excited states?). It is also interesting to note that for all these elements at long ½ life from the lightest to the heaviest, δ'' is always greater than 3 and between 5 and 8.

Table A4. Stable nuclei with a *Z* multiple of 6, determination of the shell.

Element	Mass defect in number of Δm = δ	Nber δs of Δm remaining after subtraction of δ from previous even précédent & of the new helions	neutrons in addition to helions	probable role of δs	N° of the last helion shell given by the type of bond	N° shell formula (18) (19) (20)	comments
$^{12}_{6}$**C**	**68.81**				1		
$^{24}_{12}$**Mg**	**148.38**	**148 − 69 − 63 = 16**		2 double bonds (L2) per helion (or 12Δm)	**2**	2.66	
$^{36}_{18}$**Ar**	**229.77**	**230 − 148 − 63 = 19**		2 L3/helion (or18Δm)	**3**	3.17	
$^{50}_{24}$**Cr**	**326.53**	**327 − 230 − 63 = 34**	**2**	2 L4/helion (24Δm) 10 left either 1L4 per n or at least 2L2 per n	4	4.86	The 2 n stable would be more at the 2nd shell level
$^{64}_{30}$Zn	419.96	420 − 327 − 63 = 30	4	2 L4/helion or 24Δm, 6 left for 2n (2L3)	4	4.28	shell 5 requires 30Δm and there is 2n more. So rather shell 4 (24). les 2 n are on a lower shell
$^{80}_{36}$Kr	522.89	523 − 420 − 63 = 40	8	2L5/helion or 30Δm, 10 left for 4n	5	5.00	The last 4 n are on a lower shell with several bonds
$^{92}_{42}$Mo	598.58	599 − 523 − 63 = 13	8	6L2 for 3 helions	2	2.17	Shell 2 fills up
$^{106}_{48}$Cd	680.11	680 − 599 − 63 = 18	10	6L3 for 3 helions	3	3.00	Shell 3 fills up. The 2 n take bonds to the other n
$^{124}_{54}$Xe	786.73	787 − 680 − 63 = 44	16	*2L5/helion or 30Δm, 14 left for 6n*	5	5.50	Shell 5 fills
$^{142}_{60}$Nd	891.63	892 − 787 − 63 = 42	22	*2L5/helion or 30Δm, 8 left for 6n*	5	5.25	Shell 5 fills
$^{154}_{66}$Dy*	948.43	948 − 892 − 63 = −7	22				The next 3 elements are unstable
$^{174}_{72}$Hf*	1055.87	1056 − 948 − 63 = 45	30				
$^{190}_{78}$Pt*	1135.31	1135 − 1056 − 63 =	34				

For the 1st shell, in ^{12}C, the 3 helions are linked by 6 simple bonds (6Δm) between each time a proton and a neutron. To determine on which shell *n* are the helions, we take the element having 3 more helions. The excess of mass defect δ_s corresponds to 6 additional bonds (2 per helion) which can be double, triple and to bonds for additional neutrons. The shell *n* is given by an empirical formula to account for neutron bonds. $n = \delta_s/6$ ($\delta_s < 25$) (18), $n = \delta_s/7$ ($35 > \delta_s > 25$) (19), $n = \delta_s/8$ ($\delta_s > 35$) (20).

Table A5. Stable nuclei with even *Z* from O to U.

Element	**Mass defect in number of Δm = δ**	**δs**	**N° shell given by Table A4**	**Probable role of this remaining Δm**	**Neutrons in add. to hélions**	**Comments**
$^{16}_{8}$O	95.41	5 95.41 − 68.81 − 21.07 = 5.53	2	2 double bonds for the last hellion (2 × 2.76*d*)		

