

Part 2
Chapters 3 to 6

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CHAPTER 3

NUCLEOSYNTHESIS OF THE ELEMENTS TILL OXYGEN 16

1. Purpose of the theory

The goal of the theory of nucleosynthesis is to explain the huge difference in abundance of the chemical elements from the perspective of natural processes. Hydrogen and helium are the most common. The next three elements (Li, Be, B) are rare. After hydrogen and helium, oxygen is the most abundant in nature.

The purpose of the present chapter is to explain the discrepancy between these first elements of the Periodic Table of elements and to show the nucleosynthesis way from ${}^4_2\text{He}$ to ${}^{16}_8\text{O}$. The binding energy structures of these elements are analyzed to find an explanation to that apparent anomaly. The stability of Oxygen 16 is the result of its α structure as well as its binding energy structure. According to the author the primordial nucleosynthesis does not stop with Helium or α particle but continues α step by α step.

In the following, it is shown how He 5 nucleus is structured, as well as Li 6 and Li 7, Be 8 and Be 9 nuclei etc till O 17 nucleus. This process is working at the level of Higgs boson as seen in chapters 1 and 2, at the massification/demassification stage occurring before the electronic stage, itself consequence of that massification/demassification process.

Indeed, the classical fusion process also exists but occurs once the nuclei are at the electronic stage, hence the difficulty of the Coulomb barrier.

2. Hypothesis for nucleosynthesis.

In order to determine the binding energy of the different light nuclei it is relied on the following hypothesis: each nucleus (starting from ${}^4_2\text{He}$) has a substructure made up of α particles. The N and P (neutrons and proton) supplementary to α particles can create ${}^2_1\text{H}$, ${}^3_1\text{H}$ and ${}^3_2\text{He}$ substructures or clusters. Thus, once the nucleus consists of 2 N and 2 P, its structure is that of the α particle one, and when it consists of $x \alpha + 2N + 2P$, its structure becomes $(x + 1) \alpha$. According to that hypothesis the nucleus can be conformed to in the following ways:

$$\begin{aligned} &x \alpha + N, x \alpha + P \\ &x \alpha + 2N, x \alpha + N + P, x \alpha + 2P \\ &x \alpha + 3N, x \alpha + 2N + P, x \alpha + 1N + 2P, x \alpha + 3P \\ &x \alpha + 4N, x \alpha + 3N + P, x \alpha + N + 3P, x \alpha + 4P \\ &x \alpha + 2N + 2P = (x + 1) \alpha \end{aligned}$$

This conforms to the Ikeda diagram^[1] showing how the structure of light α conjugate nuclei can be considered as comprised of α clusters.

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

When the structure of the nucleus is formed with $x \alpha$ particles to which nucleons are added, this structure is stable as long as the equilibrium between N and P remains stable. Anyway, there is a tendency to respect this symmetry by transformation of N in P or P in N, usually with the emission of particles β^- and β^+ . If the nucleons supplementary to the α particles have an odd number as a value, N prevails over P and the substructure or cluster at issue is N, or $2N + P$, if there is a stable structure. When the number of nucleons supplementary to $x \alpha$ can be described as or more than 4 (for example $3N + P$), the nucleus has a tendency of creating a

supplementary α particle through the transformation of N into P or vice versa. The stable light nuclei are therefore formed mainly by α particles.

So, primordial nucleosynthesis is not limited to the first elements of the Periodic Table, but is continued, creating α particles as far as necessary.

3. Relationships between the four types of bonds

According to author's theory, the nuclei of the various elements are constituted with α particles and other nucleons grouped in order to create sub-nuclei linked by four types of bonds called NN, NP, NNP, NPP. The binding energy values of Deuterium (NP), Tritium (NNP), Helium3 (NPP), and NN are related through the following equations:

- EB Tritium (NNP) = $2NN - 1.25/2 NP$
- EB He3 (NPP) = $NN + 1.25 NP$
- 2 NN forming the neutronic part of the binding energy of α particle.

The values used for the calculations of the binding energy are:

EB α	= 28.325 MeV		
EB NN	= 4.9365 MeV =	8.875 lines	}
EB NP (= ${}^2_1\text{H}$)	= 2.2246 MeV =	4 lines	
EB NNP (= ${}^3_1\text{H}$)	= 8.4818 MeV =	15.25 lines	
EB NPP (= ${}^3_2\text{He}$)	= 7.7180 MeV =	13.875 lines	
			One line is equal to 0.5561589 MeV

4. Conclusions

The breakdown of the binding energy of any nuclide is based on:

- the α particle bond, actually ${}^4_2\text{He}$,
- deuterium bond,
- tritium bond,
- helium 3 bond,
- NN bond, part of α particle bond.

Reference

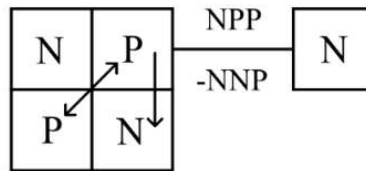
[1] K. Ikeda, N. Takigawa and H. Horiuchi, Prog. Theor. Phys. Suppl. (1968) E 464.

${}^5_2\text{He}$

$1\alpha, 1\text{N}$

EB in MeV = 27.5612

EB =	1 α	28.3250	MeV
	- NNP	- 8.4818	
	+ NPP	<u>7.7180</u>	
		27.5612	MeV
		/	



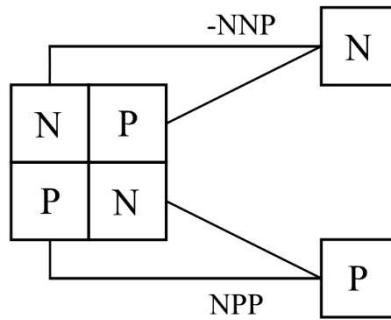
$$EB = - NNP + NPP + EB \alpha$$

He 5

The binding energy of He5 is inferior to that one of α particle ($27.561 < 28.325$). The nucleus He5, though, cannot be stable. The N(neutron) supplementary to α particle tends to create a bond with α particle, i.e. NPP. Nevertheless, this operation results in a dislocation of the nucleus since the bonds among the Ns and the Ps within the α particle are disturbed. One negative NNP bond which was occurred by the stronger α bond comes out and is recreating the NNP mass. Actually, in creating the α particle there are some bonds created, NP then NNP and NPP which are replaced by an α particle bond (see points 3.3 and 3.4 of chapter 2).

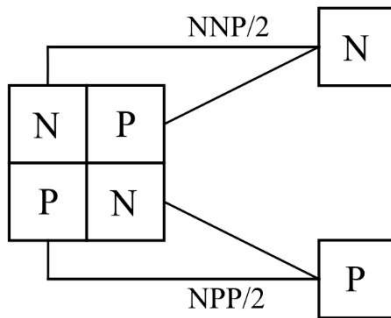
$$\begin{array}{r}
 E_B = \quad 1\alpha \quad 28.3250 \text{ MeV} \\
 \quad - 0.25 \text{ NNP} \quad - 2.1205 \\
 \quad \quad 0.75 \text{ NPP} \quad \underline{5.7885} \\
 \quad \quad \quad \quad \quad 31.9930 \text{ MeV} \\
 \quad \quad \quad \quad \quad - 0.001
 \end{array}$$

First phase:



$$E_B = - \text{NNP} + \text{NPP} + E_B \alpha$$

Second phase:



$$E_B = + 0.5 \text{ NNP} + 0.5 \text{ NPP} + E_B \alpha$$

$$\text{Average : } - \frac{\text{NNP}}{2} + 0.5 \text{ NNP} + \text{NPP} + 0.5 \text{ NPP} + 2 E_B \alpha = - 0.25 \text{ NNP} + 0.75 \text{ NPP} + E_B \alpha$$

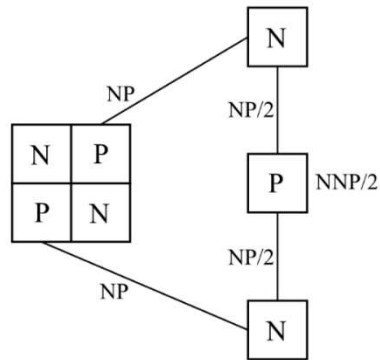
Li 6

In a first phase the P is linking with one proton and one neutron of the α particle. In reaction, a negative NNP bond arises linking the N with one neutron and one proton of the α particle. This process is the same as that of ${}^5_2\text{He}$ (see former figure).

In a second phase, one NNP and one NPP bond arise alternately to balance the structure.

The equilibrium between the two phases enables Li 6 to be stable. Nevertheless Li 7 is more stable, hence its greater occurrence in the nature (see next figure).

EB =	1 α	28.3250 MeV
	3 NP	6.6738
	0.5 NNP	4.2409
		<u>39.2397</u> MeV
		- 0.005



$$E_B = 3 \text{ NP} + 0.5 \text{ NNP} + E_B \alpha$$

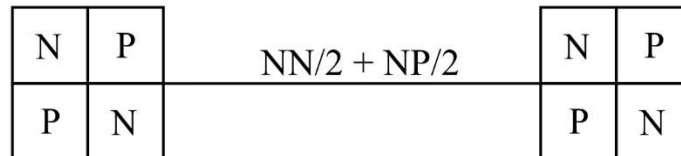
Li 7

The two N and the P external to α particle are linked by alternate bonds, NNP and two NP, forming $\text{NNP}/2 + \text{NP}/2 + \text{NP}/2$ bonds. Each N is linked to α particle by another NP bond. The whole is stable.

This nucleus has stronger bonds than Li 6. So, even if the parity between N and P is important in the case of light nuclei, the case of lithium is peculiar. The complexity of the Li 6 bonds weakens this isotope at the benefit of Li 7 which is hence more abundant in nature.

$$\begin{array}{r}
 \text{EB} = \quad 2\alpha \quad 56.6500 \text{ MeV} \\
 \quad 0.25 \text{ NN} \quad 1.2341 \\
 \quad 0.25 \text{ NP} \quad 0.5562 \\
 - 0.25 \text{ NPP} \quad 1.9295 \\
 \hline
 \quad \quad \quad 56.5108 \text{ MeV} \\
 + 0.011
 \end{array}$$

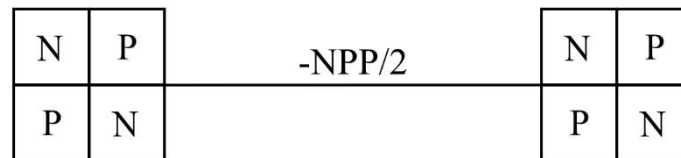
First phase



$$\text{EB} = A + 2 \text{EB } \alpha$$

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

Second phase



$$\text{EB} = -\text{NPP}/2 + 2 \text{EB } \alpha$$

$$\text{Average: } \text{EB} = \frac{A + 2 \text{EB } \alpha - 0.5 \text{NPP} + 2 \text{EB } \alpha}{2} = 0.5 A - 0.25 \text{NPP} + 2 \text{EB } \alpha$$

Be 8

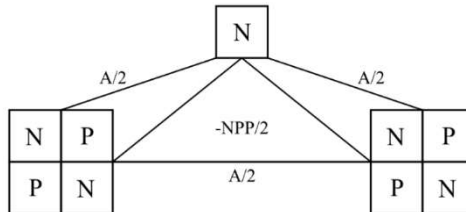
In a first phase, an A (= NN/2 + NP/2) bond tries to establish between the two α particles.

As a reaction one negative NPP/2 bond arises in a second phase.

The α particles are separating as the NPP/2 bond is stronger than the A bond.

The whole binding energy is weaker than that of the two ${}^4_2\text{He}$ binding energy, hence the splitting of the two ${}^4_2\text{He}$ structures.

EB =	2α	56.6500	MeV
	0.75 NN	3.7024	
	0.75 NP	1.6685	
	- 0.5 NPP	- 3.8590	
		58.1619	MeV
		- 0.002	



$$E_B = 1.5 A - 0.5 NPP + 2 E_B \alpha$$

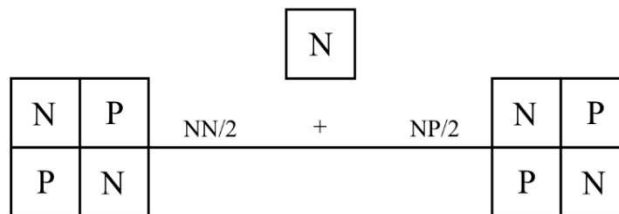
$$A = NN/2 + NP/2$$

Be 9

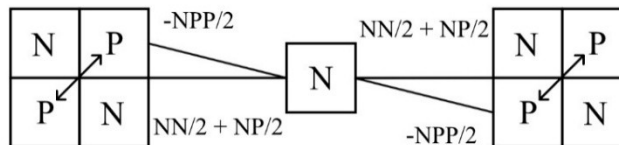
One notices the similarity with ⁸Be. The supplementary N of Be 9 generates one A bond more enabling the nucleus to be stable, even if the negative bond NPP is twice as strong than that one of Be 8.

The nucleus ⁹Be is created in two phases:

First phase (similar to Be 8):

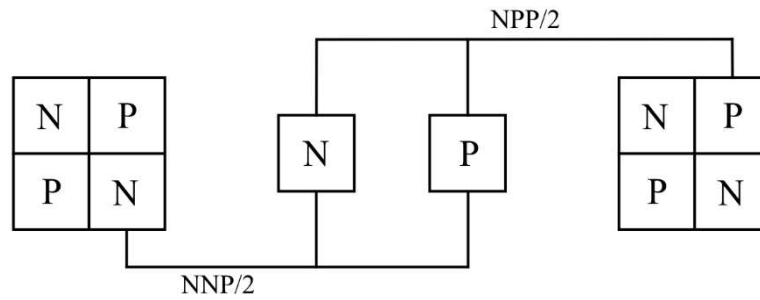


Second phase:



In a first phase, there is a bond created between the two α particles, either of NN value, or NP one. Nevertheless, N is excluded from this bond. In order to close the bond and include that N there is a new configuration appearing in a second phase. Moreover, there is the tendency to find an equilibrium between the two phases. So, the two phases oscillate, alternate. Thanks to an N introduction, it is possible to stabilize the nucleus and to create a bond between the two α particles. In this bond N acts as a catalyst.

EB =	2α	56.6500	MeV
	0.5 NNP	4.2409	
	0.5 NPP	3.8590	
		64.7499	MeV
		- 0.001	

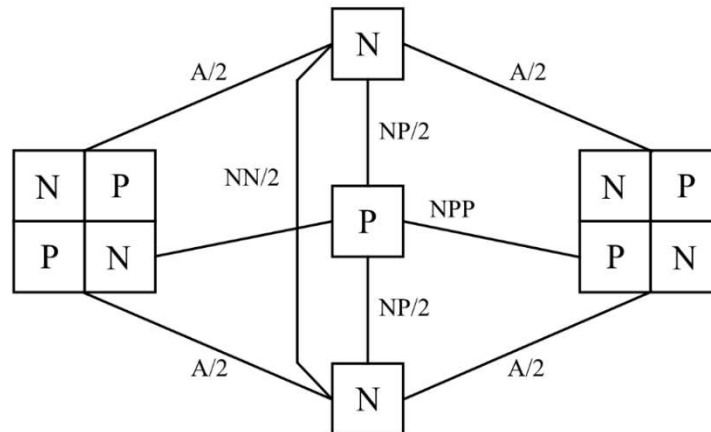


$$E_B = 0.5 \text{ NNP} + 0.5 \text{ NPP} + 2 E_B \alpha$$

B 10

In the case of B 10 the N and the P are bound to the α particles only every other time. There is parity between the N and P. So, as no internal force prevents this balance the nucleus remains stable.

$E_B =$	2α	56.6500	MeV
	1.5 NN	7.4048	
	2 NP	4.4492	
	NPP	7.7180	
		<u>76.2220</u>	MeV
		+ 0.017	



$$E_B = 2A + 0.5\text{ NN} + \text{NP} + \text{NPP} + 2E_B\alpha$$

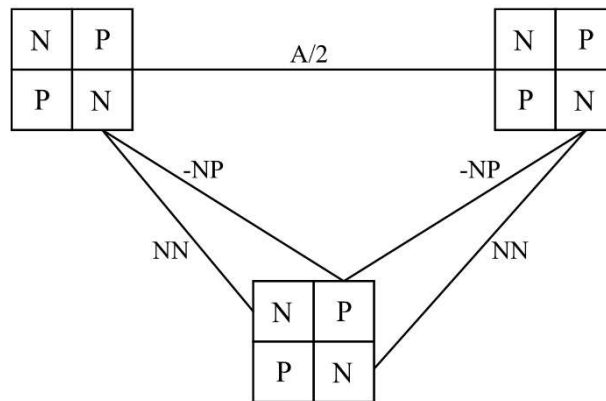
$$A = \text{NN}/2 + \text{NP}/2$$

B 11

In this nucleus the bonds are more solid than in case of B 10. This explains the greater abundance of this isotope when compared with B 10. One supplementary N can contribute, in some cases, to stabilize the light elements like in the cases of Li 7 and Be 9.

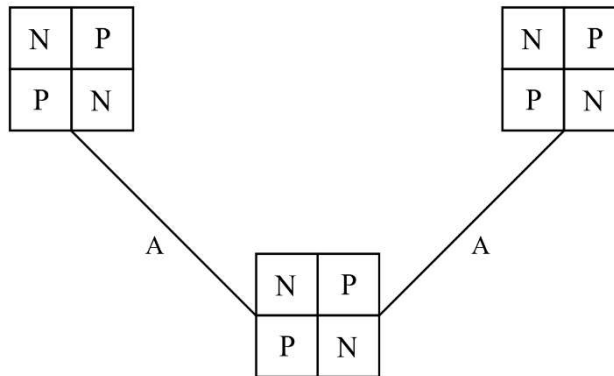
$$\begin{array}{r}
 \text{EB} = \quad 3 \alpha \quad 84.9750 \text{ MeV} \\
 \quad 1.625 \text{ NN} \quad 8.0218 \\
 \quad -0.375 \text{ NP} \quad -0.8342 \\
 \hline
 \quad \quad \quad 92.1626 \text{ MeV} \\
 \quad \quad \quad + 0.001
 \end{array}$$

First phase



$$\text{EB} = A/2 + 2 \text{ NN} - 2 \text{ NP} + 3 \text{ EB } \alpha$$

Second phase



$$\text{EB} = 2A + 3 \text{ EB } \alpha$$

$$\text{Average EB} = \frac{A/2 + 2 \text{ NN} - 2 \text{ NP} + 3 \text{ EB } \alpha + 2A + 3 \text{ EB } \alpha}{2} = 1.625 \text{ NN} - 0.375 \text{ NP} + 3 \text{ EB } \alpha$$

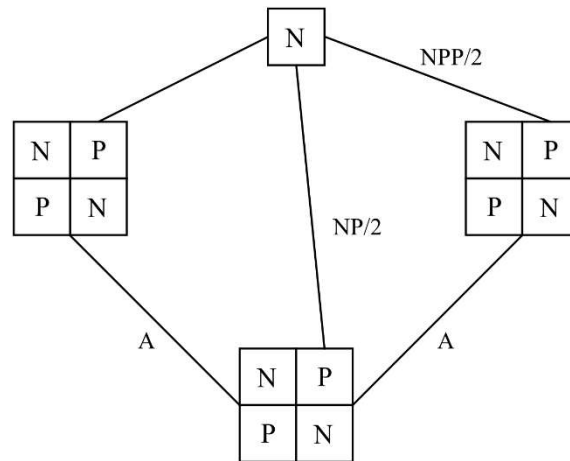
$$A = \text{NN}/2 + \text{NP}/2$$

C 12

In a first phase there is an equilibrium between two NN bonds and two negative NP bonds. One $A/2$ bond is linking two α particles.

In a second phase, this configuration is replaced with 2 A bonds. The three α particles are linked with two A bonds. See the case of O 16 which is very similar.

EB =	3 α	84.9750 MeV
	NN	4.9365
	1.5 NP	3.3369
	0.5 NPP	3.8590
		<u>97.1074</u> MeV
		/



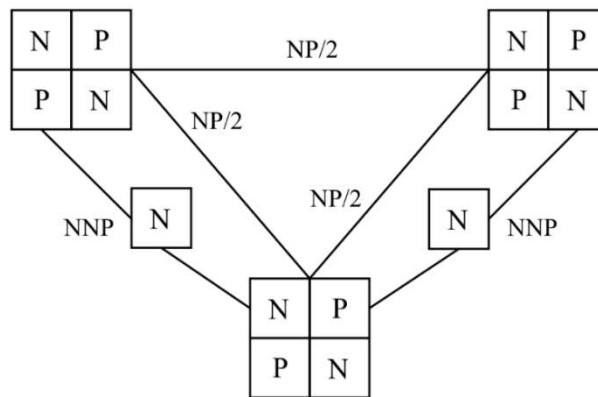
$$E_B = 2A + NP/2 + NPP/2 + 3 E_B \alpha$$

$$A = NN/2 + NP/2$$

C 13

This nucleus is stable. It is similar to C 12 (second phase). The supplementary N is once linked to one α particle through a NP bond, and once to the two other α particles through one NPP bond.

$$\begin{array}{r}
 \text{EB} = \quad 3 \alpha \quad 84.9750 \text{ MeV} \\
 \quad 1.5 \text{ NP} \quad 3.3369 \\
 \quad 2 \text{ NNP} \quad 16.9636 \\
 \hline
 \quad \quad \quad 105.2755 \text{ MeV} \\
 \quad \quad \quad - 0.009
 \end{array}$$

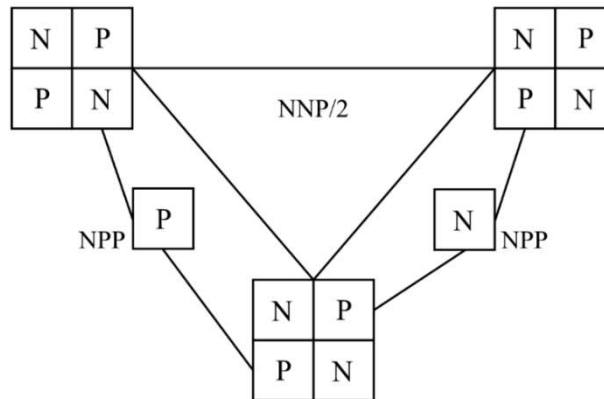


$$E_B = 1.5 \text{ NP} + 2 \text{ NNP} + 3 E_B \alpha$$

C 14

The structure of this nucleus is solid, but the N/P parity is not assured. So, C 14 decays slowly, one N turns into P through β^- emission and the nucleus transmutes to become N 14.

EB =	3 α	84.9750 MeV
	0.5 NNP	4.2409
	2 NPP	15.4360
		<u>104.6519</u> MeV
		- 0.007

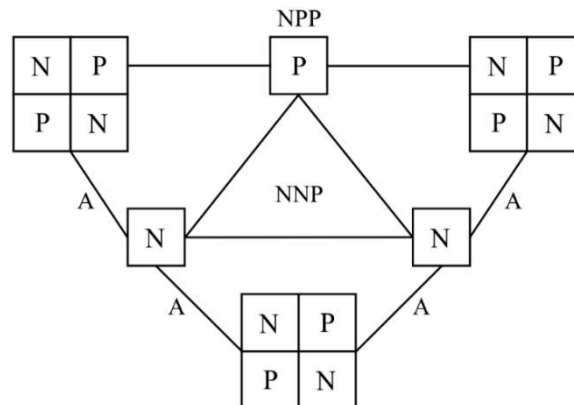


$$E_B = 0.5 \text{ NNP} + 2 \text{ NPP} + 3 E_B \alpha$$

N 14

The parity between N and P is assured and the bonds are perfectly stable. The nucleus is stable.

EB =	3 α	84.9750	MeV
	2 NN	9.8730	
	2 NP	4.4492	
	NNP	8.4818	
	NPP	7.7180	
		<u>115.4970</u>	MeV
		+ 0.005	



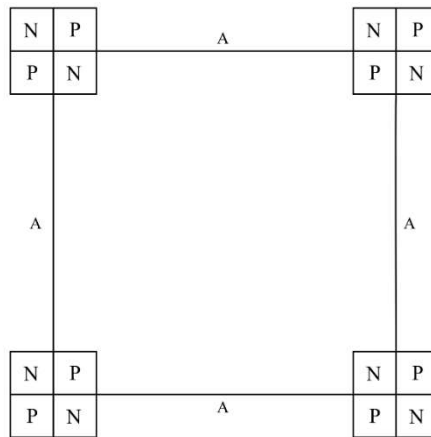
$$E_B = 4A + NNP + NPP + 3 E_B \alpha$$

$$A = NN/2 + NP/2$$

N 15

There is one N in excess. This is compatible with stability provided the bonds are stable. This is the case for N 15.

EB =	4α	113.3000	MeV
	2 NN	9.8730	
	2 NP	4.4492	
		127.6222	MeV
		+ 0.003	



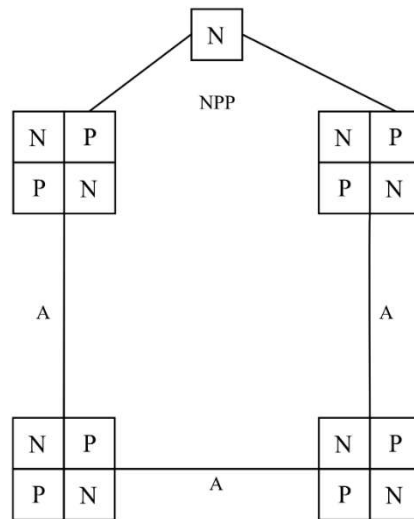
$$E_B = 4A + 4 E_B \alpha$$

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

O 16

This structure is perfectly stable, balanced between N and P as are the bonds among the α particles. Looking at this figure one sees why O 16 is more stable than the other nuclei.

EB =	4 α	113.3000	MeV
	1.5 NN	7.4048	
	1.5 NP	3.3369	
	NPP	7.7180	
		<u>131.7597</u>	MeV
		- 0.003	



$$E_B = 3A + NPP + 4 E_B \alpha$$

$$A = NN/2 + NP/2$$

O 17

One sees that, when compared with O 16, one NPP bond has replaced one A bond.

CHAPTER 4

NUCLEOSYNTHESIS OF THE ELEMENTS FROM O16 TILL CU65

Abstract

The purpose of that chapter is to show the similarity of binding energy structure of the various elements and of the various isotopes of each element. The alpha structure is put in evidence, as well as the bonds structure between α particles and that between the neutrons and protons and the α particles.

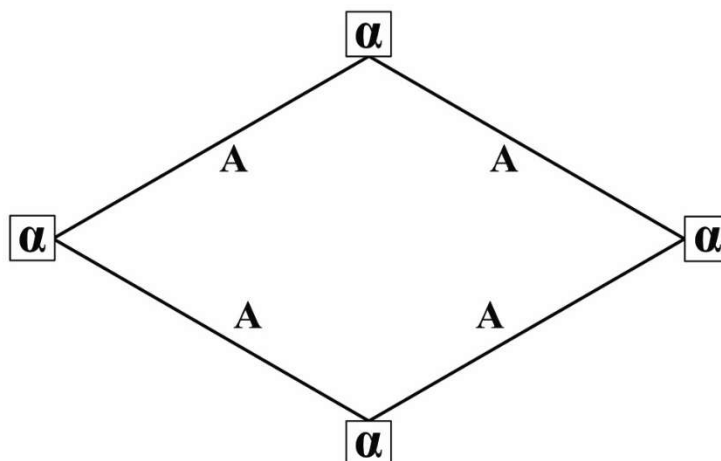
According to author's hypothesis the binding energy of every nucleus is the sum of the binding energy of its different sub-structures and the binding energy among these sub-structures.