Continued

$^{20}_{10}\text{Ne}$	120.12	4 120.12 − 95.41 − 21.07 = 3.64	2	Idem (2 × 1.82*d*)		
$^{24}_{12}\text{Mg}$	**148.38**	**7** 148.4 − 120.12 − 21.07 = 7.19	2	**idem**		**Calculation/C (shell 1) gives: 148 − 69 − 63 = 16 or 16/6 = 2.66Δm per bond thus shell 2**
$^{28}_{14}\text{Si}$	177	8	3	2 triple bonds		
$^{32}_{16}\text{S}$	204	6	3	2 triple bonds		
$^{36}_{18}\text{Ar}$	**229.77**	**230 − 204 − 21 = 5**	**3**	**2 triple bonds**		**230 − 148 − 63 = 19 or 19/6 = 3.17 (shell 3)**
$^{40}_{20}\text{Ca}$	256.28	256 − 230 − 21 = 5	4			
$^{46}_{22}\text{Ti}$	298.85	299 − 256 − 21 = 22	4		2	.δs increases strongly when 2 add. n are needed.
$^{50}_{24}\text{Cr}$	**326.53**	**327 − 299 − 21 = 7**	**4**		2	
$^{54}_{26}\text{Fe}$	354.09	354 − 327 − 21 = 6	4		2	
$^{58}_{28}\text{Ni}$	380.10	380 − 354 − 21 = 5	4		2	
$^{64}_{30}\text{Zn}$	**419.96**	**420 − 380 − 21 = 19**	**4**		**4**	
$^{70}_{32}\text{Ge}$	458.88	459 − 420 − 21 = 18	5		6	
$^{74}_{34}\text{Se}$	483	483 − 459 − 21 = 3	5		6	
$^{80}_{36}\text{Kr}$	**522.89**	**523 − 483 − 21 = 19**	**5**		**8**	
$^{84}_{38}\text{Sr}$	548	548 − 523 − 21 = 4	2		8	
$^{90}_{40}\text{Zr}$	589.63	590 − 548 − 21 = 21	2		10	
$^{92}_{42}\text{Mo}$	**598.58**	**599 − 548 − 42 = 9****	**2**		**8**	
$^{96}_{44}\text{Ru}$	620.95	621 − 599 − 21 = 1	3		8	
$^{102}_{46}\text{Pd}$	657.79	658 − 621 − 21 = 16	3		10	
$^{106}_{48}\text{Cd}$	**680.11**	**680 − 599 − 63 = 18**	**3**		**10**	
$^{112}_{50}\text{Sn}$	716.70	717 − 680 − 21 = 16	5		12	
$^{120}_{52}\text{Te}$	765.14	765 − 717 − 21 = 27	5		16	
$^{124}_{54}\text{Xe}$	**786.73**	**787 − 680 − 63 = 44**	**5**		**16**	
$^{130}_{56}\text{Ba}$*	821.83	822 − 787 − 21 = 14	5	The new He go to shell 5 with 2n	18	
$^{136}_{58}\text{Ce}$	856.62	857 − 822 − 21 = 14	5	The new He go to shell 5 with 2n	20	
$^{142}_{60}\text{Nd}$	**891.63**	**892 − 857 − 21 = 14**	**5**	**The new He go to shell 5 with 2n**	**22**	

Continued

$^{144}_{62}$Sm	899.02	899 − 892 − 21 = −14		20	From Sm to Er, we see 2 decreases of −14 followed by 2 strong increases of 21 and 24
$^{152}_{64}$Gd	941.29	941 − 899 − 21 = 21		24	It is interpreted as saying that the last helion of the Sm is placed at a nivel 4 and drives at least one other helion previously arrived in 5 at a level 4
$^{154}_{66}$Dy*	**948.43**	**948 − 941 − 21 = −14**		**22**	2 n are no longer necessary The helion brought by Gd is then placed at level 5 and requires 4n. The same goes for Dy and Er
$^{162}_{68}$Er	993.17	993 − 948 − 21 = 24		26	
$^{168}_{70}$Yb	1024.89	1025 − 993 − 21 = 11	The new He go to shell 5 with 2n	28	Yb, Hf, W. The 3 He occupy first 3 places in level 5 (filling sequence idem Kr Cd)
$^{174}_{72}$Hf*	**1055.87**	**1056 − 1025 − 21 = 10**	**The new He go to shell 5 with 2n**	**30**	
$^{180}_{74}$W	1086.48	1087 − 1056 − 21 = 10	The new He go to shell 5 with 2n	32	Os sees the end of the filling of level 4 with another He going
$^{184}_{76}$Os	1105.26	1105 − 1087 − 21 = −3		32	in 4. No new n. n decrease in level
$^{190}_{78}$Pt	1135.31	1135 − 1105 − 21 = 5		34	
$^{196}_{80}$Hg	1166.47	1167 − 1135 − 21 = 11		36	Pt to Pb end of filling shell 5
$^{204}_{82}$Pb	1209.15	1209 − 1167 − 21 = 21		40	
$^{209}_{84}$Po*	1231.57	1232 − 1209 − 21 = 1		41	
$^{222}_{86}$Rn*	1285.32	1285 − 1232 − 21 = 32		50	
$^{226}_{88}$Ra*	1302.62	1303 − 1285 − 21 = −3		50	
$^{232}_{90}$Th*	1328.93	1329 − 1303 − 21 = 5		52	
$^{234}_{92}$U*	1337.32	1337 − 1329 − 21 = −13		50	

When taking the intermediate elements (with even Z pairs), the mass defect makes it possible to verify that each new helion (its 2 neutrons) will bind by 2 multiple bonds corresponding to the shell (*The method of fixing in corona makes that the 3rd helion terminating a corona can be fixed with a longer length* (*e.g., for 2nd shell length of 2.73d close to 3 instead of 2.18d close to 2*) *and this would explain the variations to 1 or 2 near the number of Δm remaining at each new helion. Hence the importance of determining the shell on the average of each new corona of 3 helions*). δ'_s = number of remaining Δm for an element X with $\delta = \delta_x$ after subtraction of the Δm (δ_y) of the previous even element Y and of the new helion (21.07 = mass defect in Δm of helion). $\delta'_s = \delta_x - \delta_y - 21.07$.