$^{16}_8\text{O}$

Structure: 4 α , 0 N, 0 P supplementary

Linear and cross bonds: 4 A

N supplementary bonds: 0



$^{16}_8\text{O}$

4 α , 0 N, 0 P supplementary

EB in MeV = 127.6193

Stable

Nat. abundance: 99.76 %

Core structure

N, P supplementary

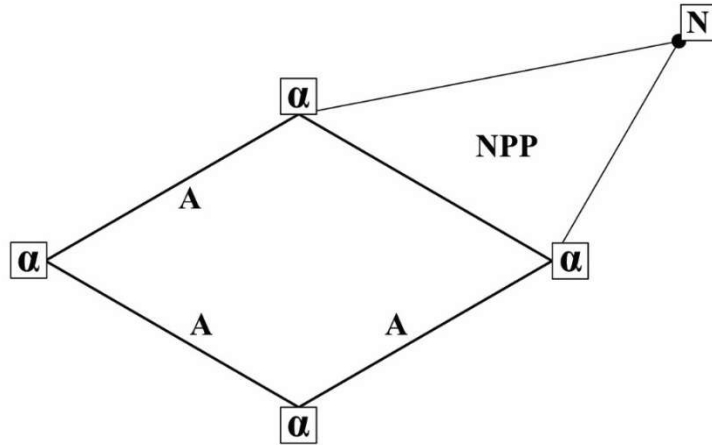
4	x	28.3250	113.3000	MeV
2	x	4.9365		
2	x	2.2246	4.4492	
0	x	8.4818	0	
0	x	7.7180	0	
0	x	4.9365	0	
0	x	2.2246	0	
0	x	8.4818	0	
0	x	7.7180	0	
			127.6222	MeV
			+ 0.003	

$^{17}_8\text{O}$

Structure: 4 α , 1 N, 0 P supplementary

Linear and cross bonds: 3 A

N supplementary bonds: 1 NPP



$^{17}_8\text{O}$

4 α , 1 N, 0 P supplementary

EB in MeV = 131.7624

Stable

Nat. abundance: 0.04 %

Core structure

N, P supplementary

$\left\{ \begin{array}{l} 4 \\ 1.5 \\ 1.5 \\ 0 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	113.3000 MeV 7.4048 3.3369 0 0
$\left\{ \begin{array}{l} 0 \\ 0 \\ 0 \\ 1 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	0 0 0 7.7180 <hr/> 131.7597 MeV - 0.003

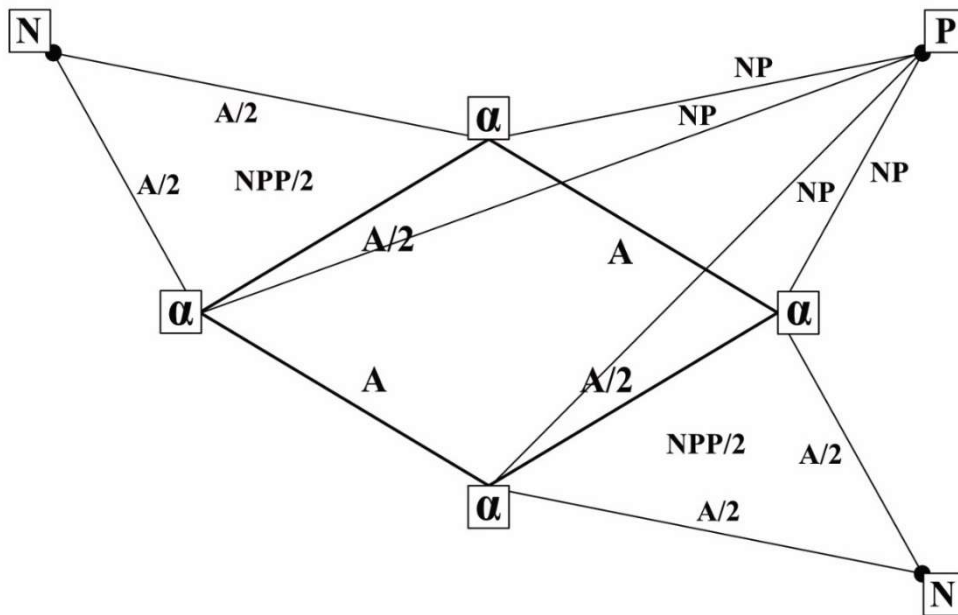
Compared to O 16, O 17 has 1 A bond less and 1 NPP bond more to link the N supplementary.

¹⁹F

Structure: 4 α , 2 N, 1 P supplementary

Linear and cross bonds: 3 A

N supplementary bonds: 2 A, 4 NP, 1 NPP



¹⁹F

4 α , 2 N, 1 P supplementary

EB in MeV = 147.8013

Stable

Nat. abundance: 100 %

Core structure

N, P supplementary

$\left\{ \begin{array}{l} 4 \\ 1.5 \\ 1.5 \\ 0 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	113.3000 MeV 7.4048 3.3369 0 0
$\left\{ \begin{array}{l} 1 \\ 5 \\ 0 \\ 1 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	4.9365 11.1230 0 7.7180
			<hr/> 147.8192 MeV + 0.018

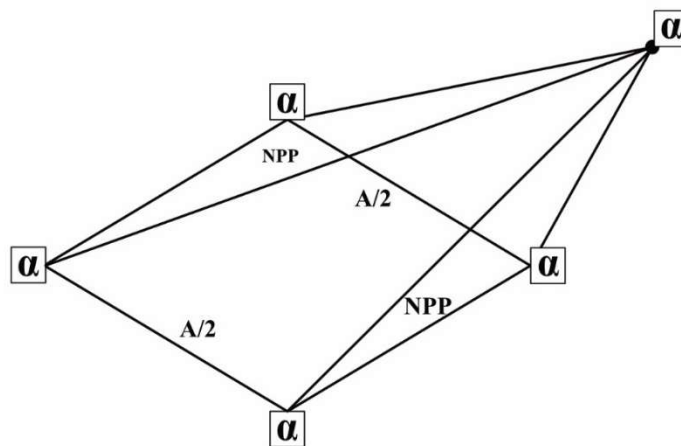
Compared to O 16, F 19 has 1 A bond less in its core and 2 A, 1 NPP and 4 NP more to link the 2 N and 1 P supplementary.

²⁰₁₀Ne

Structure: 5 α , 0 N, 0 P supplementary

Linear and cross bonds: 1 A, 2 NPP

N supplementary bonds: 0



²⁰₁₀Ne

5 α , 0 N, 0 P supplementary

EB in MeV = 160.6448

Stable

Nat. abundance: 90.51 %

Core structure

N, P supplementary

$\left\{ \begin{array}{l} 5 \\ 0.5 \\ 0.5 \\ 0 \\ 2 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	141.6250 MeV 2.4683 1.1123 0 15.4360
$\left\{ \begin{array}{l} 0 \\ 0 \\ 0 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	0 0 0 0
			<hr/> 160.6416 MeV - 0.003

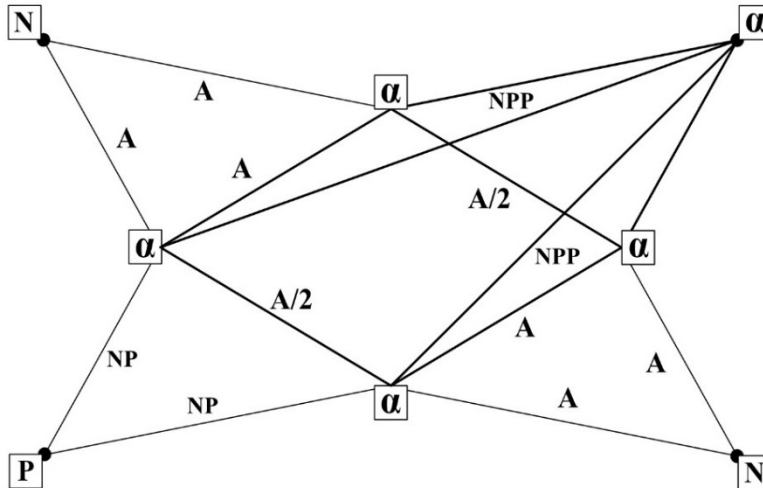
The fifth α particle links the other 4 α particles with 2 NPP bonds.

$^{23}_{11}\text{Na}$

Structure: 5 α , 2 N, 1 P supplementary

Linear and cross bonds: 3 A, 2 NPP

N supplementary bonds: 4 A, 2 NP



$^{23}_{11}\text{Na}$

5 α , 2 N, 1 P supplementary

EB in MeV = 186.5643

Stable

Nat. abundance: 100 %

Core structure

N, P supplementary

5	x	28.3250	141.6250	MeV
1.5	x	4.9365	7.4048	
1.5	x	2.2246	3.3369	
0	x	8.4818	0	
2	x	7.7180	15.4360	
2	x	4.9365	9.8730	
4	x	2.2246	8.8984	
0	x	8.4818	0	
0	x	7.7180	0	
			186.5741	MeV
			+ 0.010	

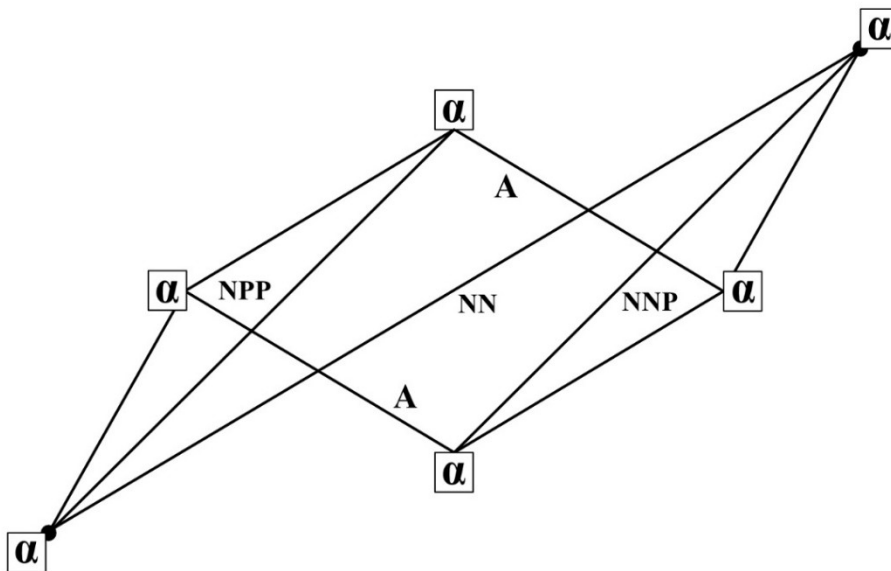
Compared to Ne 20, Na 23 has 2 A more in its core and 4 A and 2 NP to link the 2 N and 1 P supplementary.

²⁴₁₂Mg

Structure: 6 α , 0 N, 0 P supplementary

Linear and cross bonds: 2 A, 1 NN, 1 NNP, 1 NPP

N supplementary bonds: 0



²⁴₁₂Mg

6 α , 0 N, 0 P supplementary

EB in MeV = 198.2570

Stable

Nat. abundance: 78.99 %

Core structure

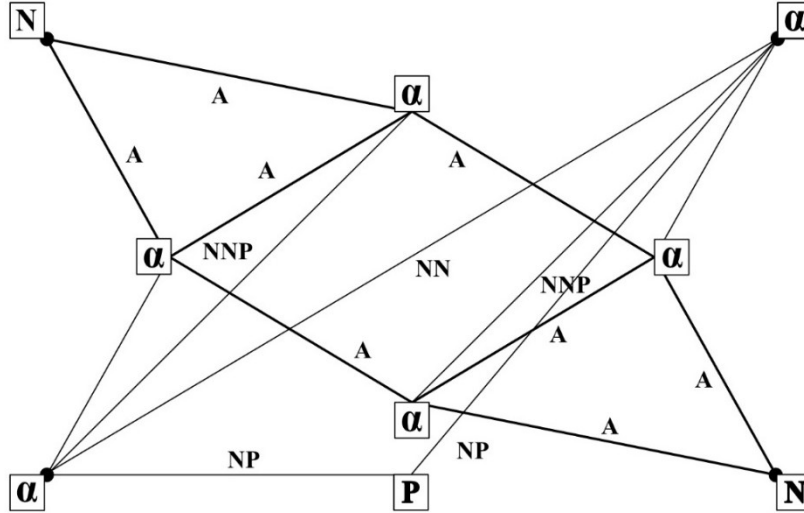
N, P supplementary

{	6	x	28.3250	169.9500	MeV
{	2	x	4.9365	9.8730	
{	1	x	2.2246	2.2246	
{	1	x	8.4818	8.4818	
{	1	x	7.7180	7.7180	
{	0	x	4.9365	0	
{	0	x	2.2246	0	
{	0	x	8.4818	0	
{	0	x	7.7180	0	
				198.2474	MeV
				- 0.010	

Mg 24 has a similar core structure as Ne 20, nevertheless with 1 α particle more.

²⁷₁₃Al

Structure: 6 α, 2 N, 1 P supplementary
 Linear and cross bonds: 4 A, 1 NN, 2 NNP
 N supplementary bonds: 4 A, 2 NP



²⁷₁₃Al

6α, 2 N, 1 P supplementary

EB in MeV = 224.9519

Stable

Nat. abundance: 100 %

Core structure

N, P supplementary

6	x	28.3250	169.9500	MeV
3	x	4.9365	14.8095	
2	x	2.2246	4.4492	
2	x	8.4818	16.9636	
0	x	7.7180	0	
2	x	4.9365	9.8730	
4	x	2.2246	8.8984	
0	x	8.4818	0	
0	x	7.7180	0	
			224.9437	MeV
			- 0.008	

Al 27 and Mg 24 cores are similar.

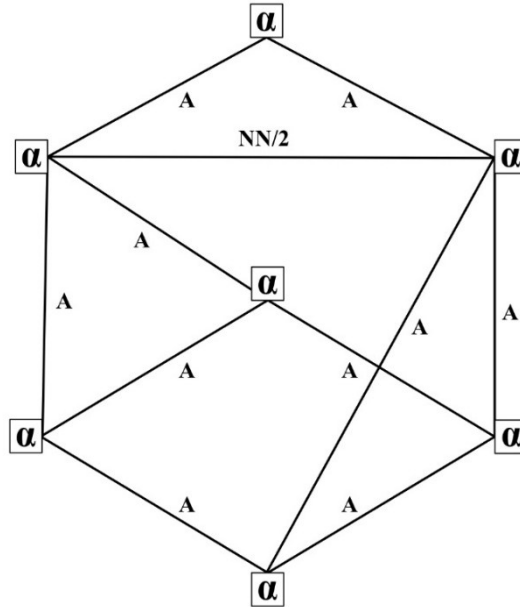
To link the 2 N and 1 P supplementary, 4 A and 2 NP bonds are added.

²⁸₁₄Si

Structure: 7 α, 0 N, 0 P supplementary

Linear and cross bonds: 10 A, 0.5 NN

N supplementary bonds: 0



²⁸₁₄Si

7α, 0 N, 0 P supplementary

EB in MeV = 236.5368

Stable

Nat. abundance: 92.23 %

Core structure

N, P supplementary

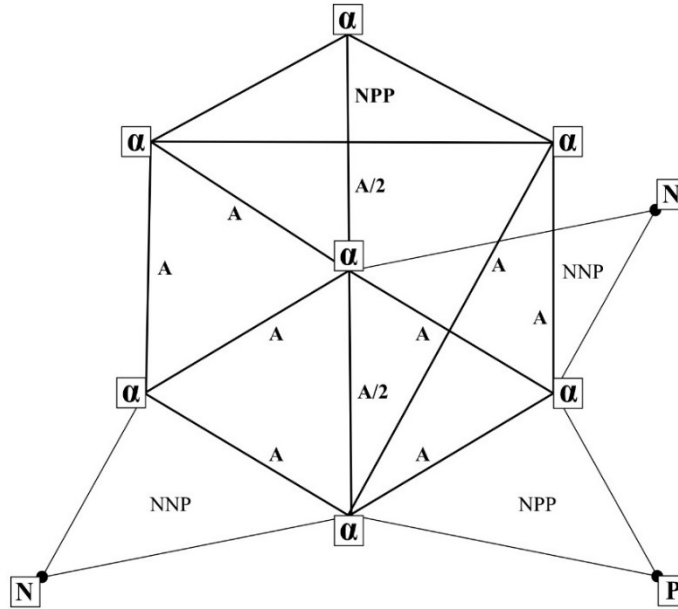
	7	x	28.3250		198.2750 MeV
	5.5	x	4.9365		27.1508
	5	x	2.2246		11.1230
	0	x	8.4818		0
	0	x	7.7180		0
	0	x	4.9365		0
	0	x	2.2246		0
	0	x	8.4818		0
	0	x	7.7180		0
					236.5488 MeV
					+ 0.012

³¹₁₅P

Structure: 7 α, 2 N, 1 P supplementary

Linear and cross bonds: 9 A, 1 NPP

N supplementary bonds: 2 NNP, 1 NPP



³¹₁₅P

7α, 0 N, 0 P supplementary

EB in MeV = 262.9162

Stable

Nat. abundance: 100 %

Core structure

N, P supplementary

{	7	x	28.3250	}	198.2750	MeV
	4.5	x	4.9365		22.2143	
	4.5	x	2.2246		10.0107	
	0	x	8.4818		0	
	1	x	7.7180		7.71800	
{	0	x	4.9365	}	0	
	0	x	2.2246		0	
	2	x	8.4818		16.9636	
	1	x	7.7180		7.7180	
					<u>262.8996</u>	MeV
					+ 0.017	

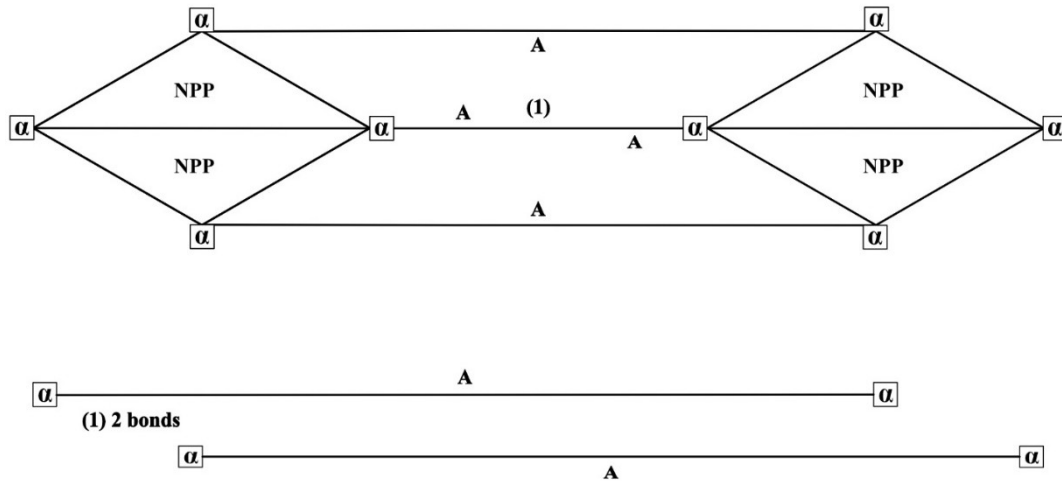
Compared to Si 28, P 31 has 1 NPP bond more to replace 1 NN/2 and 1 A.
1 NPP links the P to the core structure, and 2 NNP link the 2 N to that structure.

$^{32}_{16}\text{S}$

Structure: 8 α , 0 N, 0 P supplementary

Linear and cross bonds: 4 A, 4 NPP

N supplementary bonds: 0



$^{32}_{16}\text{S}$

8 α , 0 N, 0 P supplementary

EB in MeV = 271.7801

Stable

Nat. abundance: 95 %

Core structure

N, P supplementary

8	x	28.3250	}	226.6000	MeV
2	x	4.9365		9.8730	
2	x	2.2246		4.4492	
0	x	8.4818		0	
4	x	7.7180		30.8720	
0	x	4.9365	}	0	
0	x	2.2246		0	
0	x	8.4818		0	
0	x	7.7180		0	
				271.7942	MeV
				+ 0.014	

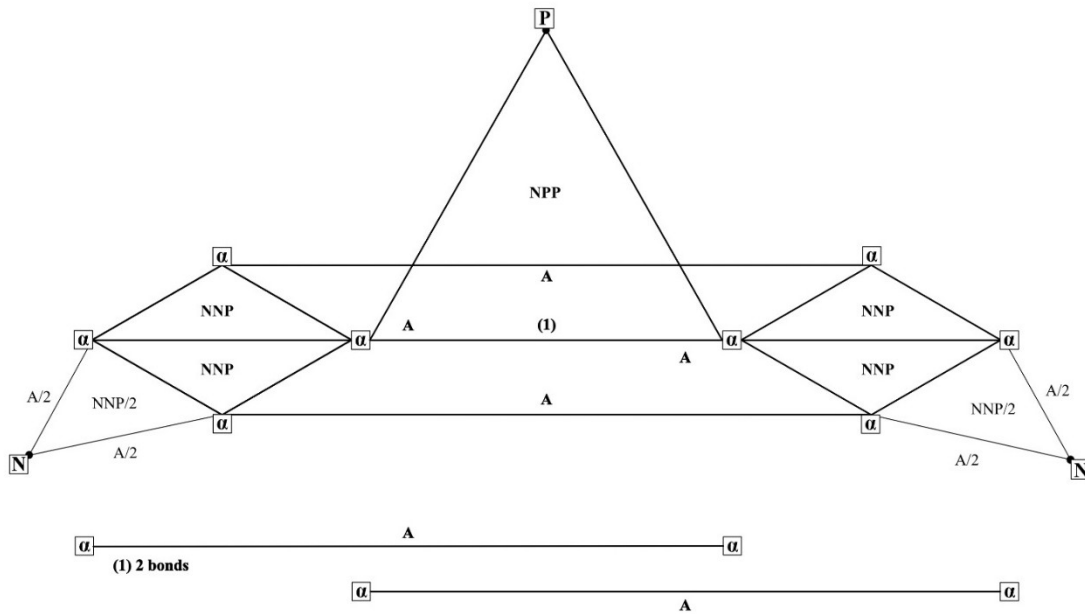
S 32 is comparable to 2 O 16 structures linked with 4 A bonds.

³⁵₁₇Cl

Structure: 8 α, 2 N, 1 P supplementary

Linear and cross bonds: 4 A, 4 NNP

N supplementary bonds: 2 A, 1 NNP, 1 NPP



³⁵₁₇Cl

8α, 2 N, 1 P supplementary

EB in MeV = 298.2097

Stable

Nat. abundance: 75.77 %

Core structure

N, P supplementary

{	8	x	28.3250	}	226.6000	MeV
	2	x	4.9365		9.8730	
	2	x	2.2246		4.4492	
	4	x	8.4818		33.9272	
	0	x	7.7180		0	
{	1	x	4.9365	}	4.9365	
	1	x	2.2246		2.2246	
	1	x	8.4818		8.4818	
	1	x	7.7180		7.7180	
				298.2103	MeV	

/

Cl 35 is comparable to S 32.

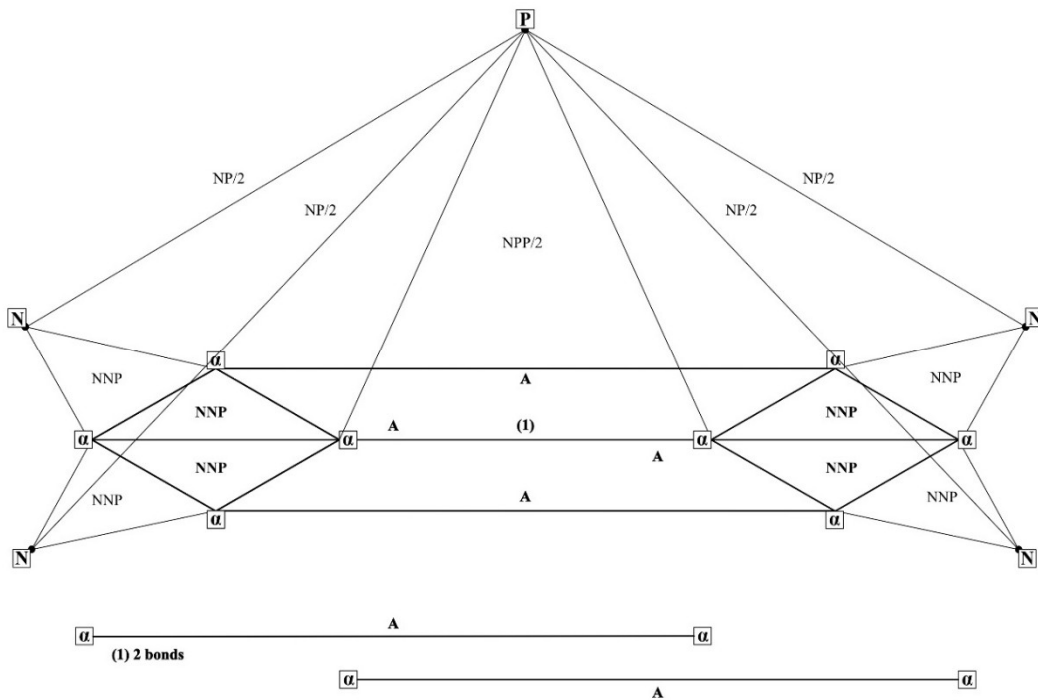
The 2 N and 1 P supplementary are linked to the core with (2 A + NNP) for the 2 N and NPP for the P.

³⁷₁₇Cl

Structure: 8α, 4 N, 1 P supplementary

Linear and cross bonds: 4 A, 4 NNP

N supplementary bonds: 2 NP, 4 NNP, 0.5 NPP



³⁷₁₇Cl

8α, 4 N, 1 P supplementary

EB in MeV = 317.1004

Stable

Nat. abundance: 24.23 %

Core structure

N, P supplementary

$\left\{ \begin{array}{l} 8 \\ 2 \\ 2 \\ 4 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	226.6000 MeV 9.8730 4.4492 33.9272 0
$\left\{ \begin{array}{l} 0 \\ 2 \\ 4 \\ 0.5 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	0 4.4492 33.9272 3.8590 <hr/> 317.0848 MeV - 0.016

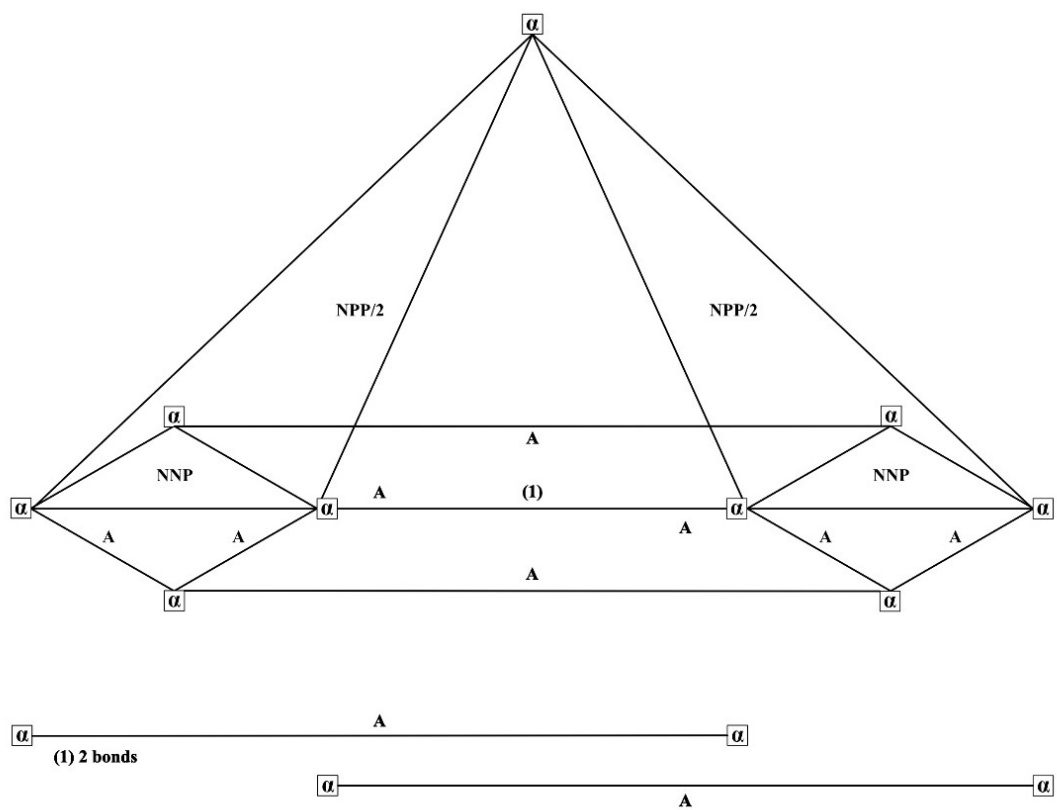
Cl 37 is similar to Cl 35. 2 NP and 1 NPP/2 are linking P to the core structure.

³⁶₁₈Ar

Structure: 9 α, 0 N, 0 P supplementary

Linear and cross bonds: 8 A, 2 NNP, 1 NPP

N supplementary bonds: 0



³⁶₁₈Ar

9α, 0 N, 0 P supplementary

EB in MeV = 308.2535

Stable

Nat. abundance: 0.34 %

Core structure

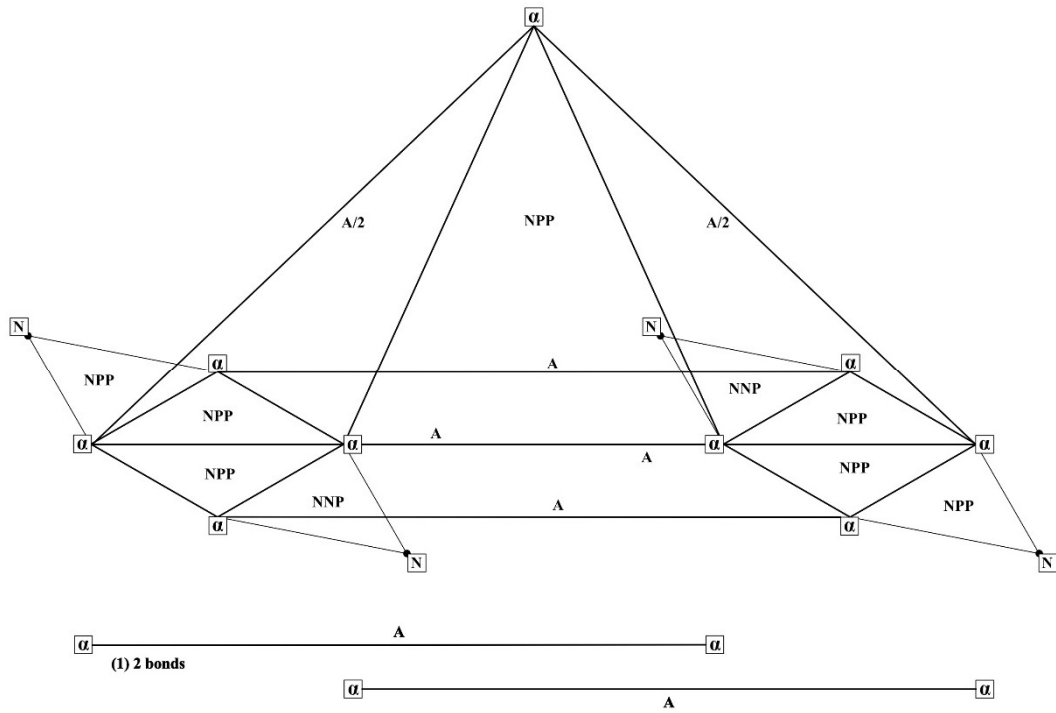
N, P supplementary

$\left\{ \begin{array}{l} 9 \\ 4 \\ 4 \\ 2 \\ 1 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	$\left\{ \begin{array}{l} 254.9250 \\ 19.7460 \\ 8.8984 \\ 16.9636 \\ 7.7180 \end{array} \right.$ MeV
$\left\{ \begin{array}{l} 0 \\ 0 \\ 0 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	$\left\{ \begin{array}{l} 0 \\ 0 \\ 0 \\ 0 \end{array} \right.$ MeV
			<hr/> 308.2510 MeV - 0.002

Ar 36 is comparable to Ne 20 and S 32.

⁴⁰₁₈Ar

Structure: 9 α , 4 N, 0 P supplementary
 Linear and cross bonds: 5 A, 5 NPP
 N supplementary bonds: 2 NNP, 2 NPP



⁴⁰₁₈Ar

9 α , 4 N, 0 P supplementary

EB in MeV = 343.8104

Stable

Nat. abundance: 99.59 %

Core structure

N, P supplementary

$\left\{ \begin{array}{l} 9 \\ 2.5 \\ 2.5 \\ 0 \\ 5 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	254.9250 MeV 12.3413 5.5615 0 38.5900
$\left\{ \begin{array}{l} 0 \\ 0 \\ 2 \\ 2 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	0 0 16.9636 15.4360 <hr/> 343.8174 MeV + 0.007

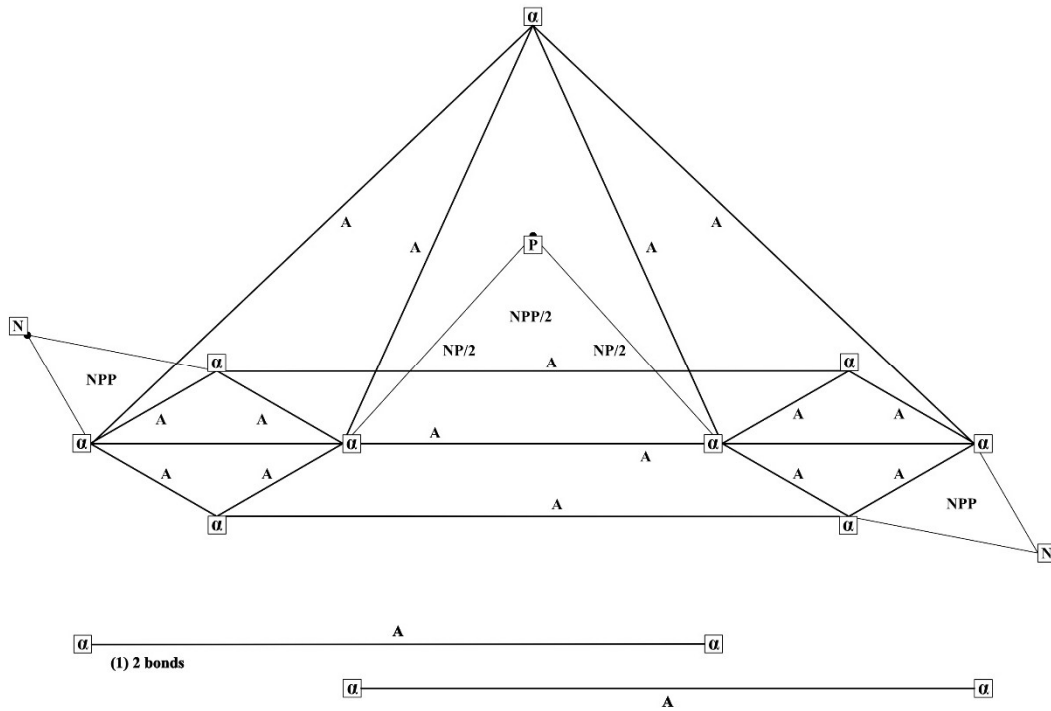
Ar 40 and Ar 36 structures are similar.

³⁹₁₉K

Structure: 9 α, 2 N, 1 P supplementary

Linear and cross bonds: 16 A

N supplementary bonds: 1 NP, 2.5 NPP



³⁹₁₉K

9α, 2 N, 1 P supplementary

EB in MeV = 333.7240

Stable

Nat. abundance: 93.26 %

Core structure

N, P supplementary

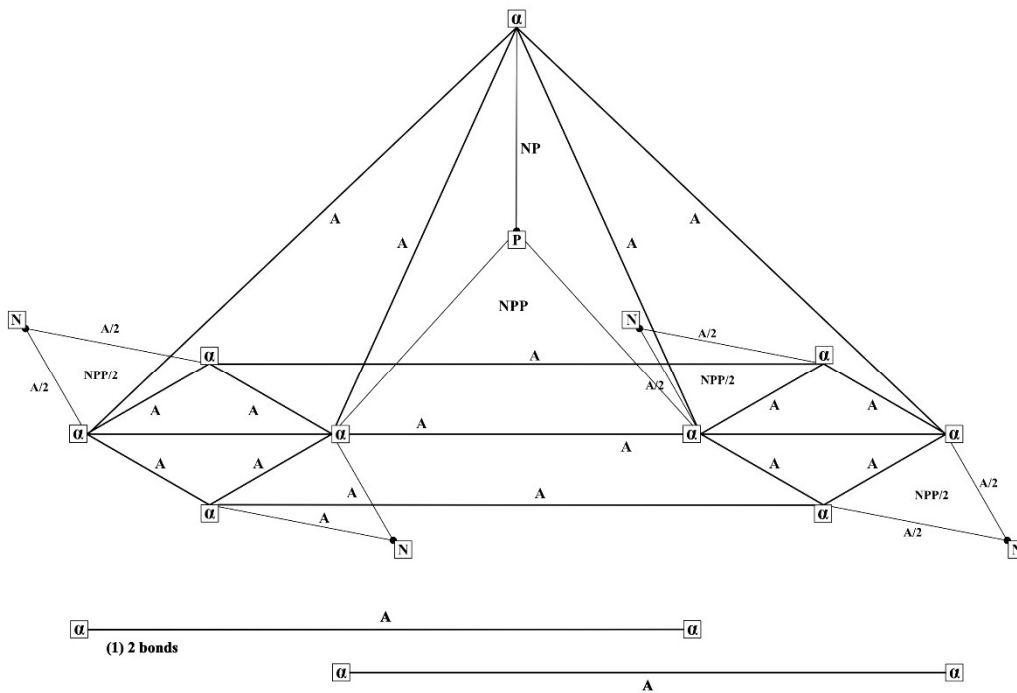
$\left\{ \begin{array}{l} 9 \\ 8 \\ 8 \\ 0 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	$\left\{ \begin{array}{l} 254.9250 \\ 39.4920 \\ 17.7968 \\ 0 \\ 0 \end{array} \right.$ MeV
$\left\{ \begin{array}{l} 0 \\ 1 \\ 0 \\ 2.5 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	$\left\{ \begin{array}{l} 0 \\ 2.2246 \\ 0 \\ 19.2950 \end{array} \right.$ MeV
			<hr/> 333.7334 MeV
			+ 0.009

⁴¹₁₉K

Structure: 9 α , 4 N, 1 P supplementary

Linear and cross bonds: 16 A

N supplementary bonds: 5 A, 1 NP, 2.5 NPP



⁴¹₁₉K

9 α , 4 N, 1 P supplementary

EB in MeV = 351.6190

Stable

Nat. abundance: 6.73 %

Core structure

N, P supplementary

9	x	28.3250	254.9250	MeV
8	x	4.9365		
8	x	2.2246	17.7968	
		0		
0	x	7.7180	0	
		2.5		
3.5	x	2.2246	7.7861	
		0		
2.5	x	7.7180	19.2950	
			+ 0.017	

K 39 and K 41 have the same core structure.

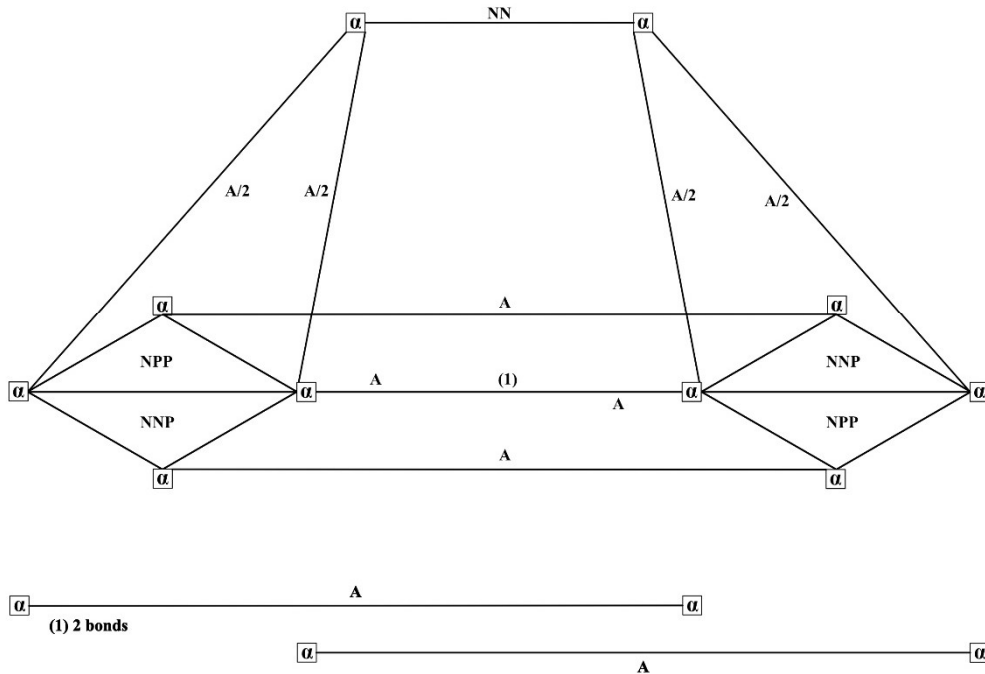
The supplementary N and P are linked to the core in the same way.

⁴⁰₂₀Ca

Structure: 10 α, 0 N, 0 P supplementary

Linear and cross bonds: 6 A, 1 NN, 2 NNP, 2 NPP

N supplementary bonds: 0



⁴⁰₂₀Ca

10α, 0 N, 0 P supplementary

EB in MeV = 342.0521

Stable

Nat. abundance: 96.94 %

Core structure

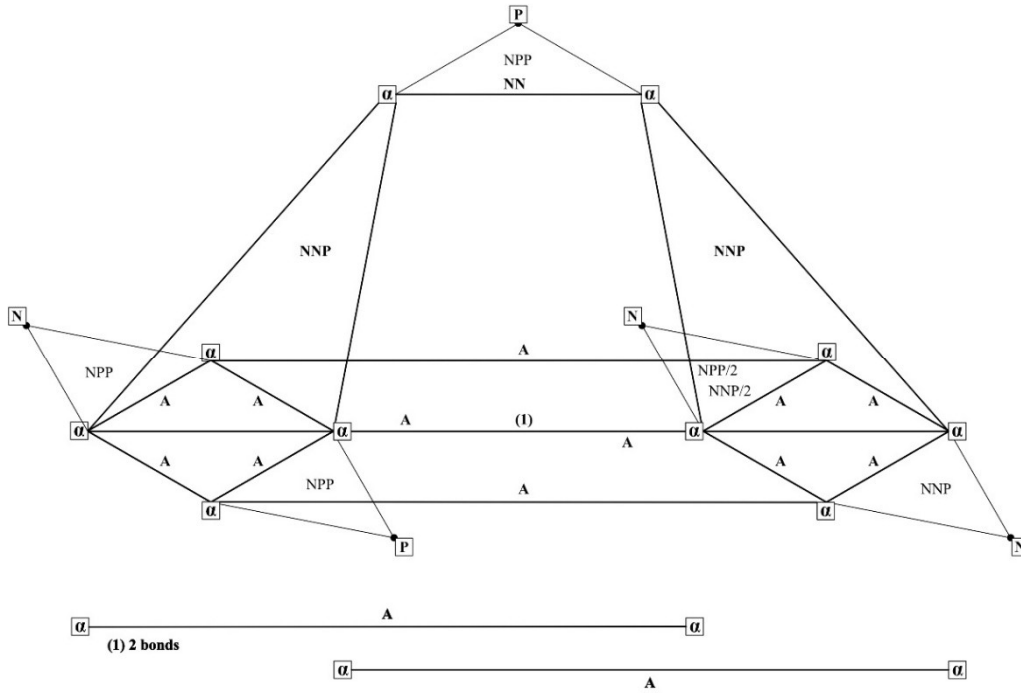
N, P supplementary

10	x	28.3250	283.2500	MeV
4	x	4.9365	19.7460	
3	x	2.2246	6.6738	
2	x	8.4818	16.9636	
2	x	7.7180	15.4360	
0	x	4.9365	0	
0	x	2.2246	0	
0	x	8.4818	0	
0	x	7.7180	0	
			342.0694	MeV
			+ 0.017	

The core structure of Ca 40 is similar to the former ones.

⁴⁵₂₁Sc

Structure: 10 α , 4 N, 1 P supplementary
 Linear and cross bonds: 12 A, 1 NN, 2 NNP
 N supplementary bonds: 1.5 NNP, 3.5 NPP



⁴⁵₂₁Sc

10 α , 4 N, 1 P supplementary

EB in MeV = 387.8519

Stable

Nat. abundance: 100 %

Core structure

N, P supplementary

10	x	28.3250	}	283.2500	MeV
7	x	4.9365		34.5555	
6	x	2.2246	}	13.3476	
2	x	8.4818		16.9636	
0	x	7.7180	0		
0	x	4.9365	}	0	
0	x	2.2246		0	
1.5	x	8.4818	}	12.7227	
3.5	x	7.7180		27.0130	
				387.8524	MeV
				/	

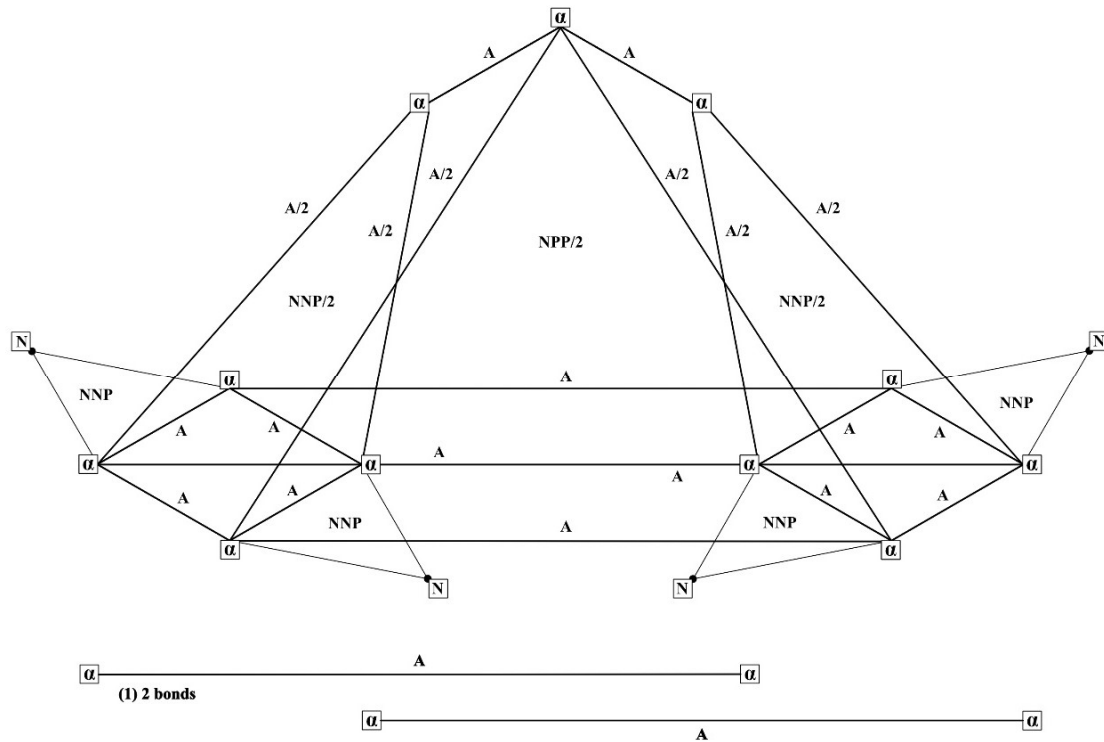
Compared to Ca 40, 6 A have replaced 2 NPP in the core of Sc 45.

⁴⁸₂₂Ti

Structure: 11 α , 4 N, 0 P supplementary

Linear and cross bonds: 17 A, 1 NNP, 0.5 NPP

N supplementary bonds: 4 NNP



⁴⁸₂₂Ti

11 α , 4N, 0P supplementary

EB in MeV = 418.7043

Stable

Nat. abundance: 73.7%

Core structure

N, P supplementary

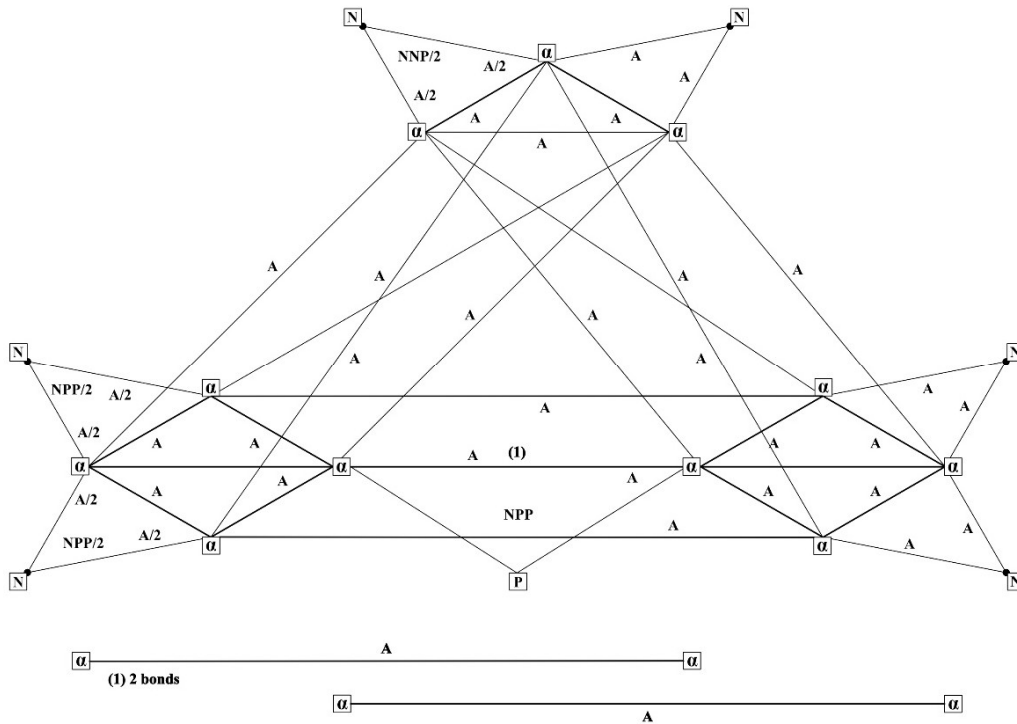
11	x	28.3250	}	311.5750	MeV
8.5	x	4.9365		41.9603	
8.5	x	2.2246	}	18.9091	
1	x	8.4818		8.4818	
0.5	x	7.7180		3.8590	
0	x	4.9365		0	
0	x	2.2246	}	0	
4	x	8.4818		33.9272	
0	x	7.7180		0	
				418.7124	
			+ 0.008		

⁵¹₂₃V

Structure: 11 α, 6 N, 1 P supplementary

Linear and cross bonds: 23 A

N supplementary bonds: 9 A, 0.5 NNP, 2 NPP



⁵¹₂₃V

11α, 6 N, 1 P supplementary

EB in MeV = 445.8470

Stable

Nat. abundance: 99.75 %

Core structure

N, P supplementary

11	x	28.3250	311.5750	MeV
11.5	x	4.9365	56.7698	
11.5	x	2.2246	25.5829	
0	x	8.4818	0	
0	x	7.7180	0	
4.5	x	4.9365	22.2143	
4.5	x	2.2246	10.0107	
0.5	x	8.4818	4.2409	
2	x	7.7180	15.4360	
			445.8296	MeV
			- 0.017	

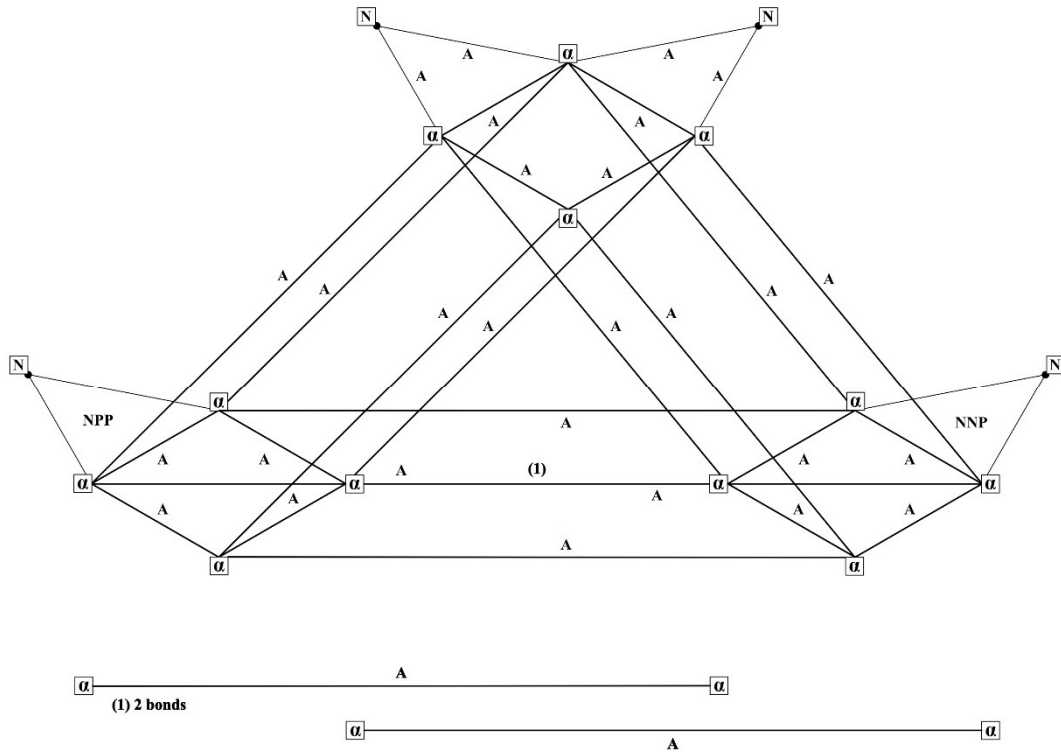
Compared to Ti 48, 6 A have replaced 1 NNP and 1 NPP/2 in the core of V 51.

⁵²₂₄Cr

Structure: 12 α, 4 N, 0 P supplementary

Linear and cross bonds: 24 A

N supplementary bonds: 4 A, 1 NNP, 1 NPP



⁵²₂₄Cr

12α, 4 N, 0 P supplementary

EB in MeV = 456.3514

Stable

Nat. abundance: 83.79 %

Core structure

N, P supplementary

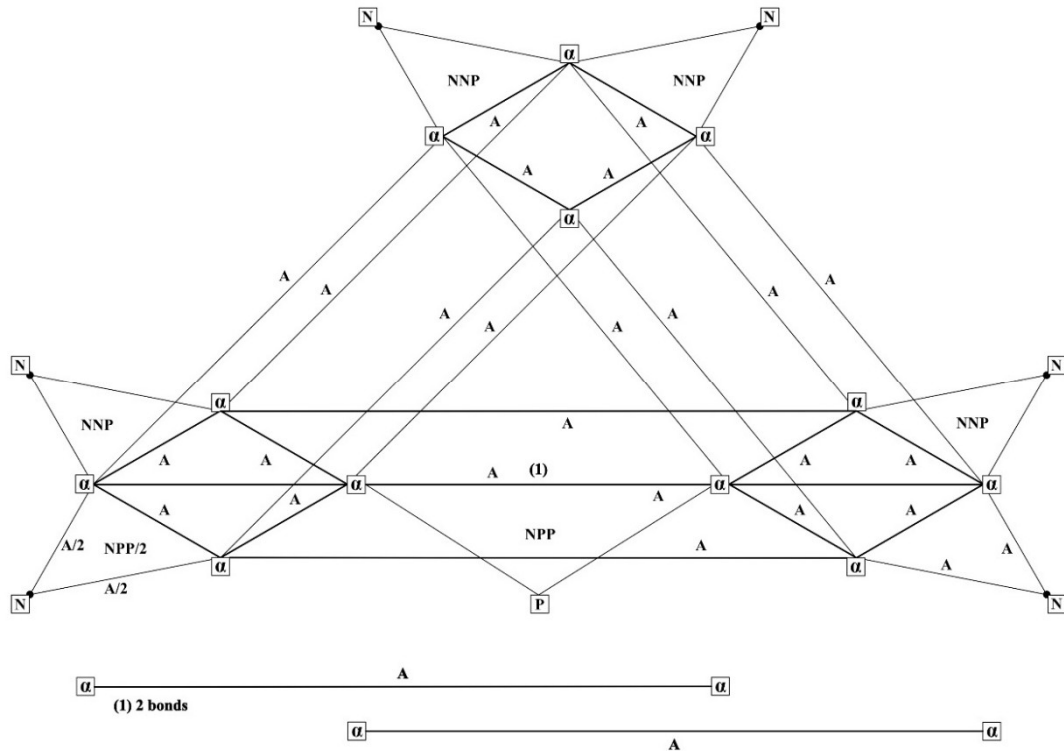
12	x	28.3250	339.9000	MeV
12	x	4.9365	59.2380	
12	x	2.2246	26.6952	
0	x	8.4818	0	
0	x	7.7180	0	
2	x	4.9365	9.8730	
2	x	2.2246	4.4492	
1	x	8.4818	8.4818	
1	x	7.7180	7.7180	
			456.3552	MeV
			+ 0.004	

⁵⁵₂₅ Mn

Structure: 12 α , 6 N, 1 P supplementary

Linear and cross bonds: 24 A

N supplementary bonds: 3 A, 4 NNP, 1.5 NPP



⁵⁵₂₅ Mn

12 α , 6 N, 1 P supplementary

EB in MeV = 482.0762

Stable

Nat. abundance: 100 %

Core structure

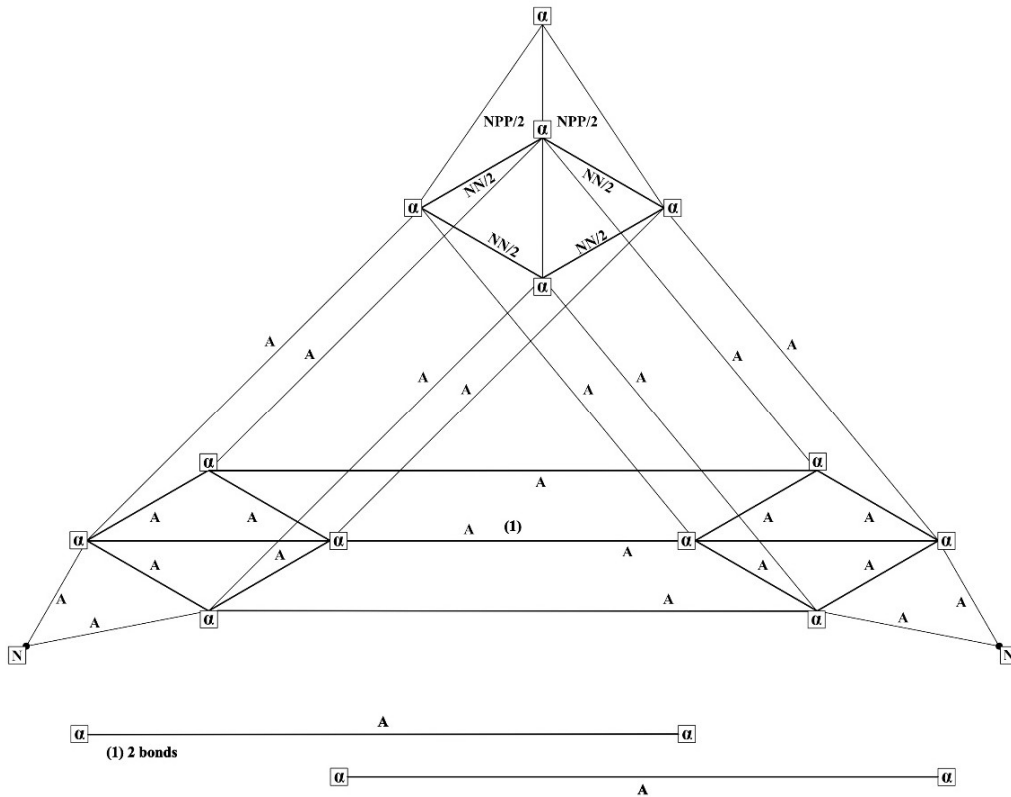
N, P supplementary

{	12	x	28.3250	}	339.9000	MeV
	12	x	4.9365		59.2380	
	12	x	2.2246		26.6952	
	0	x	8.4818		0	
	0	x	7.7180		0	
{	1.5	x	4.9365	}	7.4048	
	1.5	x	2.2246		3.3369	
	4	x	8.4818		33.9272	
	1.5	x	7.7180		11.5770	
					472.0791	MeV
					+ 0.003	

Cr 52 and Mn 55 have the same core structure.

⁵⁴₂₆Fe

Structure: 13 α, 2 N, 0 P supplementary
 Linear and cross bonds: 20 A, 2 NN, 1 NPP
 N supplementary bonds: 4 A



⁵⁴₂₆Fe

13α, 2 N, 0 P supplementary

EB in MeV = 471.7640

Stable

Nat. abundance: 5.8%

Core structure

N, P supplementary

13	x	28.3250	}	368.2250	MeV
12	x	4.9365		59.2380	
10	x	2.2246		22.2460	
0	x	8.4818		0	
1	x	7.7180		7.7180	
2	x	4.9365	}	9.8730	
2	x	2.2246		4.4492	
0	x	8.4818		0	
0	x	7.7180		0	
				471.7492	
			- 0.015		

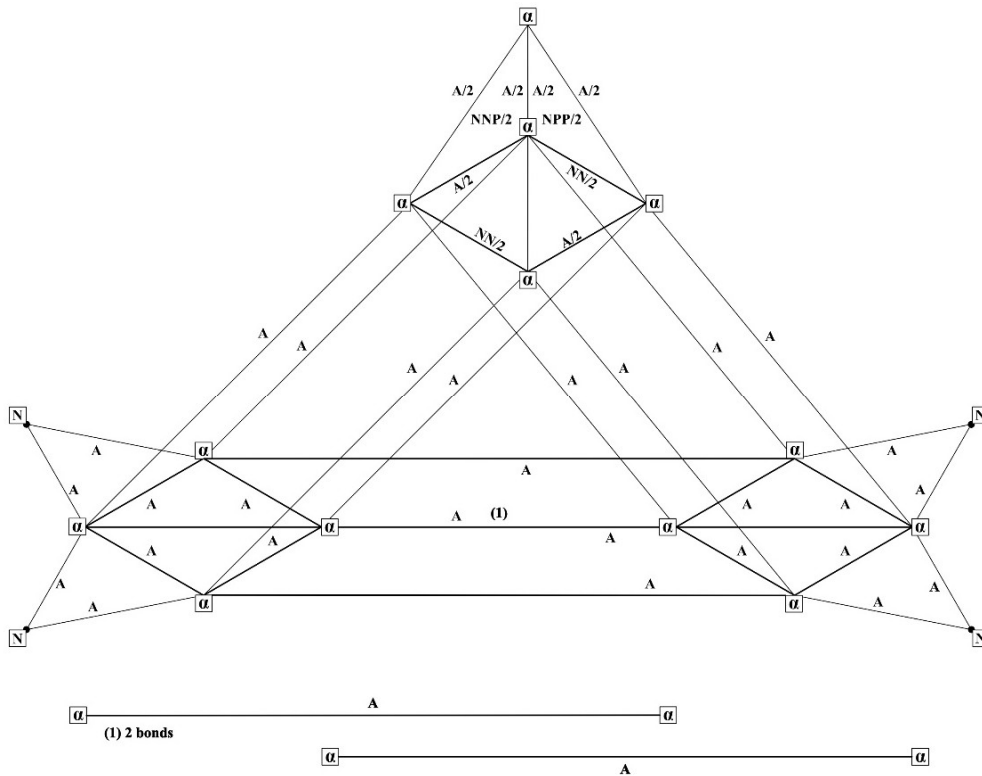
The core structure of Fe 54 is comparable to the former ones.

⁵⁶₂₆Fe

Structure: 13 α, 4 N, 0 P supplementary

Linear and cross bonds: 23 A, 1 NN, 0.5 NNP, 0.5 NPP

N supplementary bonds: 8 A



⁵⁶₂₆Fe

13α, 4 N, 0 P supplementary

EB in MeV = 492.2598

Stable

Nat. abundance: 91.8%

Core structure

N, P supplementary

{	13	x	28.3250	}	368.2250	MeV
	12.5	x	4.9365	}	61.7063	
	11.5	x	2.2246	}	25.5829	
	0.5	x	8.4818	}	4.2409	
	0.5	x	7.7180	}	3.8590	
	4	x	4.9365	}	19.7460	
	4	x	2.2246	}	8.8984	
	0	x	8.4818	}	0	
	0	x	7.7180	}	0	
					492.2585	MeV
					- 0.001	

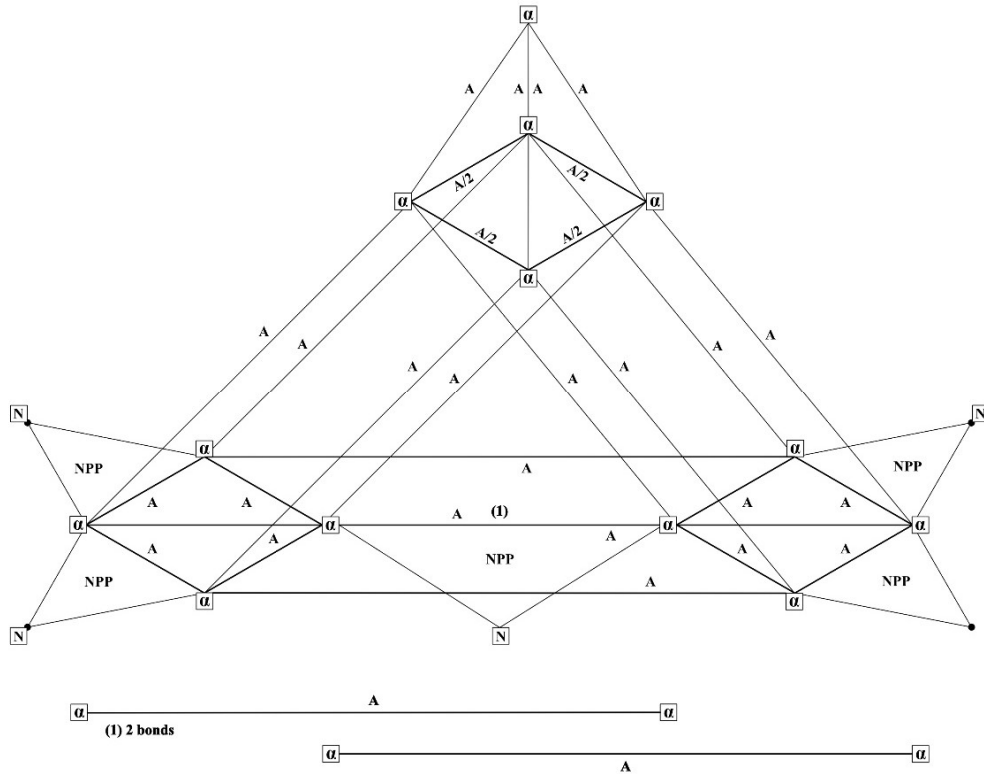
Fe 56 and Fe 54 are similar.

⁵⁷₂₆Fe

Structure: 13 α, 5 N, 0 P supplementary

Linear and cross bonds: 26 A

N supplementary bonds: 5 NPP



⁵⁷₂₆Fe

13α, 5 N, 0 P supplementary

EB in MeV = 499.9059

Stable

Nat. abundance: 2.1%

Core structure

N, P supplementary

13	x	28.3250	368.2250	MeV
13	x	4.9365	64.1745	
13	x	2.2246	28.9198	
0	x	8.4818	0	
0	x	7.7180	0	
0	x	4.9365	0	
0	x	2.2246	0	
0	x	8.4818	0	
5	x	7.7180	38.5900	
			499.9093	MeV
			+ 0.004	

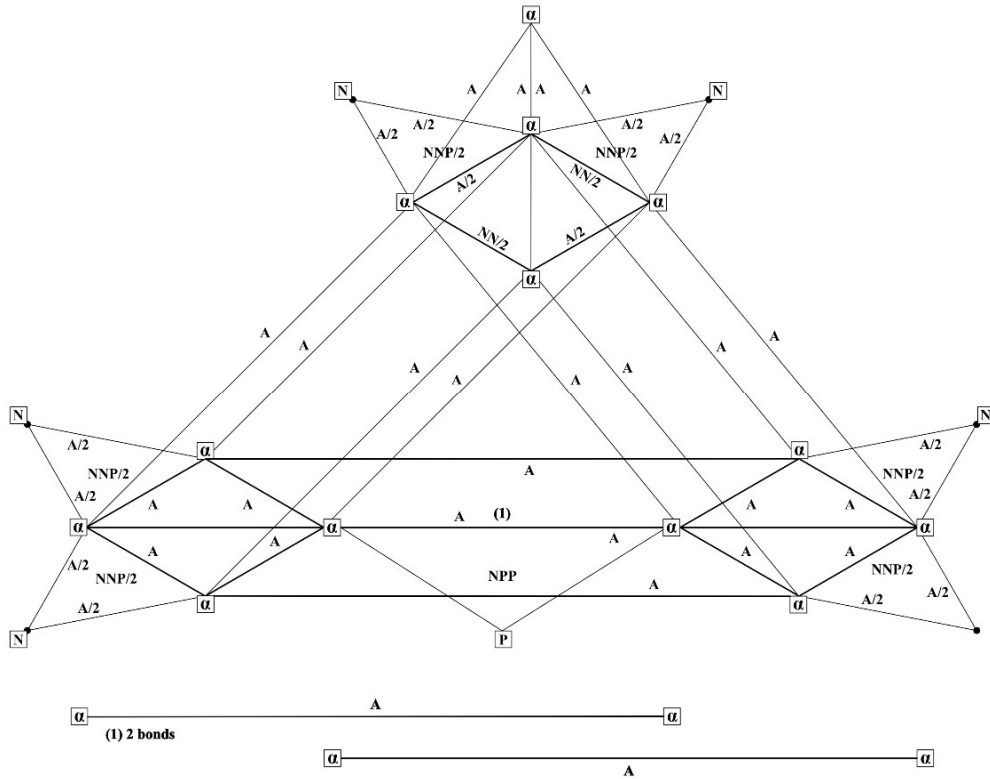
Fe 57 and Fe 56 are similar.

⁵⁹₂₇Co

Structure: 13 α, 6 N, 1 P supplementary

Linear and cross bonds: 25 A, 1 NN

N supplementary bonds: 6 A, 3 NNP, 1 NPP



⁵⁹₂₇Co

13α, 6 N, 1 P supplementary

EB in MeV = 517.3141

Stable

Nat. abundance: 100 %

Core structure

N, P supplementary

13	x	28.3250	}	368.2250	MeV
13.5	x	4.9365		66.6428	
12.5	x	2.2246		27.8075	
0	x	8.4818		0	
0	x	7.7180		0	
3	x	4.9365	}	14.8095	
3	x	2.2246		6.6738	
3	x	8.4818		25.4454	
1	x	7.7180		7.7180	
				517.3220	MeV
				+ 0.008	

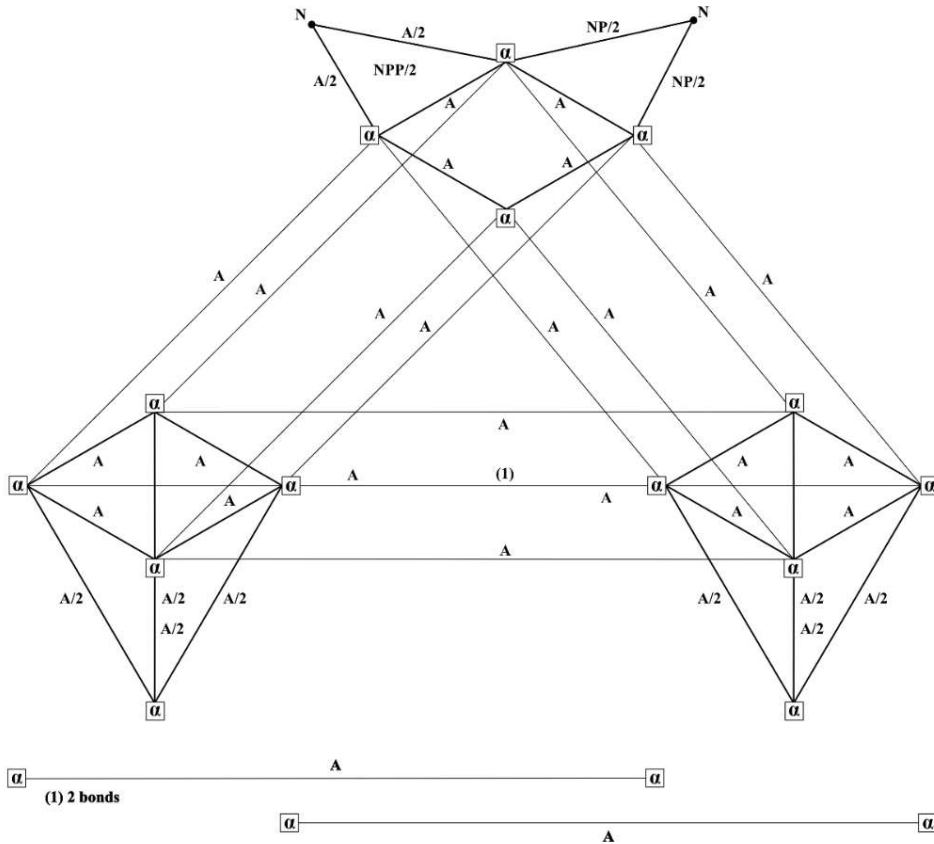
Co 59 and Fe 57 are similar.

⁵⁸₂₈Ni

Structure: 14 α, 2 N, 0 P supplementary

Linear and cross bonds: 28 A

N supplementary bonds: 1 A, 1 NP, 0.5 NPP



⁵⁸₂₈Ni

14α, 2N, 0P supplementary

EB in MeV = 506.4594

Stable

Nat. abundance: 68.27 %

Core structure

N, P supplementary

14	x	28.325	396.5500	MeV
14	x	4.9365	69.1110	
14	x	2.2246	31.1444	
0	x	8.4818	0	
0	x	7.7180	0	
0.5	x	4.9365	2.4683	
1.5	x	2.2246	3.3369	
0	x	8.4818	0	
0.5	x	7.7180	3.8590	
			506.4696	MeV
			+ 0.010	

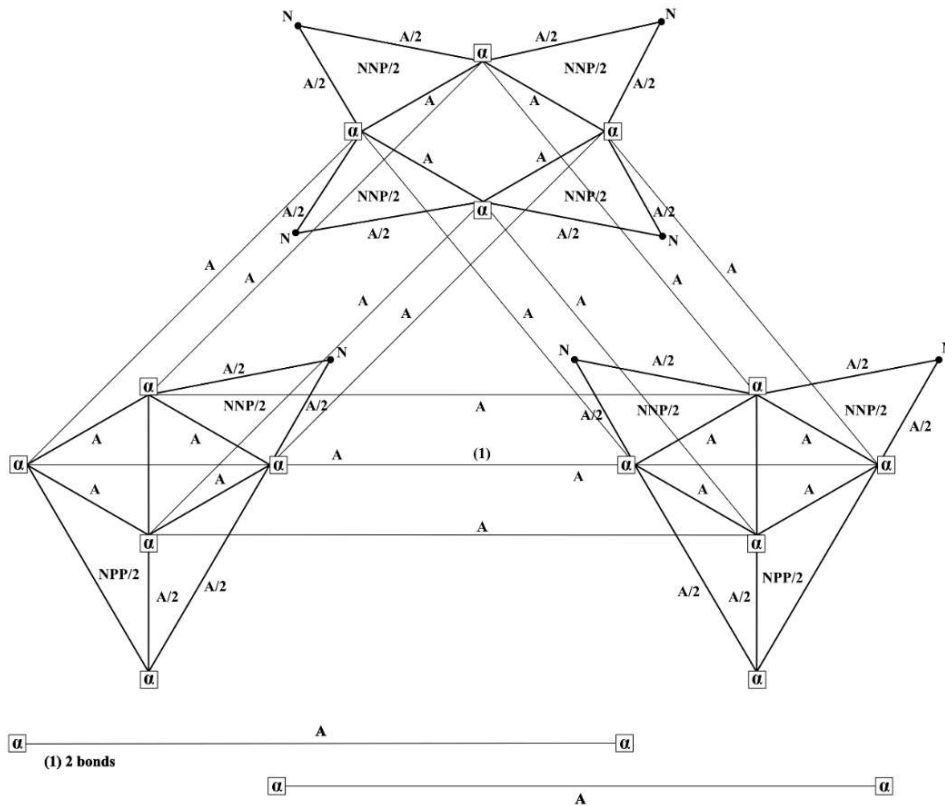
The whole core structure of Ni 58 is constituted out of A type bonds. Only the 2 N supplementary are linked with different bonds to the α particles. One N is linked to the α particles with one NP bond instead of an NPP bond as usually. This type of modification is frequent within a given nucleus; when there is not enough energy available for a NNP or NPP bond, the most stable arrangement is occurring. In the present case it is a NP bond. So, Ni 58 is stable.

⁶³₂₈Ni

Structure: 14 α, 7 N, 0 P supplementary

Linear and cross bonds: 26A, 1 NPP

N supplementary bonds: 7A, 3.5 NNP



⁶³₂₈Ni

14α, 7N, 0P supplementary

EB in MeV = 552.1001

Lifetime: 92 years

Mode of decay: β⁻

Core structure

N, P supplementary

{	14	x	28.325	}	396.5500 MeV
	13	x	4.9365		
	13	x	2.2246		
	0	x	8.4818		
	1	x	7.7180		
{	3.5	x	4.9365	}	17.2778
	3.5	x	2.2246		
	3.5	x	8.4818		
	0	x	7.7180		
	0	x	7.7180		
					552.1125 MeV
					+ 0.012

The core is stable. There are 7 N supplementary. This nucleus is submitted to β⁻ decay which transforms a N into P; in the present case Ni 63 is transmuted into Cu 63.

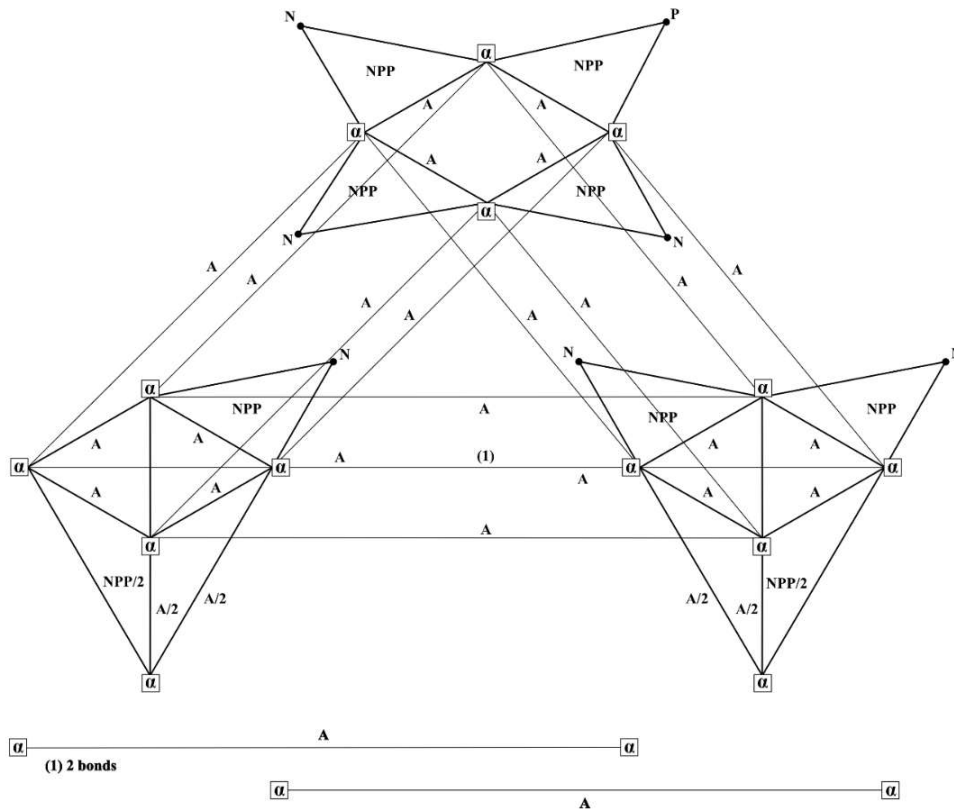
The 7 N supplementary are bound to the α particles with 7A (3.5 NN + 3.5 NP) + 3.5 NNP bonds. These bonds are transformed into 7 NPP bonds (see ⁶³₂₉Cu).

⁶³₂₉ Cu

Structure: 14 α, 6 N, 1 P supplementary

Linear and cross bonds: 26A, 1 NPP

N, P supplementary bonds: 7 NPP



⁶³₂₉ Cu

14α, 6N, 1P supplementary

EB in MeV = 551.3847

Stable

Nat. abundance: 69.2 %

Core structure

N, P supplementary

{	14	x	28.325	}	396.5500	MeV
	13	x	4.9365		64.1745	
	13	x	2.2246		28.9198	
	0	x	8.4818		0	
	1	x	7.7180		7.7180	
{	0	x	4.9365	}	0	
	0	x	2.2246		0	
	0	x	8.4818		0	
	7	x	7.7180		54.0260	
					551.3883	MeV
					+ 0.004	

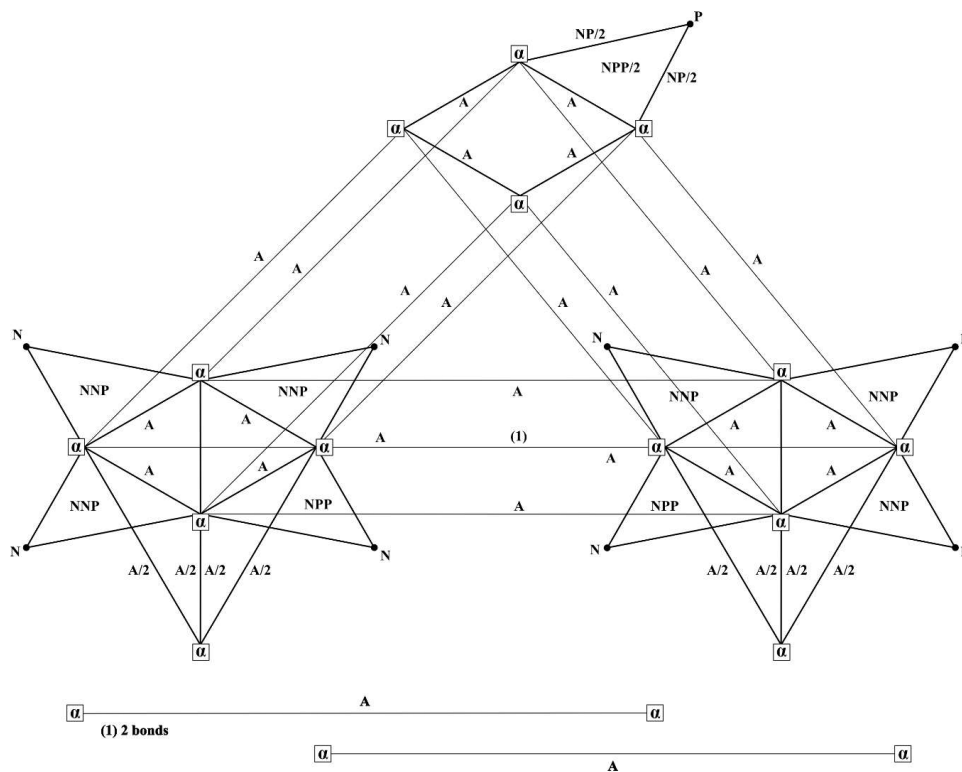
This nucleus is stable. Its structure is comparable to that one of Ni 63 (see former figure).
 Actually, 7A bonds (3.5NN + 3.5NP) + 3.5 NNP bonds are transformed into 7 NPP bonds.

⁶⁵₂₉Cu

Structure: 14 α, 8 N, 1 P supplementary

Linear and cross bonds: 28A

N, P supplementary bonds: 1 NP, 6 NNP, 2.5 NPP



⁶⁵₂₉Cu

14α, 8N, 1P supplementary

EB in MeV = 569.2112

Stable

Nat. abundance: 30.8 %

Core structure

N, P supplementary

{	14	x	28.325	}	396.5500	MeV
	14	x	4.9365		69.1110	
	14	x	2.2246		31.1444	
	0	x	8.4818		0	
{	0	x	7.7180	}	0	
	0	x	4.9365		0	
{	1	x	2.2246	}	2.2246	
	6	x	8.4818		50.8908	
	2.5	x	7.7180		19.2950	
					569.2158	MeV
					+ 0.005	

This nucleus is stable.

CHAPTER 5

ATOMIC NUCLEI BINDING ENERGY: CASE OF ${}_{26}\text{Fe}$ ISOTOPES

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 nucleon clusters, Linus Pauling found that the magic numbers have a very simple structural significance. He assumed that in nuclei the nucleons may, as a first approximation, be described as occupying localized $1s$ orbitals to form small clusters. These small clusters, called spherons, are usually helions (i.e. α particles), tritons and dineutrons. In nuclei containing an odd number of neutrons, an ${}^3\text{He}$ cluster or a deuteron may serve as a spheron. The close-packed-spheron model differs from the conventional liquid-drop model of the nucleus in having spherons rather than nucleons as the units. This enables to determine the systematic of binding energy in a much simpler way than the approach based on individual nucleons. The author developed that idea, i.e. having clusters as basic bricks within the nucleus instead of nucleons. He considered the binding energy of α particle, Deuterium, Tritium, ${}^3\text{He}$, and the way these spherons are bonded instead of the bonding between individual nucleons. According to that hypothesis the nuclei of the various elements are constituted out of α particles and other nucleons grouped in order to form sub-nuclei bound together by four types of bonds called NN, NP, NNP and NPP. So, the author favored an approach trying to breakdown the binding energy value of each element and its isotopes in the sub-values indicated above.

Keywords: Alpha particle, Dineutron (NN), Deuterium (NP), Tritium (NNP), ${}^3\text{He}$ (NPP).

1. Introduction

Several authors [1] predict that α particle structures could be present in atomic nuclei. Convincing arguments of such structures are provided by systematics of the binding energies of the even-even nuclei with equal number of protons and neutrons. A first point to consider concerns the binding energy (EB) of α particle and its relationship with those of Deuterium, Tritium and Helium 3 which are nuclei preexisting that one of Helium4. A second point is to see if and how these three binding energies play a role in the bonds between the α particles, binding a nucleon of an α particle to a nucleon of the second α particle.

So, according to author's theory, the nuclei of the various elements are constituted with α particles and other nucleons grouped in order to create sub-nuclei linked by four types of bonds called NN, NP, NNP, NPP. The binding energies of Deuterium (NP), Tritium (NNP), Helium3 (NPP) and NN are related in the following way:

$$-EB \text{ Tritium (NNP)} = 2NN - 1.25/2 NP$$

$$-EB \text{ He3 (NPP)} = NN + 1.25 NP$$

-2NN forming the neutronic part of the binding energy of α particle (see chapter 2).

According to author's hypothesis the binding energy of every nucleus is the sum of the binding energy of its different sub-structures and the binding energy among these sub-structures.

The examples shown in the present article are the various isotopes of Iron: ${}_{26}\text{Fe}$.

2. Values used for the calculation of the binding energy.

$EB \alpha$	=	28.325 MeV	
$EB NN$	=	4.9365 MeV =	8.875 lines
$EB NP (= {}^2_1H)$	=	2.2246 MeV =	4 lines
$EB NNP (= {}^3_1H)$	=	8.4818 MeV =	15.25 lines
$EB NPP (= {}^3_2He)$	=	7.7180 MeV =	13.875 lines

} One line is equal to 0.5561589 MeV

NN and NP are the most used bonds. Generally, they oscillate to form an “A” (A for average) bond equal to $(NN/2 + NP/2)$.

3. Basic rule for determining the nuclei binding energy.

3.1. The author’s theory:

- The calculation of binding energy of the stable light elements satisfies the following rule:
 $EB_n = x EB_\alpha + x EB (NN/2 + NP/2) + y EB (NN + NP)$
 (x = number of α particles, y = number of N and P supplementary within a given nucleus).
- The basic rule valid for the stable elements located at the center of the periodic table, is:
 $EB_n = x EB_\alpha + (x + y) EB (NN + NP)$ This is the case for Iron.
 One should note that $(NN + NP)$ bonds could be replaced by NNP or NPP bonds which have a higher energy value. As well, some bonds are not completed, $(NN/2 + NP/2)$ being replaced by NP. This happens in the case of non-stable isotopes of an element.
- The rule for the heaviest nuclei is close to the first formulation, valid for the light elements.

3.2. The constraints:

Each α particle is linked linearly to another α particle with one A bond. Also, each α particle is linked transversally to another α particle with one A bond. So, ${}_{26}Fe$ has 13 A linear bonds and 13 A cross bonds. Nevertheless, A bonds could be replaced by NP, NN, NNP and NPP bonds.

The N supplementary are linked to two α particles by $(NP + NN)$ bonds or by NNP or NPP bonds.

The P supplementary is linked by NP or NPP bonds, exceptionally by an NNP bond, to one or two α particles.

3.3. Remark:

Geometrical structure of atomic nuclei.

In author’s theory the binding energy of the nuclei has a unidimensional value, broken down by EB_α , NN, NP, NNP, NPP. So, this work does not address the three-dimensional model of nuclei in the sense that it is not looking for a structure of these nuclei but rather for the distribution of binding energy among them. Nevertheless, a comparison with 3D nuclei models is attempted in this article showing the various isotopes of ${}_{26}Fe$ behaving like crystals with stationary configuration and shape, and with defined bond values between the various α particles and other sub-nuclei.

4. Binding energy distribution among $^{52}_{26}\text{Fe}$ to $^{61}_{26}\text{Fe}$

Table 1. Binding energy (EB) distribution for $^{52}_{26}\text{Fe}$ to $^{61}_{26}\text{Fe}$.

Nucleus	Structure	Status	EB Core				EB N, P supplementary				Difference with the basic rule, in lines		
			NN	NP	NNP	NPP	NN	NP	NNP	NPP	Total of lines	Average	Difference
$^{52}_{26}\text{Fe}$	13 α	Lifetime: 8.2 hours	5	17	2	0					142.8750	167.3750 = 26 A	- 24.5000
	0 N, 0 P	Mode of decay: β^+ , EC					0	0	0	0	0	0	/
$^{53}_{26}\text{Fe}$	13 α	Lifetime: 8.5 min	1	13	3	3					148.2500	167.3750 = 26A	- 19.1250
	1 N, 0 P	Mode of decay: β^+ , EC					0	0	0	1	13.8750 = NPP	12.8750 = 2A	+ 1.0000
$^{54}_{26}\text{Fe}$	13 α	Stable	12	12	0	1					168.3750	167.3750 = 26A	+ 1.0000
	2 N, 0 P	Nat. abundance: 5.8%					2	0	0	0	17.7500 = 2 NN	25.7500 = 4A	- 8.0000
$^{55}_{26}\text{Fe}$	13 α	Lifetime: 2.6 years	14	12	0	0					172.2500	167.3750 = 26A	+ 4.8750
	3 N, 0 P	Mode of decay: EC					3	1	0	0	30.6250 = 3 NN + 1 NP	38.6250 = 6A	- 8.0000
$^{55}_{26}\text{Fe}$ Second figure	13 α	Lifetime: 2.6 years	14	10	0	0					164.2500	167.3750 = 26A	- 3.1250
	3 N, 0 P	Mode of decay: EC					3	3	0	0	38.6250 = 6A	38.6250 = 6A	/

		EB Core				EB N, P supplementary				Difference with the basic rule, in lines			
Nucleus	Structure	Status	NN	NP	NNP	NPP	NN	NP	NNP	NPP	Total of lines	Average	Difference
$^{55}_{25}\text{Mn}$	12 α	Stable	14	10	0	0					164.2500	154.5000 = 24A	+ 9.7500
	6 N, 1 P	Nat. abundance: 100%					0	1	3	3	91.3750 = 1 NP + 3 NNP + 3 NPP	91.1250 = 12A + NPP	+ 0.2500
$^{55}_{25}\text{Mn}$ Second figure	12 α	Stable	12	12	0	0					154.5000	154.5000 = 24A	/
	6 N, 1 P	Nat. abundance: 100%					0	0.5	6.5	0	101.1250 = 6.5 NNP + 0.5 NP	91.1250 = 12A + NPP	+ 10.0000
$^{55}_{25}\text{Mn}$ Third figure	12 α	Stable	12	12	0	0					154.5000	154.5000 = 24A	/
	6 N, 1 P	Nat. abundance: 100%					0	1	0	7	101.1250 = NP + 7 NPP	91.1250 = 12A + NPP	+ 10.0000
$^{55}_{25}\text{Mn}$ Fourth figure	12 α	Stable	8	8	0	4					158.5000	154.5000 = 24A	+ 4.0000
	6 N, 1 P	Nat. abundance: 100%					0	0	0	7	97.1250 = 7 NPP	91.1250 = 12A + NPP	+ 6.0000
$^{56}_{26}\text{Fe}$	13 α	Stable	13	13	0	0					167.3750	167.3750 = 26A	/
	4 N, 0 P	Nat. abundance: 91.8%					3.5	2.5	0.5	0.5	55.6250 = 5A + NN + NNP/2 + NPP/2	51.5000 = 8A	+ 4.1250

		EB Core				EB N, P supplementary				Difference with the basic rule, in lines			
Nucleus	Structure	Status	NN	NP	NNP	NPP	NN	NP	NNP	NPP	Total of lines	Average	Difference
$^{56}_{26}\text{Fe}$ Second figure	13 α	Stable	7	9	0	5					167.5000	167.3750 = 26A	+ 0.1250
	4 N, 0 P	Nat. abundance: 91.8%					0	0	0	4	55.5000 = 4 NPP	51.5000 = 8A	+ 4.0000
$^{57}_{26}\text{Fe}$	13 α	Stable	13	13	0	0					167.3750	167.3750 = 26A	/
	5 N, 0 P	Nat. abundance: 2.1%					0	0	0	5	69.3750 = 5 NPP	64.3750 = 10A	+ 5.0000
$^{58}_{26}\text{Fe}$	13 α	Stable	13	13	0	0					167.3750	167.3750 = 26A	/
	6 N, 0 P	Nat. abundance: 0.3%					1.5	0.5	2	3	87.4375 = A + NN + 2 NNP + 3 NPP	77.2500 = 12A	+ 10.1875
$^{59}_{26}\text{Fe}$	13 α	Lifetime: 45.1 days	13	13	0	0					167.3750	167.3750 = 26A	/
	7 N, 0 P	Mode of decay: β^-					2	2	3	2	99.2500 = 4A + 3 NNP + 2 NPP	90.1250 = 14A	+ 9.1250
$^{59}_{27}\text{Co}$	13 α	Stable	13	13	0	0					167.3750	167.3750 = 26A	/
	6 N, 1 P	Nat. abundance: 100%					3.5	2.5	3	1	100.6875 = 5A + NN + 3 NNP + NPP	91.1250 = 12A + NPP	+ 9.5625

		EB Core				EB N, P supplementary				Difference with the basic rule, in lines			
Nucleus	Structure	Status	NN	NP	NNP	NPP	NN	NP	NNP	NPP	Total of lines	Average	Difference
$^{59}_{27}\text{Co}$ Second figure	13 α	Stable	12	12	1	0					169.7500	167.3750 = 26A	+ 2.3750
	6 N, 1 P	Nat. abundance: 100%					0	1	3	3.5	98.3125 = NP + 3 NNP + 3.5 NPP	91.1250 = 12A + NPP	+ 7.1875
$^{60}_{26}\text{Fe}$	13 α	Lifetime: 3×10^5 years	13	13	0	0					167.3750	167.3750 = 26A	/
	8 N, 0 P	Mode of decay: β^-					0	0	3	5	115.1250 = 3 NNP + 5 NPP	103.0000 = 16A	+ 12.1250
$^{61}_{26}\text{Fe}$	13 α	Lifetime: 6 min	13	13	0	0					167.3750	167.3750 = 26A	/
	9 N, 0 P	Mode of decay: β^-					2.5	2.5	2	4.5	125.1250 = 5A + 2 NNP + 4.5 NPP	115.8750 = 18A	+ 9.2500

5. Analysis of table 1.

- 5.1.** The zone of stability stretches from - 7 lines (^{54}Fe) to + 10.1875 (^{58}Fe)
The most abundant isotope is ^{56}Fe with + 4.125 lines.
- 5.2.** Number of N supplementary.
The isotopes which are stable contain 2N, 4N, 5N, 6N.
 ^{55}Fe with 3 N supplementary is not stable but has a high lifetime.
 ^{60}Fe with 8 N supplementary has a very high lifetime.
- 5.3.** The presence of N supplementary has as consequence the increase of the value of the binding energy of a given nucleus:
- 24. 5000 lines in case of ^{52}Fe which has no N supplementary.
+ 10.1875 lines for ^{58}Fe
+ 12.1250 lines for ^{60}Fe
But + 9.25 lines for ^{61}Fe
- 5.4.** As a consequence of the increasing number of N supplementary there is a progressive increase of NN bonds versus NP ones in order to achieve a maximum of parity between both bonds to create as many A bonds as locations (26 in case of ^{26}Fe).
- 5.5.** ^{52}Fe (see table and figure 1 in the appendices).
There are 26 linear and cross-bonds, but only 10A bonds (instead of 26) linking the α particles on the top and the bottom of the structure. Also, 2 NNP are replacing 4A bonds. The cross-bonds are of NP type. Actually, there are some bonds missing in order to achieve the shape of the structure. The table indicates a deficit of 24.5 lines. The structure cannot be stable until the linear and cross-bonds are of A type, hence the EC and β^+ decay.
- 5.6.** ^{53}Fe (see table and figure 2).
This structure is similar to that one for ^{52}Fe .
Nevertheless, more linear bonds are of NNP and NPP type. There is a deficit of 19.125 lines in the core which shows that the presence of one N supplementary has occurred an increase of the number of lines: + 5.375 in the core of the structure if compared with ^{52}Fe . This structure is not stable for the same reasons than ^{52}Fe .
- 5.7.** ^{54}Fe (see table and figure 3).
The core of this structure is almost perfectly shaped, hence its stability. The 2 supplementary N are bound to the core with each 1 NN bond. Even if there is a global deficit of 7 lines, it allows the structure to be stable. The NPP bond on the top and the 2 NN bonds of the 2 N supplementary are interchangeable to assume stability.
- 5.8.** ^{55}Fe (see table and figures 4 and 5).
This structure is comparable to ^{54}Fe . Nevertheless, to achieve the bonding of the 3 N supplementary it is necessary to use at minimum 6A bonds (3 x 2A). The 2 NN bonds on the top of the structure and the 2 NN bonds of the 2 N supplementary are interchangeable. Nevertheless, if one wants to interchange the 3 N supplementary bonds with the structure of the top, the result is 6A bonds for the 3 N supplementary and 4 NN bonds for the top of the structure. As result there is no more bonds between the α particle on the top and the other 4 α particles (see figure 5). This leads to an α particle without bonding and so, to EC or to β^+ decay. The α particle splits into 3 N and 1 P (see figure 6).
- 5.9.** ^{55}Mn (see table and figure 6).
Compared to ^{55}Fe (see figure 5), the 3 N supplementary are bonded with 3 NPP instead of 3 x 2A bonds. The 3 N and 1 P issued from the splitting of α particle on the top of the structure are bonded with 3 NNP and 1 NP to the 4 α particles sub-structure.

- 5.10.** ⁵⁵Mn second figure (see table and figure 7).
The structure on the figure 6 is not stable and a rearrangement is necessary. Instead of 4 NN bonds linking the 3 N and the P to the top structure of figure 6, there are 4A on the figure 7. Moreover, the P is bonded with the 3 N and no longer with the α particles. It is now bonded alternately to 2 N (NNP/2) and to 1 N (NP/2). As a consequence, the 3 NPP bonds of the 3 N supplementary on the bottom of the structure become NNP bonds.
- 5.11.** ⁵⁵Mn third figure (see table and figure 8)
There are other rearrangements within ⁵⁵Mn. Now, the 6 N supplementary are linked to the α particles with 6 NPP bonds. The P supplementary is also linked to α particles with 1 NPP bond and linked to two N supplementary with 2 NP/2 bonds. Nevertheless, this last link is creating one NP bond supplementary to the 14 (7 NPP) necessary.
- 5.12.** ⁵⁵Mn fourth figure (see table and figure 9)
So, this NP bond supplementary, of value 4 lines is distributed between the 8A cross bonds, which become 4 NPP bonds. The number of bonds in the core is 24 and that one of the N and P supplementary is 14.
- 5.13.** ⁵⁶Fe (see table and figure 10)
The linear and cross bonds are equal to 26A. This configuration is the best possible. The 4 N are linked to the α particles with 5A, NN, NNP/2 and NPP/2 bonds.
- 5.14.** ⁵⁶Fe second figure (see table and figure 11)
To avoid the unevenness on the preceding structure, one can distribute the bonds in the way presented on figure 11. The interchangeability between the structures on figures 10 and 11 are creating more stability.
- 5.15.** ⁵⁷Fe (see table and figure 12)
The ⁵⁷Fe core structure is perfect. The 5 N supplementary are linked to the α particles with 5 NPP bonds which is an odd number. Nevertheless, the structure is stable.
- 5.16.** ⁵⁸Fe (see table and figure 13)
The core structure is perfect, the 6 N supplementary are being linked to the α particles with A, NN, 2 NNP, 3 NPP bonds. In order to have 6 NPP bonds for the 6 N supplementary the number of lines in the core should be increased with 4.1875 lines. This would mean 19A, 3 NPP and NNP/2 bonds in the core instead of 26A bonds.
- 5.17.** ⁵⁹Fe (see table and figure 14)
The core structure of ⁵⁹Fe is perfectly shaped, like for ⁵⁸Fe. Nevertheless, there are 7 N supplementary and an excess of 9.125 lines. This configuration leads to β^- decay.
- 5.18.** ⁵⁹Co (see table and figures 15 and 16)
⁵⁹Co is the decay result of ⁵⁹Fe, 1 N supplementary decaying into P, the bond remaining the same (NPP). One bond of another N supplementary is consequently modified from NPP to (NN + A) bonds (see figure 15). After rearrangement, the structure looks like on figure 16.
- 5.19.** ⁶⁰Fe (see table and figure 17)
⁶⁰Fe structure is not stable but has a long lifetime. Nevertheless, the core structure is stable (26A) and there are 8 N supplementary linked to the α particles with 5 NPP and 3 NNP. Note the similarity with ⁵⁷Fe. Both ⁵⁷Fe and ⁶⁰Fe have a core structure with 26A. ⁵⁷Fe has 5 N supplementary linked to α particles with 5 NPP as well as ⁶⁰Fe, but ⁶⁰Fe has 3 N supplementary more linked to α particles with 3 NNP bonds.

Let us take the EB of both isotopes (Ame 2016):

^{57}Fe	^{60}Fe	Difference
499.9059 MeV	525.3511 MeV	25.4452 MeV
This difference is equal to 3 x 8.4817 MeV or 3 NNP		

5.20. ^{61}Fe (see table and figure 18)

^{61}Fe is comparable to the structure ^{60}Fe . Nevertheless, the N supplementary are too numerous. So, 1 N decays rapidly into P.

6. The method of calculation.

6.1. Mind experiments

The author makes mind experiments, having the choice between only a few bonds each time a new neutron or proton is entering a nucleus. So, he chooses that one which fits. This way is comparable to the work of a chemist looking for several solutions in his experiments and validating that one which fits best. Moreover, the author is looking at the compliance of the solution for one nucleus with the solution for another nucleus in order to avoid discrepancies, especially between isotopes. The author also takes care of symmetry within a given nucleus and between nuclei. Indeed, this work is not addressing the three-dimensional model of nuclei but rather the distribution of binding energy among them. So, this work could be complementary to those dealing with this topic. A comparison with 3D nuclei models could be relevant, as attempted in this paper.

6.2. Examples of calculation for $^{55}_{25}\text{Mn}$, $^{59}_{27}\text{Co}$, $^{63}_{29}\text{Cu}$.

According to the general rule (see point 3.1) the binding energy of these three nuclei should be the following:

Table 2. Binding energy values among $^{55}_{25}\text{Mn}$, $^{59}_{27}\text{Co}$ and $^{63}_{29}\text{Cu}$.

	$^{55}_{25}\text{Mn}$: 12 α , 6 N, 1 P		$^{59}_{27}\text{Co}$: 13 α , 6 N, 1 P		$^{63}_{29}\text{Cu}$: 14 α , 6 N, 1 P	
α EB	EB 12 α	339.9000	EB 13 α	368.2250	EB 14 α	396.5500
Core EB	12 (NN+NP)	85.9332	13 (NN+NP)	93.0943	14 (NN+NP)	100.2554
N suppl. EB	6 (NN+NP)	42.9666	6 (NN+NP)	42.9666	6 (NN+NP)	42.9666
P suppl. EB	NPP	7.7180	NPP	7.7180	NPP	7.7180
Total (MeV)		476.5178		512.0039		547.4900

Experimental values of the binding energy of the three nuclei minus totals determined:

$^{55}_{25}\text{Mn}$: 482.0762 MeV (Ame 2016 value) - 476.5178 MeV = 5.5584 MeV or 10 lines (for value of lines see point 2).

$^{59}_{27}\text{Co}$: 517.3141 MeV (Ame 2016 value) - 512.0039 MeV = 5.3102 MeV or 9.5625 lines.

$^{63}_{29}\text{Cu}$: 551.3847 MeV (Ame 2016 value) - 547.4900 MeV = 3.8947 MeV or 7 lines.

So, these lines have to be added to the former calculations (see table 2).

Results:

$^{55}_{25}\text{Mn}$: 24A (12 NN + 12 NP) + 4 lines = 16A + 4 NPP (see figure 9).
 12A (6 NN + 6 NP) + 6 lines = 6 NPP
 NPP = NPP

$^{59}_{27}\text{Co}$: 26A (13 NN + 13 NP) = 26A (see figure 15).
 12A (6 NN + 6 NP) + 9.5625 lines = 5A + NN + 3 NNP
 NPP = NPP

$^{59}_{27}\text{Co}$: Alternative solution:
 26A (13 NN + 13 NP) + 2.375 lines = 24A + NNP (see figure 16).
 12A (6 NN + 6 NP) + 10.1250 lines = 3 NNP + 3 NPP
 NPP - 2.9375 lines = NP + NPP/2
 (2.375 + 10.125 - 2.9375 = 9.5625 lines)

$^{63}_{29}\text{Cu}$: 28A (14 NN + 14 NP) + 7 lines = 14A + 7 NPP (no figure, see chapter 6).
 12A (6 NN + 6 NP) = 12A
 NPP = NPP

6.3. Decay of $^{63}_{28}\text{Ni}$ into $^{63}_{29}\text{Cu}$.

$^{63}_{28}\text{Ni}$ decays β^- into $^{63}_{29}\text{Cu}$. See below (table 3) their respective binding energy structure according to the author's theory.

Table 3. Comparison of binding energy distribution among $^{63}_{28}\text{Ni}$ and $^{63}_{29}\text{Cu}$.

$^{63}_{28}\text{Ni}$	14 α , 7N supplementary EB in MeV = 552.1001 Lifetime: 92 years Mode of decay: β^-	$^{63}_{29}\text{Cu}$	14 α , 6N, 1P supplementary EB in MeV = 551.3847 Stable Nat. abundance: 69.2 %
$\left\{ \begin{array}{l} 14 \text{ x } 28.325 \\ 10.5 \text{ x } 4.9365 \\ 10.5 \text{ x } 2.2246 \\ 3.5 \text{ x } 8.4818 \\ 0 \text{ x } 7.7180 \end{array} \right\}$	396.5500 MeV	$\left\{ \begin{array}{l} 14 \text{ x } 28.325 \\ 7 \text{ x } 4.9365 \\ 7 \text{ x } 2.2246 \\ 0 \text{ x } 8.4818 \\ 7 \text{ x } 7.7180 \end{array} \right\}$	396.5500 MeV
$\left\{ \begin{array}{l} 6 \text{ x } 4.9365 \\ 6 \text{ x } 2.2246 \\ 0 \text{ x } 8.4818 \end{array} \right\}$	29.6190 13.3476 0	$\left\{ \begin{array}{l} 6 \text{ x } 4.9365 \\ 6 \text{ x } 2.2246 \\ 0 \text{ x } 8.4818 \end{array} \right\}$	29.6190 13.3476 0
$\left\{ \begin{array}{l} 1 \text{ x } 7.7180 \end{array} \right\}$	7.7180	$\left\{ \begin{array}{l} 1 \text{ x } 7.7180 \end{array} \right\}$	7.7180
	<u>552.1125</u> MeV + 0.012		<u>551.3883</u> MeV + 0.004

Comparing the two calculation results one notes the following:

(3.5 NN + 3.5 NP + 3.5 NNP) of $^{63}_{28}\text{Ni}$ have decayed into 7 NPP of $^{63}_{29}\text{Cu}$.

In other terms (7 NN + 7 NP + 7 NNP) / 2 decayed into 7 NPP.

So, the (NN + NP) bonds and NNP bonds which alternate within $^{63}_{28}\text{Ni}$ decay into NPP bonds within $^{63}_{29}\text{Cu}$.

Consequently, one N supplementary of $^{63}_{28}\text{Ni}$ decays into one P to create $^{63}_{29}\text{Cu}$

7. Conclusion.

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

Basically, only five bond types are necessary to describe the systematics of the binding energy within the nuclei: the binding energy of α particle, of NN which is part of α particle binding energy, NP (Deuterium binding energy), NNP (Tritium binding energy), and NPP (${}^3\text{He}$ binding energy).

Each element needs to reach its stability point which is determined by a certain number of lines per nucleus. Each α particle is linked to two other α particles in a linear way and in a cross way. As well, each N supplementary is linked to two α particles by (NN + NP) bonds. These bonds could be replaced by NNP or NPP bonds. So, the stability of a nucleus is reached if the number of lines is optimal. If the number of lines is not important enough the nucleus decays EC or β^+ , if the number of lines is too important the nucleus decays β^- . The valley of stability is reached when the binding energy value of the nucleus is located between +/- 1% of its experimental value. Also, the number of N supplementary is important for the stability of the nucleus. In the case of Iron, this number stretches from 2 N to 6 N supplementary with a peak at 4 N (${}_{26}^{56}\text{Fe}$). The increase of N supplementary number allows for the increase of lines number within the nucleus and so for its stability. Nevertheless, if this lines number is too big, the β^- decay occurs.

Reference

[1] L. Pauling, *Science* **150** (1965) d 297. K. Ikeda, N. Takigawa and H. Horiuchi, *Prog. Theor. Phys. Suppl.* (1968) E 464.

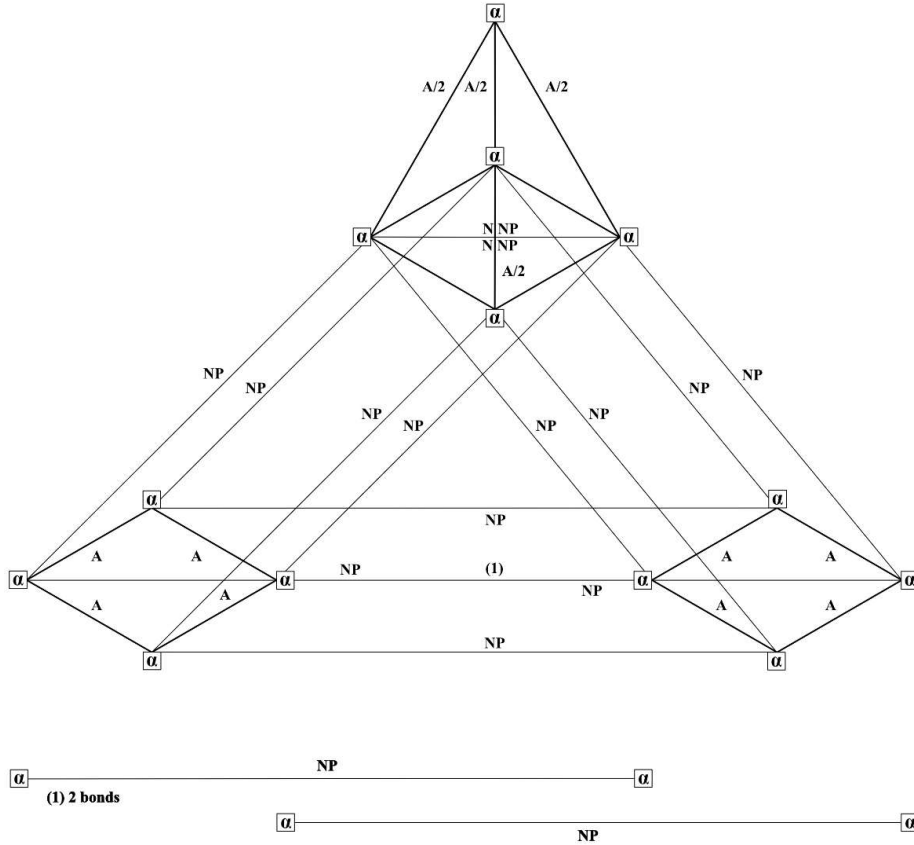
Appendices

$^{52}_{26}\text{Fe}$

Structure: 13 α , 0 N, 0 P

Linear and cross bonds: 10A, 12 NP, 2 NNP

N supplementary bonds: 0



$^{52}_{26}\text{Fe}$

13 α , 0N, 0P supplementary

EB in MeV = 447.6978

Lifetime: 8.2 hours
Mode of decay: β^+ , EC

13	x	28.3250	}	368.2250	MeV
(6.5-1.5)	x	4.9365		24.6825	
(6.5+10.5)	x	2.2246		37.8182	
2	x	8.4818		16.9636	
0	x	7.7180	}	0	
0	x	4.9365		0	
0	x	2.2246	}	0	
0	x	8.4818		0	
0	x	7.7180		0	
				447.6893	MeV
				- 0.009	

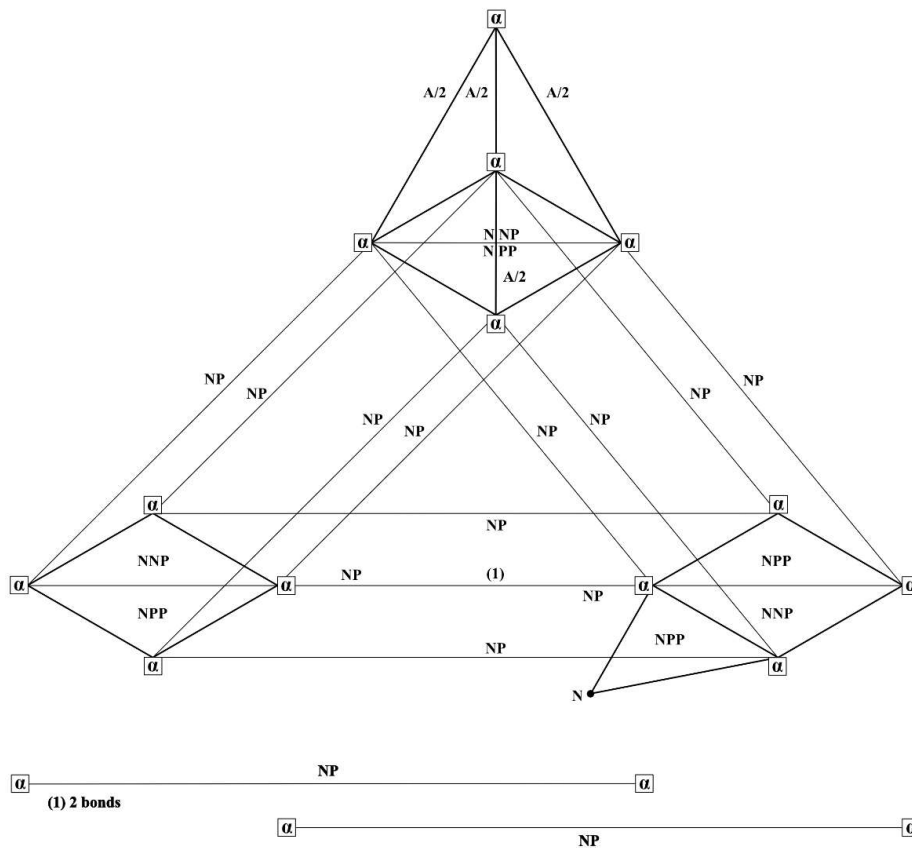
Figure 1. Binding energy distribution among ^{52}Fe .

⁵³₂₆Fe

Structure: 13 α, 1 N, 0 P

Linear and cross bonds: 2A, 12 NP, 3 NNP, 3 NPP

N supplementary bond: NPP



⁵³₂₆Fe

13α, 1N, 0P supplementary

EB in MeV = 458.3863

Lifetime: 8.5 min.

Mode of decay: β⁺, EC

$\left\{ \begin{array}{l} 13 \\ (6.5-5.5) \\ (6.5+6.5) \\ 3 \\ 3 \\ 0 \\ 0 \\ 0 \\ 1 \end{array} \right.$	x	28.3250	$\left. \begin{array}{l} 368.2250 \\ 4.9365 \\ 28.9198 \\ 25.4454 \\ 23.1540 \\ 0 \\ 0 \\ 0 \\ 7.7180 \end{array} \right\}$	MeV	
	x	4.9365		4.9365	
	x	2.2246		28.9198	
	x	8.4818		25.4454	
	x	7.7180		23.1540	
	x	4.9365		0	
	x	2.2246		0	
	x	8.4818		0	
	x	7.7180		7.7180	
				458.3987	MeV
		+ 0.012			

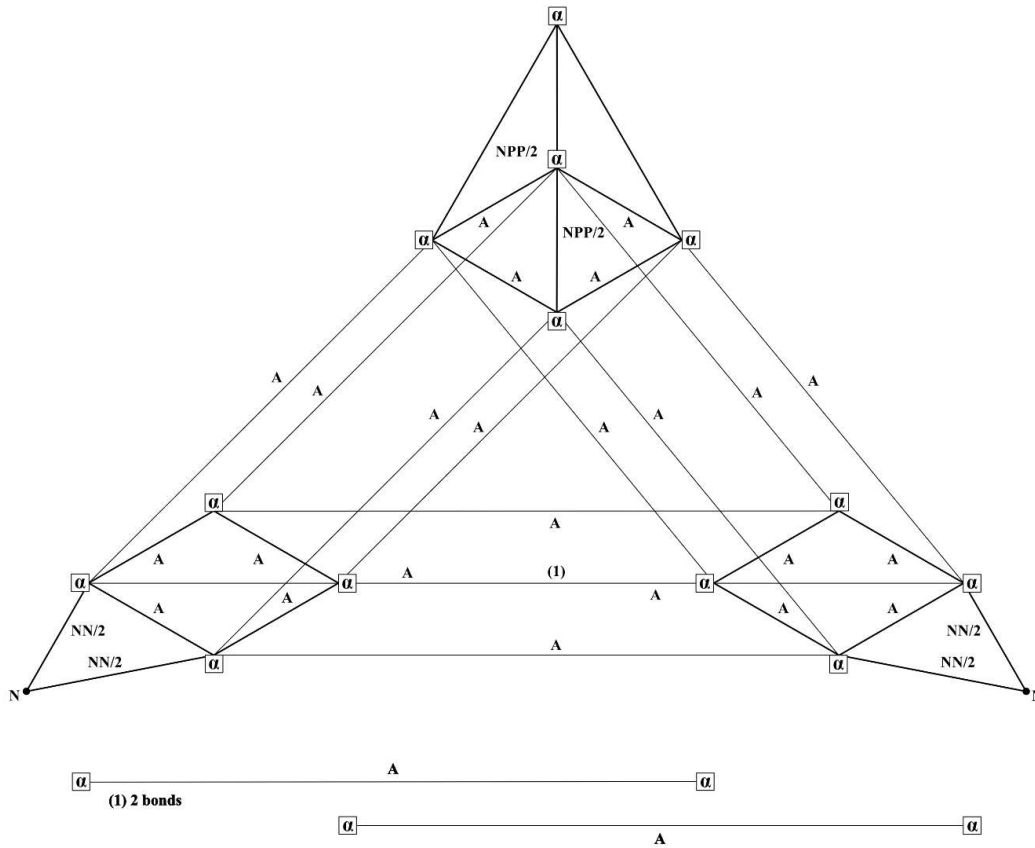
Figure 2. Binding energy distribution among ⁵³Fe.

⁵⁴₂₆Fe

Structure: 13 α, 2 N, 0 P

Linear and cross bonds: 24A, NPP

N supplementary bonds: 2 NN



⁵⁴₂₆Fe

13α, 2N, 0P supplementary

EB in MeV = 471.7646

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+5.5) \\ (6.5+5.5) \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \end{array} \right.$	368.2250	MeV
Nat. abundance: 5.8%				$\left\{ \begin{array}{l} 0 \\ 1 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \end{array} \right.$
	$\left\{ \begin{array}{l} 2 \\ 0 \\ 0 \\ 0 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	9.8730	0
				0	0
				0	0
				0	0
				0	0
				471.7492	MeV
				- 0.015	

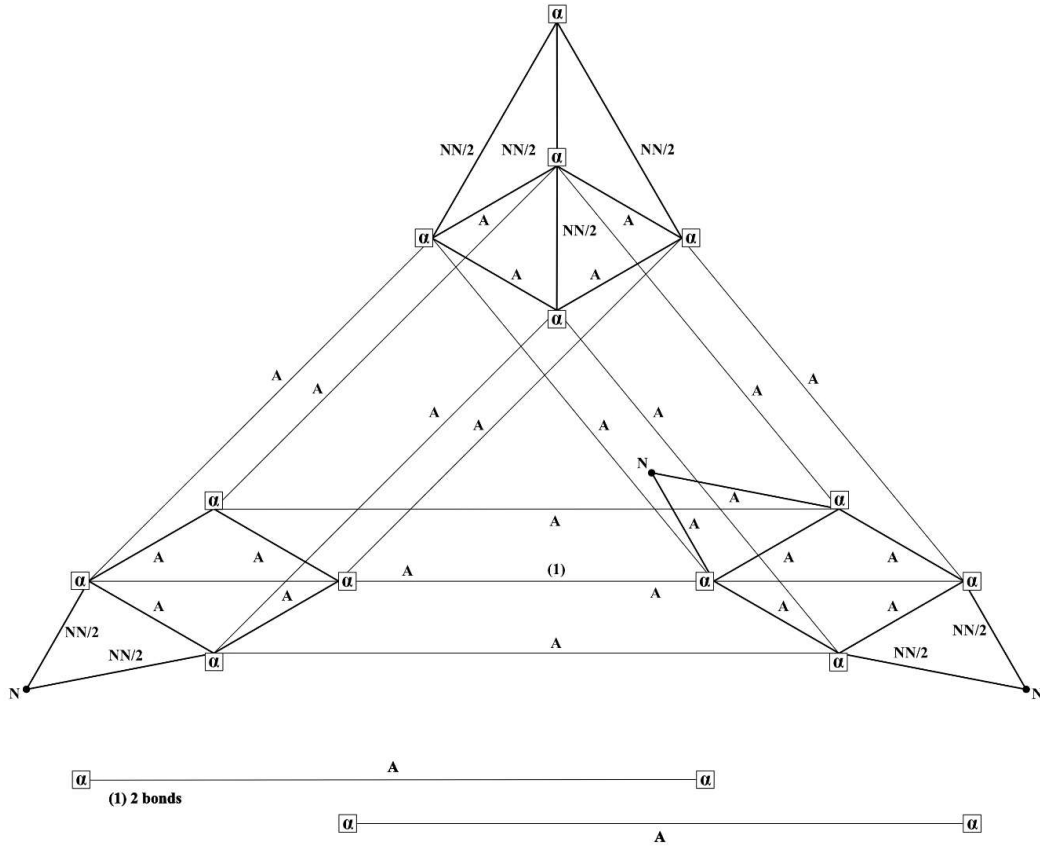
Figure 3. Binding energy distribution among ⁵⁴Fe.

⁵⁵₂₆Fe

Structure: 13 α, 3 N, 0 P

Linear and cross bonds: 24A, 2 NN

N supplementary bonds: 2A, 2 NN



⁵⁵₂₆Fe

13α, 3N, 0P supplementary

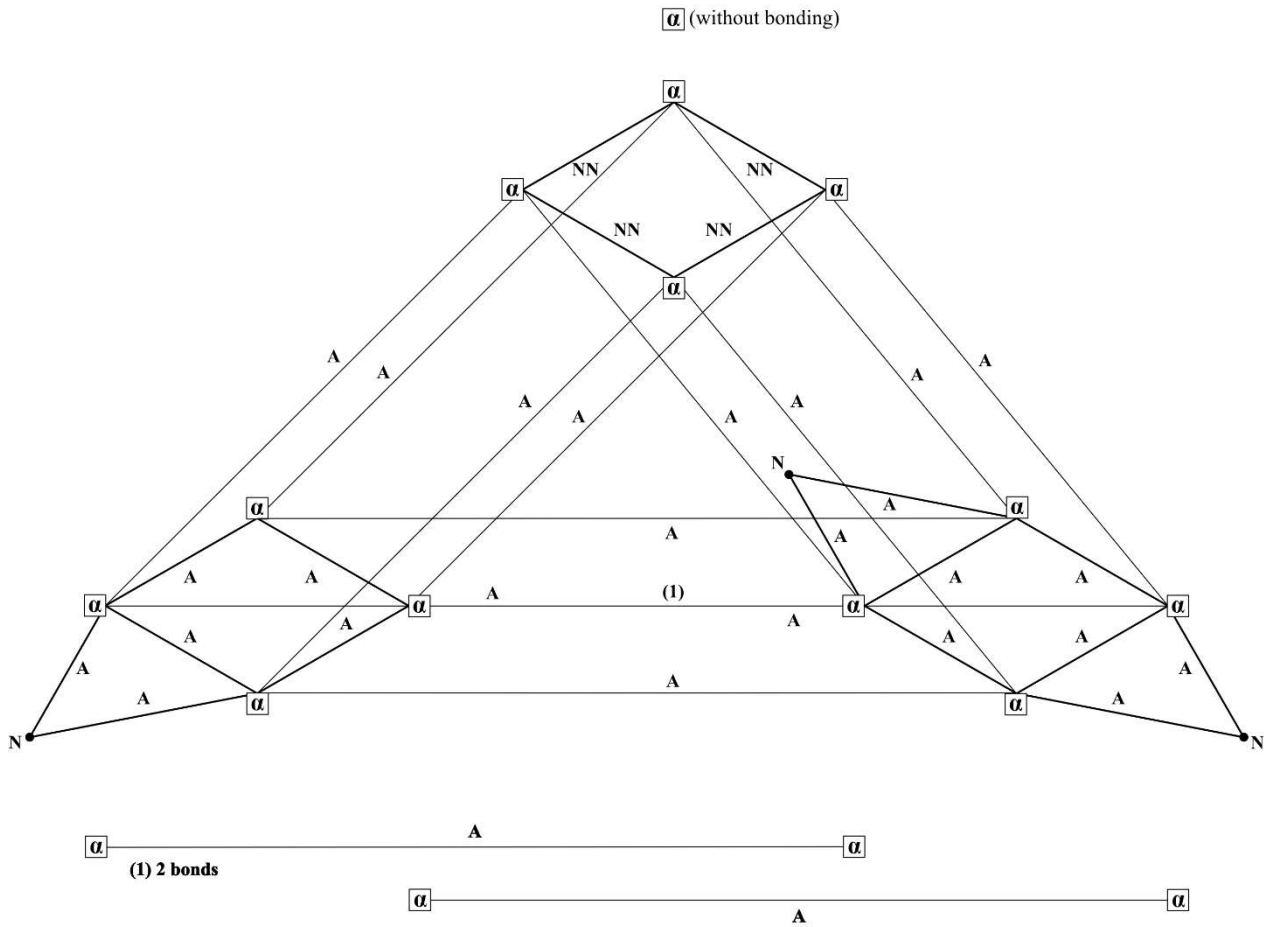
EB in MeV = 481.0627

Lifetime: 2.6 years
Mode of decay: EC

$\left\{ \begin{array}{l} 13 \\ (6.5+7.5) \\ (6.5+5.5) \\ 0 \\ 0 \end{array} \right\}$	x	28.3250	$\left. \begin{array}{l} 368.2250 \\ 69.1110 \\ 26.6952 \\ 0 \\ 0 \end{array} \right\}$	MeV	
	x	4.9365			
	x	2.2246			
	x	8.4818			
	x	7.7180			
	$\left\{ \begin{array}{l} 3 \\ 1 \\ 0 \\ 0 \end{array} \right\}$	x	4.9365	$\left. \begin{array}{l} 14.8095 \\ 2.2246 \\ 0 \\ 0 \end{array} \right\}$	MeV
		x	2.2246		
		x	8.4818		
		x	7.7180		
				481.0653	MeV
			+ 0.003		

Figure 4. Binding energy distribution among ⁵⁵Fe.

⁵⁵₂₆Fe second figure
 Structure: 13 α, 3 N, 0 P
 Linear and cross bonds: 20A, 4 NN
 N supplementary bonds: 6A



⁵⁵₂₆Fe second figure

13α, 3N, 0P supplementary

EB in MeV = 481.0627

Lifetime: 2.6 years
 Mode of decay: EC

$\left\{ \begin{array}{l} 13 \\ (6.5+7.5) \\ (6.5+3.5) \\ 0 \\ 0 \\ 3 \\ 3 \\ 0 \\ 0 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	368.2250	MeV
			69.1110	
			22.2460	
			0	
			0	
			14.8095	
			6.6738	
			0	
			0	
		+ 0.003		

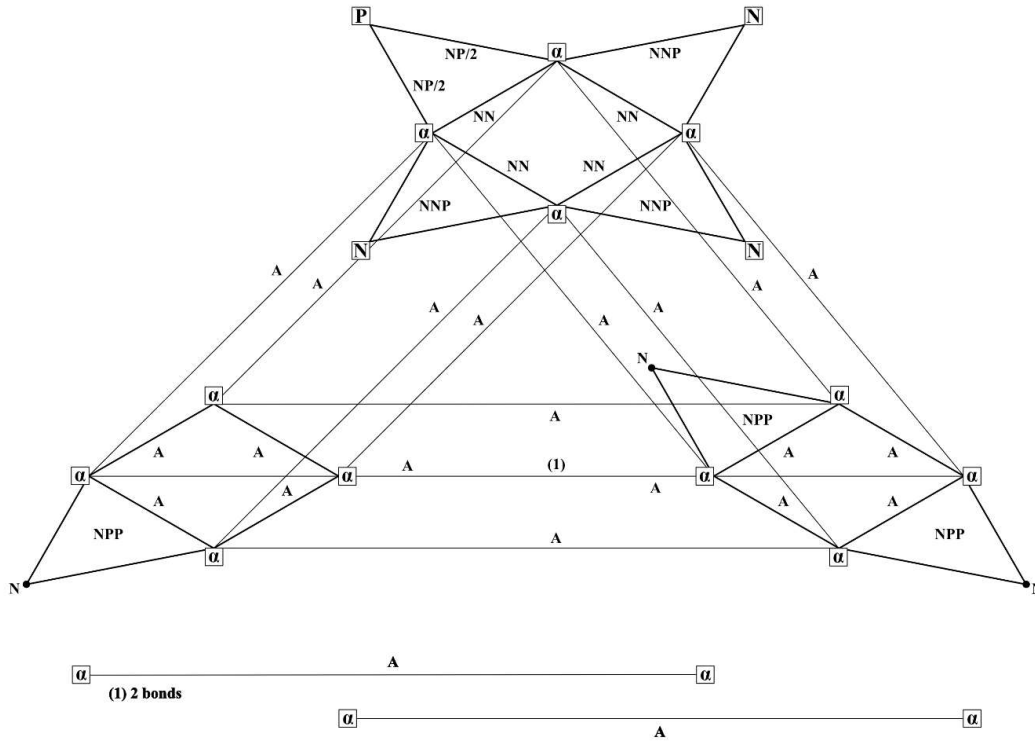
Figure 5. Binding energy distribution among ⁵⁵Fe second figure.

⁵⁵₂₅Mn

Structure: 12 α, 6 N, 1 P

Linear and cross bonds: 20A, 4 NN

N, P supplementary bonds: NP, 3 NNP, 3 NPP



⁵⁵₂₅Mn

12α, 6N, 1P supplementary

EB in MeV = 482.0762

Stable	$\left\{ \begin{array}{l} 12 \\ (6.5+7.5) \\ (6.5+3.5) \\ 0 \\ 0 \\ 0 \\ 1 \\ 3 \\ 3 \end{array} \right\} \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	339.9000	MeV
Nat. abundance: 100%		69.1110	
		22.2460	
		0	
		0	
		0	
		2.2246	
	25.4454		
	23.1540		
		482.0810	MeV
		+ 0.005	

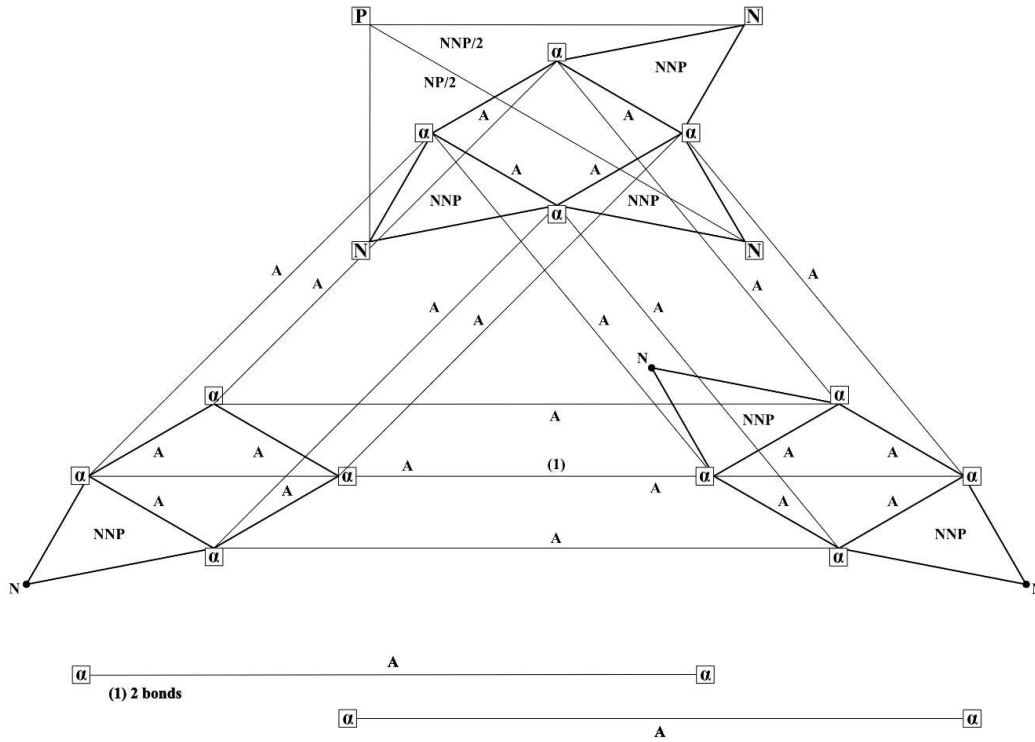
Figure 6. Binding energy distribution among ⁵⁵Mn.

⁵⁵₂₅Mn second figure

Structure: 12 α, 6 N, 1 P

Linear and cross bonds: 24A

N, P supplementary bonds: NP/2, 6.5 NNP



⁵⁵₂₅Mn second figure

12α, 6N, 1P supplementary

EB in MeV = 482.0762

Stable	$\left\{ \begin{array}{l} 12 \\ (6+6) \\ (6+6) \\ 0 \\ 0 \\ 0 \\ 0.5 \\ 6.5 \\ 0 \end{array} \right\} \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	339.9000	MeV
Nat. abundance: 100%		59.2380	
		26.6952	
		0	
		0	
		0	
		1.1123	
		55.1317	
	0		
	482.0772	MeV	
	+ 0.001		

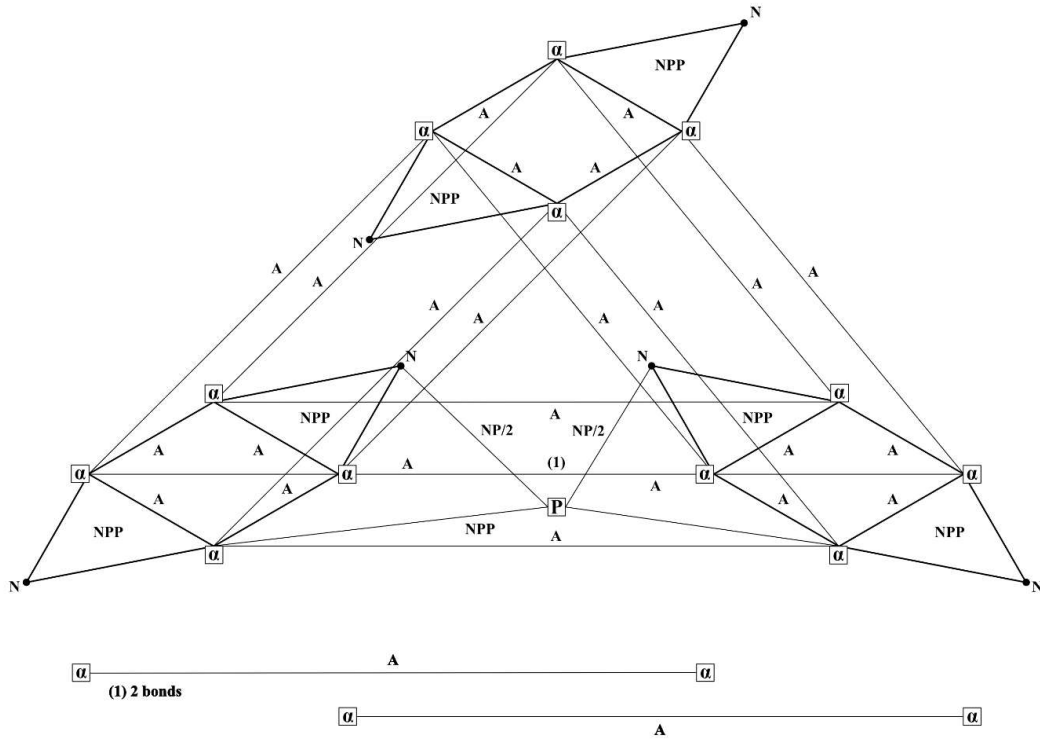
Figure 7. Binding energy distribution among ⁵⁵Mn second figure.

⁵⁵₂₅Mn third figure

Structure: 12 α, 6 N, 1 P

Linear and cross bonds: 24A

N, P supplementary bonds: NP, 7 NPP



⁵⁵₂₅Mn third figure

12α, 6N, 1P supplementary

EB in MeV = 482.0762

Stable	$\left\{ \begin{array}{l} 12 \\ (6+6) \\ (6+6) \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 7 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	339.9000	MeV
Nat. abundance: 100%		59.2380	
		26.6952	
		0	
		0	
		0	
		2.2246	
		0	
		54.0260	
		482.0838	MeV
	+ 0.008		

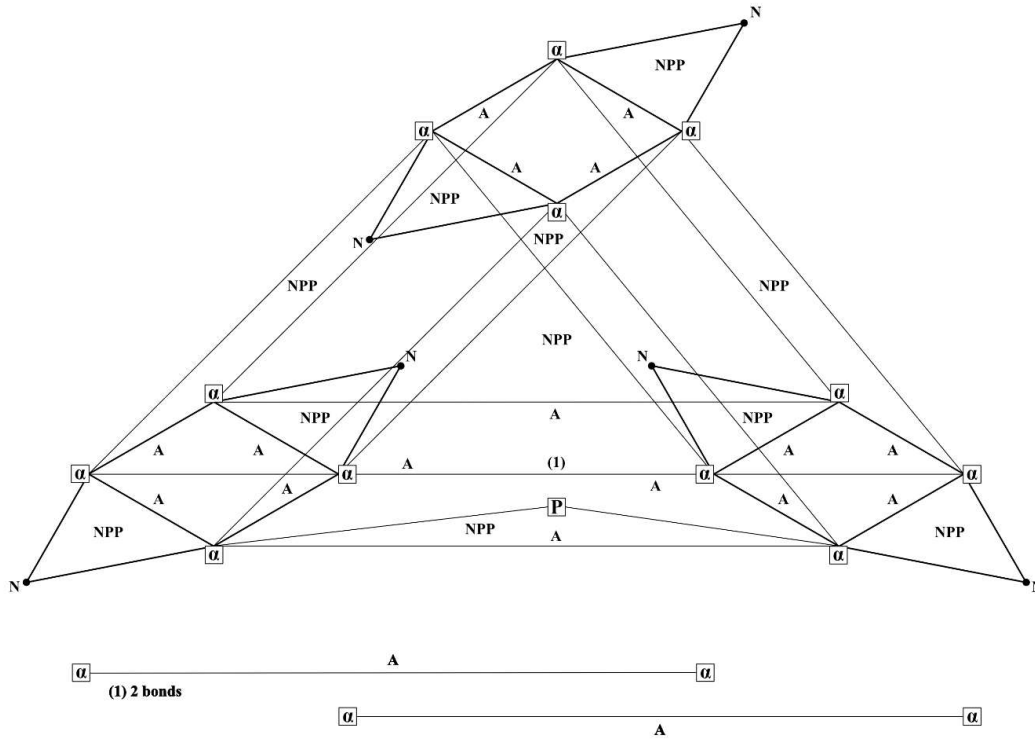
Figure 8. Binding energy distribution among ⁵⁵Mn third figure.

⁵⁵₂₅Mn fourth figure

Structure: 12 α, 6 N, 1 P

Linear and cross bonds: 16A, 4 NPP

N, P supplementary bonds: 7 NPP



⁵⁵₂₅Mn fourth figure

12α, 6N, 1P supplementary

EB in MeV = 482.0762

Stable	$\left\{ \begin{array}{l} 12 \\ (6+2) \\ (6+2) \\ 0 \\ 4 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	339.9000	MeV	
Nat. abundance: 100%		$\left\{ \begin{array}{l} 0 \\ 0 \\ 0 \\ 7 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	39.4920	
			17.7968	
			0	
			30.8720	
			0	
			0	
		0		
		54.0260		
		<u>482.0868</u>	MeV	
		+ 0.011		

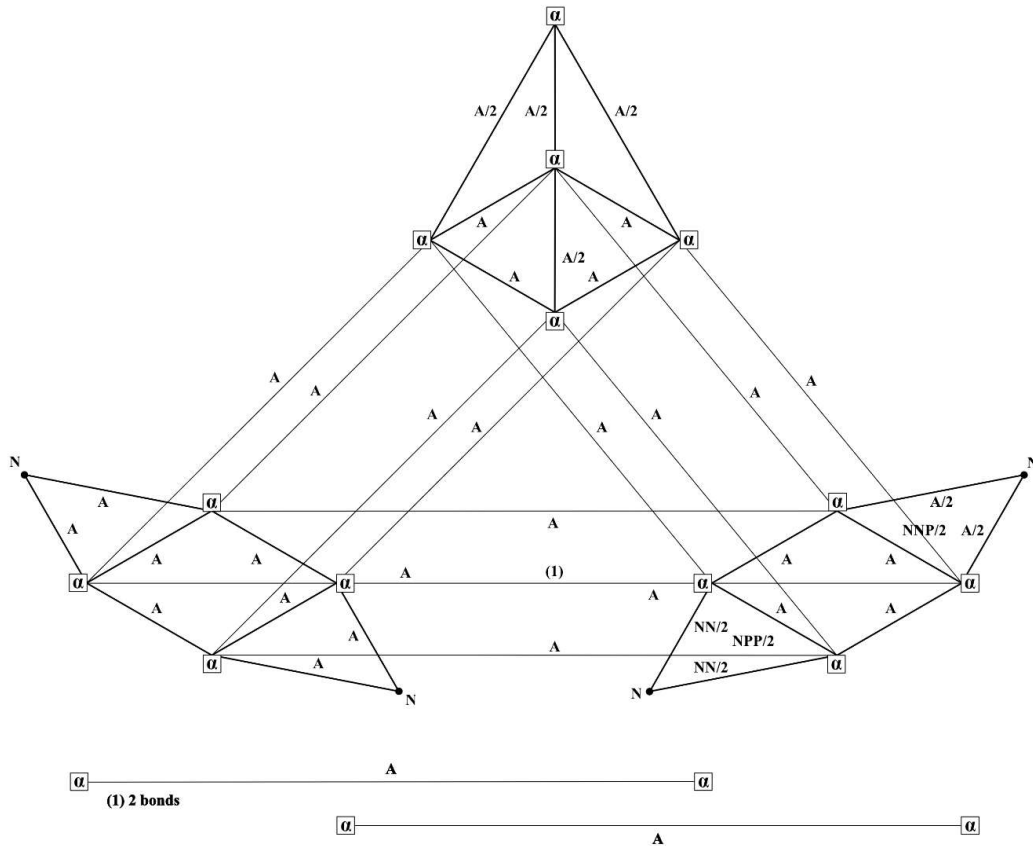
Figure 9. Binding energy distribution among ⁵⁵Mn fourth figure.

$^{56}_{26}\text{Fe}$

Structure: 13 α , 4 N, 0 P

Linear and cross bonds: 26A

N supplementary bonds: 5A, NN, NNP/2, NPP/2



$^{56}_{26}\text{Fe}$

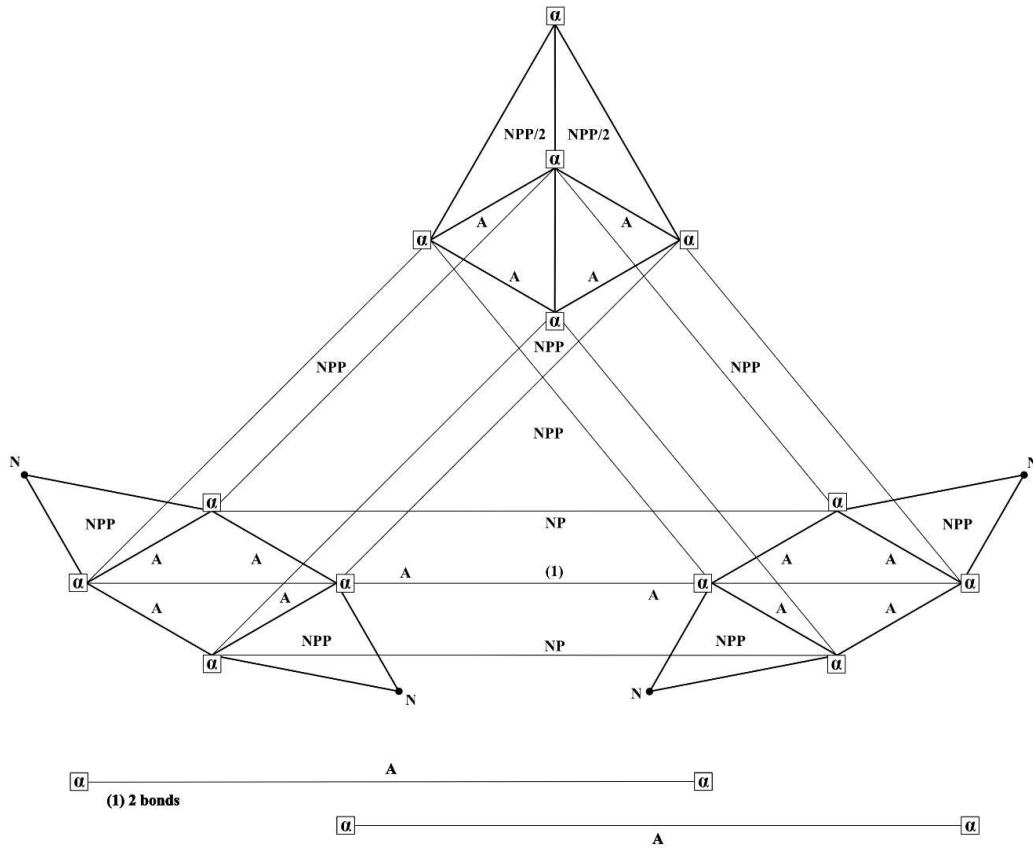
13 α , 4N, 0P supplementary

EB in MeV = 492.2598

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \\ 3.5 \\ 2.5 \\ 0.5 \\ 0.5 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	368.2250	MeV
Nat. abundance: 91.8%				64.1745	
				28.9198	
				0	
				0	
				17.2778	
				5.5615	
				4.2409	
				3.8590	
				492.2585	MeV
	- 0.001				

Figure 10. Binding energy distribution among ^{56}Fe .

$^{56}_{26}\text{Fe}$ second figure
 Structure: 13 α , 4 N, 0 P
 Linear and cross bonds: 14A, 2 NP, 5 NPP
 N supplementary bonds: 4 NPP



$^{56}_{26}\text{Fe}$ second figure

13 α , 4N, 0P supplementary

EB in MeV = 492.2598

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+0.5) \\ (6.5+2.5) \\ 0 \\ 5 \end{array} \right\}$	x	28.3250	$\left. \begin{array}{l} 368.2250 \\ 34.5555 \\ 20.0214 \\ 0 \\ 38.5900 \end{array} \right\}$	MeV
Nat. abundance: 91.8%		x	4.9365		
		x	2.2246		
		x	8.4818		
		x	7.7180		
	$\left\{ \begin{array}{l} 0 \\ 0 \\ 0 \\ 4 \end{array} \right\}$	x	4.9365	$\left. \begin{array}{l} 0 \\ 0 \\ 0 \\ 30.8720 \end{array} \right\}$	
		x	2.2246		
		x	8.4818		
		x	7.7180		
				492.2639	MeV
				+ 0.004	

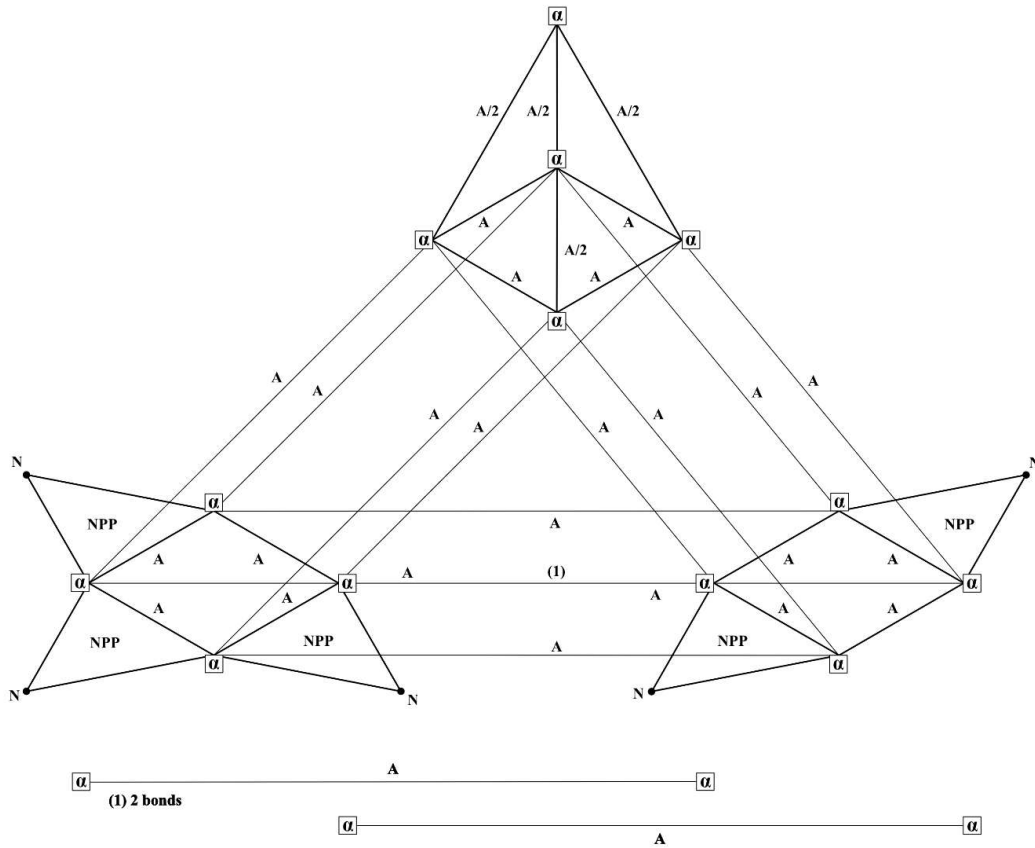
Figure 11. Binding energy distribution among ^{56}Fe second figure.

⁵⁷₂₆Fe

Structure: 13 α, 5 N, 0 P

Linear and cross bonds: 26A

N supplementary bonds: 5 NPP



⁵⁷₂₆Fe

13α, 5N, 0P supplementary

EB in MeV = 499.9059

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 5 \end{array} \right\} \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	368.2250	MeV
Nat. abundance: 2.1%		64.1745	
		28.9198	
		0	
		0	
		0	
		0	
		0	
		0	
		38.5900	
	<u>499.9093</u>	MeV	
	+ 0.004		

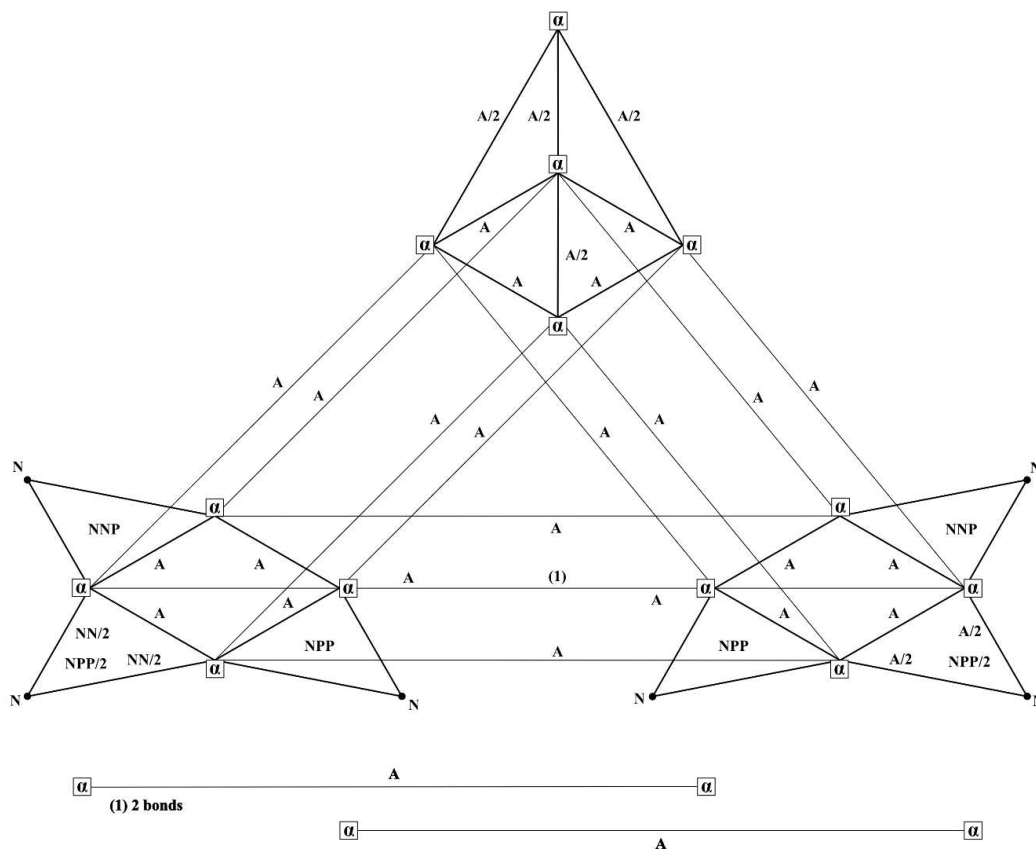
Figure 12. Binding energy distribution among ⁵⁷Fe.

⁵⁸₂₆Fe

Structure: 13 α, 6 N, 0 P

Linear and cross bonds: 26A

N supplementary bonds: A, NN, 2 NNP, 3 NPP



⁵⁸₂₆Fe

13α, 6N, 0P supplementary

EB in MeV = 509.9505

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \end{array} \right\}$	x	28.3250	$\left. \begin{array}{r} 368.2250 \\ 64.1745 \\ 28.9198 \\ 0 \\ 0 \end{array} \right\} \text{ MeV}$
Nat. abundance: 0.3%		x	4.9365	
		x	2.2246	
		x	8.4818	
		x	7.7180	
	$\left\{ \begin{array}{l} 1.5 \\ 0.5 \\ 2 \\ 3 \end{array} \right\}$	x	4.9365	7.4048
		x	2.2246	1.1123
		x	8.4818	16.9636
		x	7.7180	23.1540
				<hr/> 509.9540 MeV
				+ 0.003

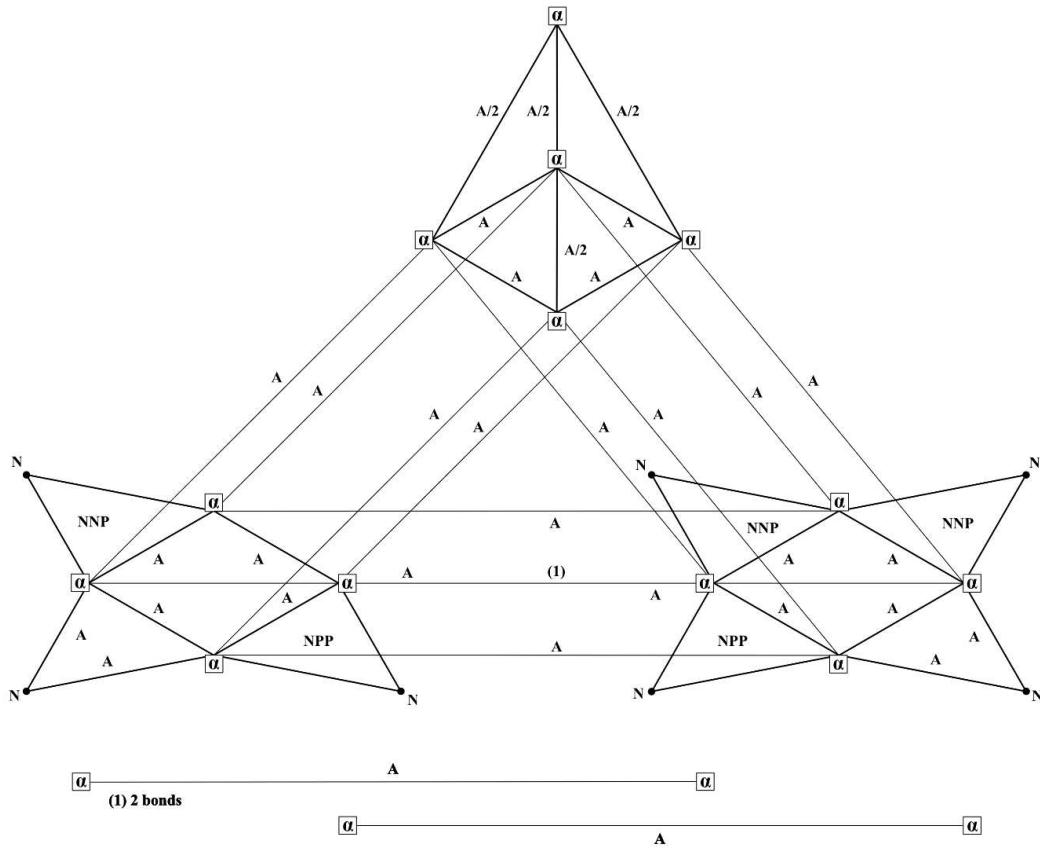
Figure 13. Binding energy distribution among ⁵⁸Fe.

⁵⁹₂₆Fe

Structure: 13 α, 7 N, 0 P

Linear and cross bonds: 26A

N supplementary bonds: 4A, 3 NNP, 2 NPP



⁵⁹₂₆Fe

13α, 7N, 0P supplementary

EB in MeV = 516.5315

Lifetime: 45.1 days

Mode of decay: β⁻

$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \\ 2 \\ 2 \\ 3 \\ 2 \end{array} \right\}$	x	28.3250	$\left. \begin{array}{r} 368.2250 \\ 64.1745 \\ 28.9198 \\ 0 \\ 0 \\ 9.8730 \\ 4.4492 \\ 25.4454 \\ 15.4360 \\ \hline 516.5229 \\ - 0.008 \end{array} \right\} \text{ MeV}$
	x	4.9365	
	x	2.2246	
	x	8.4818	
	x	7.7180	
	x	4.9365	
	x	2.2246	
	x	8.4818	
	x	7.7180	

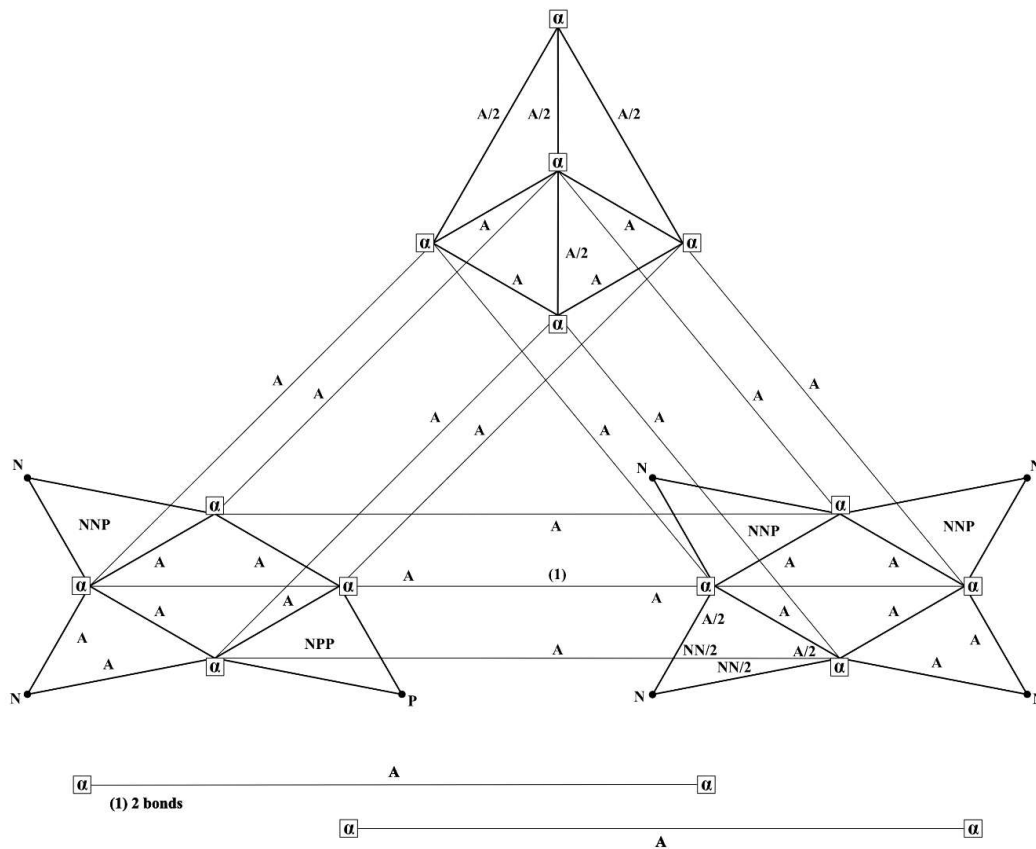
Figure 14. Binding energy distribution among ⁵⁹Fe.

⁵⁹₂₇Co

Structure: 13 α, 6 N, 1 P

Linear and cross bonds: 26A

N supplementary bonds: 5A, NN, 3 NNP, 1 NPP



⁵⁹₂₇Co

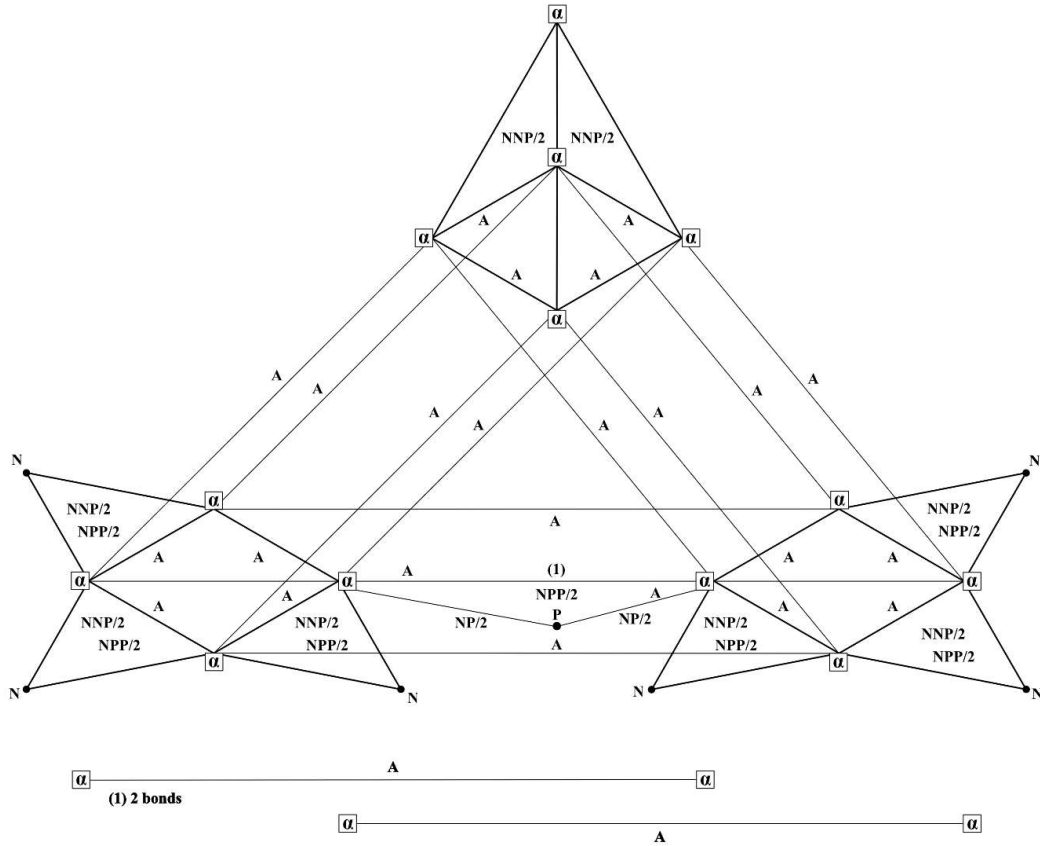
13α, 6N, 1P supplementary

EB in MeV = 517.3141

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	368.2250	MeV
Nat. abundance: 100%			64.1745
			28.9198
			0
			0
		$\left\{ \begin{array}{l} 3.5 \\ 2.5 \\ 3 \\ 1 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	17.2778
			5.5615
		25.4454	
		7.7180	
		<u>517.3220</u>	MeV
		+ 0.008	

Figure 15. Binding energy distribution among ⁵⁹Co.

$^{59}_{27}\text{Co}$ second figure
 Structure: 13 α , 6 N, 1 P
 Linear and cross bonds: 24A, NNP
 N supplementary bonds: NP, 3 NNP, 3.5 NPP



$^{59}_{27}\text{Co}$ second figure

13 α , 6N, 1P supplementary

EB in MeV = 517.3141

Stable	$\left\{ \begin{array}{l} 13 \\ (6.5+5.5) \\ (6.5+5.5) \end{array} \right\}$	x	28.3250	$\left. \begin{array}{l} 368.2250 \\ 59.2380 \\ 26.6952 \end{array} \right\}$	MeV
Nat. abundance: 100%		x	4.9365		
		x	2.2246		
	$\left\{ \begin{array}{l} 1 \\ 0 \end{array} \right\}$	x	8.4818	$\left. \begin{array}{l} 8.4818 \\ 0 \end{array} \right\}$	
		x	7.7180		
		x	4.9365		
	$\left\{ \begin{array}{l} 0 \\ 1 \\ 3 \end{array} \right\}$	x	2.2246	$\left. \begin{array}{l} 2.2246 \\ 25.4454 \\ 27.0130 \end{array} \right\}$	
		x	8.4818		
		x	7.7180		
				517.3230	MeV
				+ 0.009	

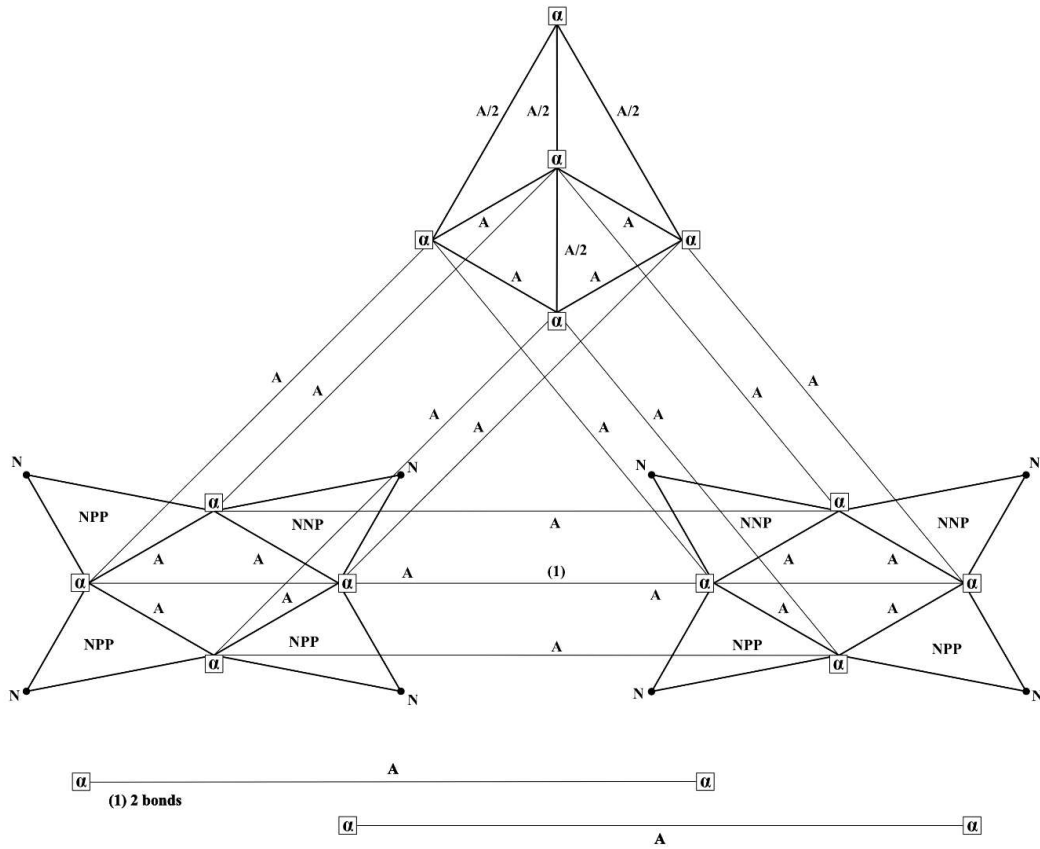
Figure 16. Binding energy distribution among ^{59}Co .

⁶⁰₂₆Fe

Structure: 13 α, 8 N, 0 P

Linear and cross bonds: 26A

N supplementary bonds: 3 NNP, 5 NPP



⁶⁰₂₆Fe

13α, 8N, 0P supplementary

EB in MeV = 525.3511

Lifetime: 3 x 10⁵ years

Mode of decay: β⁻

$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \\ 0 \\ 0 \\ 3 \\ 5 \end{array} \right.$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right.$	$\left\{ \begin{array}{l} 28.3250 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right.$	368.2250	MeV
			64.1745	
			28.9198	
			0	
			0	
			0	
			0	
			25.4454	
			38.5900	
			525.3547	MeV
			+ 0.004	

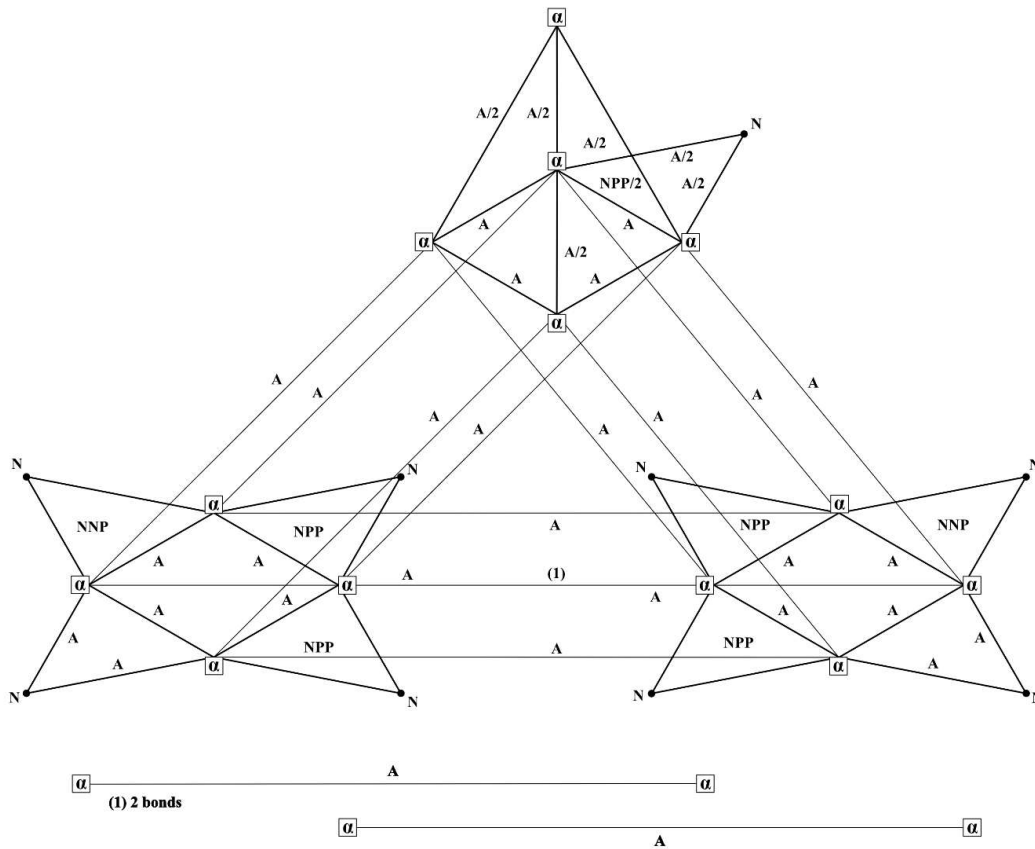
Figure 17. Binding energy distribution among ⁶⁰Fe.

$^{61}_{26}\text{Fe}$

Structure: 13 α , 9 N, 0 P

Linear and cross bonds: 26A

N supplementary bonds: 5A, 2 NNP, 4.5 NPP



$^{61}_{26}\text{Fe}$

13 α , 9N, 0P supplementary

EB in MeV = 530.9298

Lifetime: 6 min

Mode of decay: β^-

$\left\{ \begin{array}{l} 13 \\ (6.5+6.5) \\ (6.5+6.5) \\ 0 \\ 0 \\ 2.5 \\ 2.5 \\ 2 \\ 4.5 \end{array} \right\}$	x	28.3250	$\left. \begin{array}{r} 368.2250 \\ 64.1745 \\ 28.9198 \\ 0 \\ 0 \\ 12.3413 \\ 5.5615 \\ 16.9636 \\ 34.7310 \\ \hline 530.9167 \\ - 0.013 \end{array} \right\} \text{ MeV}$
	x	4.9365	
	x	2.2246	
	x	8.4818	
	x	7.7180	
	x	4.9365	
	x	2.2246	
	x	8.4818	
	x	7.7180	
			- 0.013

Figure 18. Binding energy distribution among ^{61}Fe .

CHAPTER 6

SIMILARITIES BETWEEN BINDING ENERGY VALUES OF CHEMICAL ELEMENTS

Example of nickel and copper

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 nucleon clusters, Linus Pauling found that the magic numbers have a very simple structural significance. He assumed that in nuclei the nucleons may, as a first approximation, be described as occupying localized $1s$ orbitals to form small clusters. These small clusters, called spherons, are usually helions (i.e. α particles), tritons and dineutrons. In nuclei containing an odd number of neutrons, an ${}^3\text{He}$ cluster or a deuteron may serve as a spheron. The close-packed-spheron model differs from the conventional liquid-drop model of the nucleus in having spherons rather than nucleons as the units. This enables to determine the systematic of binding energy in a much simpler way than the approach based on individual nucleons. The author developed that idea, i.e. having clusters as basic bricks within the nucleus instead of nucleons. He considered the binding energy of α particle, deuterium, tritium, ${}^3\text{He}$, and the way these spherons are bonded instead of the bonding between individual nucleons. According to that hypothesis the nuclei of the various isotopes of each element are constituted out of α particles and other nucleons grouped in order to form sub-nuclei bound together by four types of bonds called NN, NP, NNP and NPP. So, the author favored an approach trying to breakdown the binding energy value of each nuclide in the sub-values indicated above.

Keywords: alpha particle, dineutron (NN), deuterium (NP), tritium (NNP), ${}^3\text{He}$ (NPP).

1. Introduction

Several authors ^{[1][2]} predict that α particle structures could be present in atomic nuclei. Convincing arguments of such structures are provided by systematics of the binding energies of the even-even nuclei with equal number of protons and neutrons. So, a first point to consider concerns the binding energy (E_B) of an α particle and its relationship with the binding energies of deuterium, tritium, and helium-3, which are nuclear clusters smaller than helium-4. A second point is to see if and how these three binding energies play a role in the bonds between the α particles, binding a nucleon of one α particle to a nucleon of a second α particle.

The author tried to organize the nucleus in a way similar to Pauling's model of the nuclear structure, with some clusters within the nucleus Pauling called spherons. The clusters or sub nuclei taken into consideration are the α particles and 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.
- ${}^3\text{He}$ like bond, called NPP with value 7.718 MeV, having a similar function as NNP.
- a dineutron bond, 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.

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

The case of the light elements like ${}^{16}\text{O}$, ${}^{20}\text{Ne}$, ${}^{24}\text{Mg}$, ${}^{28}\text{Si}$, ${}^{32}\text{S}$, ${}^{36}\text{Ar}$, and ${}^{40}\text{Ca}$ were already treated (see chapter 4). There are by definition only α particles within these nuclei. The problem to solve is how they are bound together.

For instance, ^8Be is not stable as there is no room for bonds between the two α particles, the E_B of that nuclide being more or less equal to the E_B of its two α particles. It is not the case of ^{16}O 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

The author assumes that the bonds between α particles should be of NN and NP types if involving two nucleons, and of NNP and NPP types if involving three nucleons. So, the bonds of NNN and PPP types are eliminated as non “realistic” and NP, NNP, and NPP are accepted because they are equivalent to deuterium, tritium and ^3He bonds already existing before the α particle is constituted.

As far as NN and PP are concerned, these being part of the α particle binding energy, only NN is accepted as inter α bond for the following reasons:

- with the exception of ^3He there are no stable nuclides containing more protons than neutrons. So, for the stable nuclides, there is only one possible proton outside the α particles. There could, of course, be more neutrons. This fact excludes proton-proton bonds outside an α particle in a stable nuclide.
- coming back to ^{16}O and to the binding energy in excess to that one of the α 's, the following is noticed: The four α 's could be linked by a minimum of three bonds, one bond between each α . One NNP or NPP bond together with one NN or one NP bond are possible. However, the only suitable values are two NP bonds, together with the neutron–neutron (2 NN) binding energy within α particle. So, the binding energies of four α particles, plus two NP bonds, plus the “neutronic” (2 NN) part of the α particle binding energy can be summed together, and this sum can be described as the binding energy of ^{16}O . The NN value is deduced from the neutron-neutron binding energy within α particle.

These are the assumptions concerning the four bonds NN, NP, NNP, and NPP. To simplify the author merges NP and NN in one bond called A (for average) = $(\text{NN}/2 + \text{NP}/2)$.

The key idea of the theory is to find a common distribution of binding energy within the various nuclides. It is about finding a kinship between these various nuclides. According to the theory there is the following sequence in binding energy:

NP } bonds smaller than that of
 NNP \Rightarrow NPP } α particle bond
 α particle bond

In case of two or more α particles in a nucleus, it is assumed that the binding energy between these α particles is based on bonds linking their nucleons, and that the value of these bonds is related to the values of NP, NNP, NPP and NN bonds.

3. Calculation of binding energy

3.1. Basic values

$$\text{NP} = 2.2246 \text{ MeV},$$

$$\text{NNP} = 8.4818 \text{ MeV},$$

$$\text{NPP} = 7.7180 \text{ MeV},$$

$$E_B \alpha \text{ particle} = 28.325 \text{ MeV},$$

$$\text{NN} = 4.9365 \text{ MeV}.$$

3.2. Determining the binding energy of any nuclide.

The results are obtained by comparing binding energy values of isotopes of the same element and by breaking down these values in NP, NNP, NPP, and α particle binding energy values. The α particle binding energy value is also broken down in 2 NN and PP values. Only NN is active outside α particle, PP being active within α particle. One single process is used by the author, i.e. looking step by step, isotope of one element after isotope of the same element, for binding energy differences. Having this in mind it is possible to determine the binding energy value of every nuclide. See the figures displayed in the following appendices. The geometrical schemas displayed there are not designed to build a structure of nuclei, but rather to be a visual support for research, especially to see the kinship between the binding energy distribution among the various nuclides. For instance, in case of ^{16}O the figure is based on four α particles bound by four equal bonds called "A", actually the average of NN and NP ($\text{NN}/2 + \text{NP}/2$). If a neutron is added it becomes ^{17}O . The author looks for a bond connecting the new neutron to two nucleons located within two of the α particles in the ^{16}O structure. This is the state closest to ^{16}O . The choice is between (NN + NP), NNP and NPP. It is NPP which fits, so that bond is taken arbitrarily. Actually, the author uses the three bonds corresponding to the three nuclides pre-existing to the α particle, i.e. NP, NNP, NPP, and a fourth one deduced from α particle bond, i.e. NN.

This method is based on mind experiments and choosing between a few bonds each time a new neutron or proton enters a nucleus. The bond which fits is chosen. This unconventional way is comparable to the work of a chemist looking for several solutions in his experiments and validating that one which fits best.

Moreover, the author is looking at the compliance of the solution for one nucleus with the solution for another nucleus in order to avoid discrepancies, especially between isotopes of the same element. In doing so it is cared about symmetry within isotopes of one element and hence between all element's isotopes. Indeed, this work is not addressing the three-dimensional model of nuclei in the sense that the author is not looking for a structure of these nuclei but rather for the distribution of binding energy among them. Nevertheless, this work could be complementary to those dealing with that topic.

3.3. In a nutshell:

The author tries to explain the transmutation process.

- According to his theory the nucleus is constituted with α particles and other nucleons grouped as follows:
 - NP or deuterium,
 - NNP or tritium,
 - NPP or helium 3,
 - NN, part of α particle.
- The nucleus has a core made out of α particles linked together mainly with A bonds equal to $(\text{NN}/2 + \text{NP}/2)$ bonds. The other nucleons, not being part of α particles, actually neutrons plus one proton maximum, are bound to the α particles with (NN + NP) bonds or NNP or NPP bonds.
- If the bonds between α particles are not at a minimum of two A value per α the core of the nucleus is not stable and a β^+ or EC decay occurs till achievement of that stability.
- Once that core stability is achieved, the nucleus is stable provided that there are not too many neutrons outside the core of the nucleus. If there are too many of them a β^- decay occurs and a new element is created, stable or not.

4. Hypothesis for nucleosynthesis.

In order to determine the binding energy of the different light nuclei it is relied on the following hypothesis: each nucleus (starting from ${}^4_2\text{He}$) has a substructure made up of α particles. The N and P (neutrons and proton) supplementary to α particles can create ${}^2_1\text{H}$, ${}^3_1\text{H}$ and ${}^3_2\text{He}$ substructures or clusters. Thus, once the nucleus consists of 2 N and 2 P, its structure is that of the α particle one, and when it consists of $x \alpha + 2N + 2P$, its structure becomes $(x + 1) \alpha$. According to that hypothesis the nucleus can be conformed to in the following ways:

$$\begin{aligned}
 &x \alpha + N, \quad x \alpha + P \\
 &x \alpha + 2N, \quad x \alpha + N + P, \quad x \alpha + 2P \\
 &x \alpha + 3N, \quad x \alpha + 2N + P, \quad x \alpha + 1N + 2P, \quad x \alpha + 3P \\
 &x \alpha + 4N, \quad x \alpha + 3N + P, \quad x \alpha + N + 3P, \quad x \alpha + 4P \\
 &x \alpha + 2N + 2P = (x + 1) \alpha
 \end{aligned}$$

This conforms to the Ikeda diagram ^[2] showing how the structure of light α conjugate nuclei can be considered as comprised of α clusters.

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

When the structure of the nucleus is formed with $x \alpha$ particles to which nucleons are added, this structure is stable as long as the equilibrium between N and P remains stable. Anyway, there is a tendency to respect this symmetry by transformation of N in P or P in N, usually with the emission of particles β^- and β^+ . If the nucleons supplementary to the α particles have an odd number as a value, N prevails over P and the substructure or cluster at issue is N, or $2N + P$, if there is a stable structure. When the number of nucleons supplementary to $x \alpha$ can be described as or more than 4 (for example $3N + P$), the nucleus has a tendency of creating a supplementary α particle through the transformation of N into P or vice versa. The stable light nuclei are therefore formed mainly by α particles.

So, primordial nucleosynthesis is not limited to the first elements of the Periodic Table, but is continued, creating α particles as far as necessary.

According to the author's hypothesis the binding energy of every nucleus is the sum of the binding energy of its different sub-structures and the binding energy among these sub-structures. This is an assumption which is in contradiction with conventional theory. So, this assumption should be discussed in the light of the results already obtained by the author for hundreds of nuclides (see the appendices to the present chapter and the other chapters).

5. Relationships between the four types of bonds

According to author's theory, the nuclei of the various elements are constituted with α particles and other nucleons grouped in order to create sub-nuclei linked by four types of bonds called NN, NP, NNP, NPP. The binding energy values of Deuterium (NP), Tritium (NNP), Helium3 (NPP), and NN are related through the following equations:

- EB Tritium (NNP) = $2NN - 1.25/2 NP$
- EB He3 (NPP) = $NN + 1.25 NP$
- 2 NN forming the neutronic part of the binding energy of α particle.

5.1. Values used for the calculations of the binding energy:

EB α	=	28.325 MeV	
EB NN	=	4.9365 MeV =	8.875 lines
EB NP (= ${}^2_1\text{H}$)	=	2.2246 MeV =	4 lines
EB NNP (= ${}^3_1\text{H}$)	=	8.4818 MeV =	15.25 lines
EB NPP (= ${}^3_2\text{He}$)	=	7.7180 MeV =	13.875 lines

} One line is equal to 0.5561589 MeV

5.2. Examples of calculation:

$$\text{EB } {}^{16}_8\text{O} = 4 \text{ EB } \alpha + 25.75 \text{ lines} = 4 \text{ EB } \alpha + 2\text{NN} + 2\text{NP} = 4 \text{ EB } \alpha + 4\text{A} = 127.6222 \text{ MeV}$$

(+ 0.003 MeV, Ame 2016)

${}^{69}_{31}\text{Ga}$ and ${}^{71}_{31}\text{Ga}$ comparison

Compared to ${}^{69}_{31}\text{Ga}$, ${}^{71}_{31}\text{Ga}$ has two more neutrons in its structure.

$$\text{EB } {}^{69}_{31}\text{Ga} = 601.9960 \text{ MeV} \qquad \text{EB } {}^{71}_{31}\text{Ga} = 618.9499 \text{ MeV}$$

The EB difference can be described as 16.9539 MeV, that is two EB tritium (NNP), i.e $2 \times 8.4818 \text{ MeV} = 16.9636 \text{ MeV}$
(-0.010 MeV)

${}^{57}_{26}\text{Fe}$ and ${}^{60}_{26}\text{Fe}$ comparison

Compared to ${}^{57}_{26}\text{Fe}$, ${}^{60}_{26}\text{Fe}$ has three more neutrons in its structure.

$$\text{EB } {}^{57}_{26}\text{Fe} = 499.9059 \text{ MeV} \qquad \text{EB } {}^{60}_{26}\text{Fe} = 525.3511 \text{ MeV}$$

The difference can be described as 25.4452 MeV, i.e three EB tritium (NNP), i.e $3 \times 8.4818 \text{ MeV} = 25.4454 \text{ MeV}$

6. Conclusions

6.1. The breakdown of the binding energy of any nuclide is based on:

- the α particle bond,
- deuterium bond,
- tritium bond,
- helium 3 bond,
- NN bond, part of α particle bond.

6.2. Assumptions about the structure of the nuclei based on their similarities could be made:

- the isotopes of each chemical element have the same core structure based on α particles bound together with the bonds determined above,
- the neutrons and proton supplementary to that core are bound to the α particles in the same way.

References

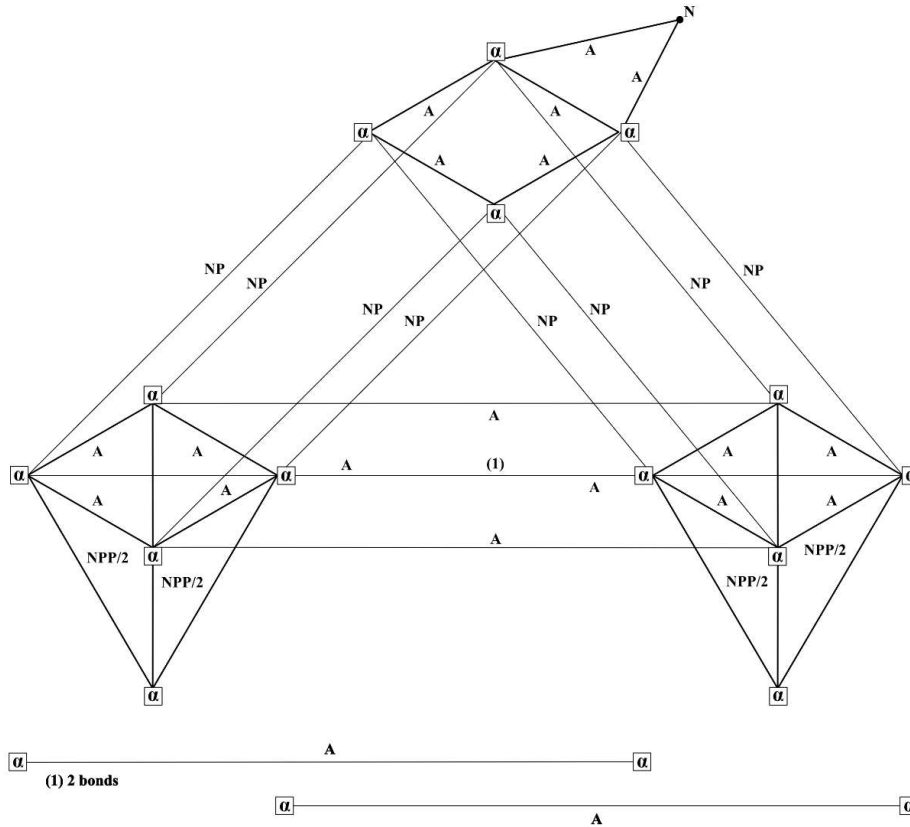
- [1] L. Pauling, Science 150 (1965) d 297.
[2] K. Ikeda, N. Takigawa and H. Horiuchi, Prog. Theor. Phys. Suppl. (1968) E 464.

⁵⁷₂₈ Ni

Structure: 14 α, 1 N, 0 P

Linear and cross bonds: 16A, 8 NP, 2 NPP

N supplementary bonds: 2A



⁵⁷₂₈ Ni

14α, 1N, 0P supplementary

EB in MeV = 494.2432

Lifetime: 36 hours

Modes of decay: β⁺, EC

$\left\{ \begin{array}{l} 14 \\ (7+1) \\ (7+9) \\ 0 \\ 2 \\ 1 \\ 1 \\ 0 \\ 0 \end{array} \right\}$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 39.4920 \\ 35.5936 \\ 0 \\ 15.4360 \\ 4.9365 \\ 2.2246 \\ 0 \\ 0 \end{array} \right\}$	MeV
	x	4.9365		
	x	2.2246		
	x	8.4818		
	x	7.7180		
	x	4.9365		
	x	2.2246		
	x	8.4818		
	x	7.7180		
	x	0		0
			494.2327	MeV
			- 0.011	

Figure 2. Binding energy distribution among ⁵⁷₂₈ Ni.

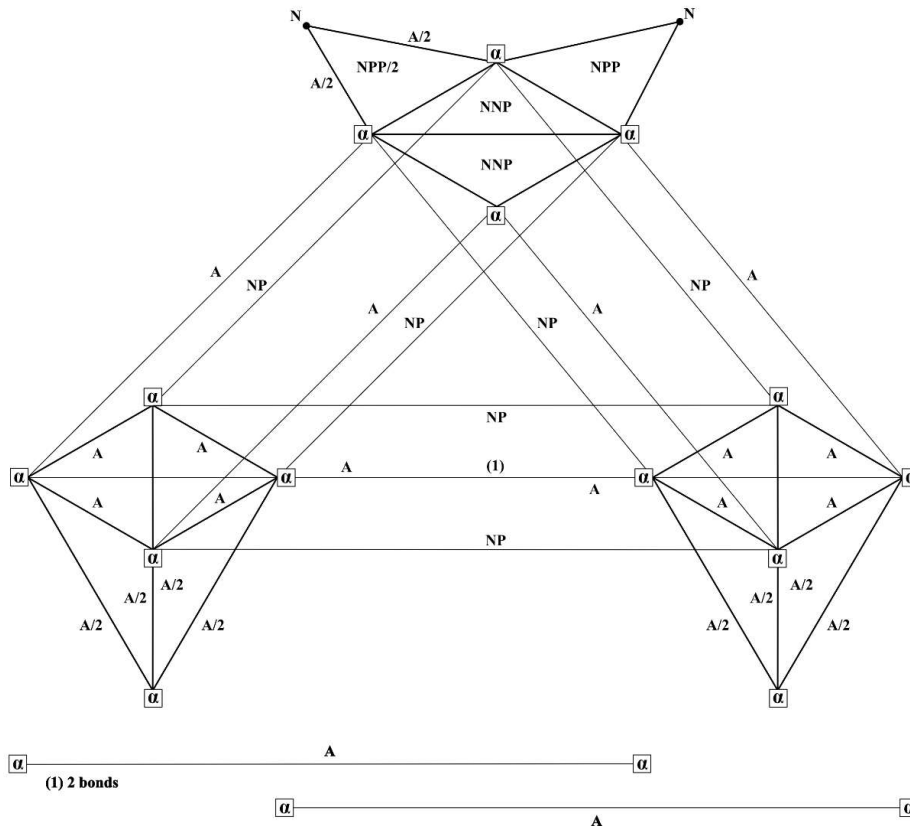
8 out of the 12 bonds are of NP type, 4 of A (NN/2 + NP/2) type. Binding energy value has increased compared to ⁵⁶₂₈ Ni but not enough. The β⁺ decay goes on.

⁵⁸₂₈Ni First figure

Structure: 14 α, 2 N, 0 P

Linear and cross bonds: 18A, 6 NP, 2 NNP

N supplementary bonds: A, 1.5 NPP



⁵⁸₂₈Ni First figure

14α, 2N, 0P supplementary

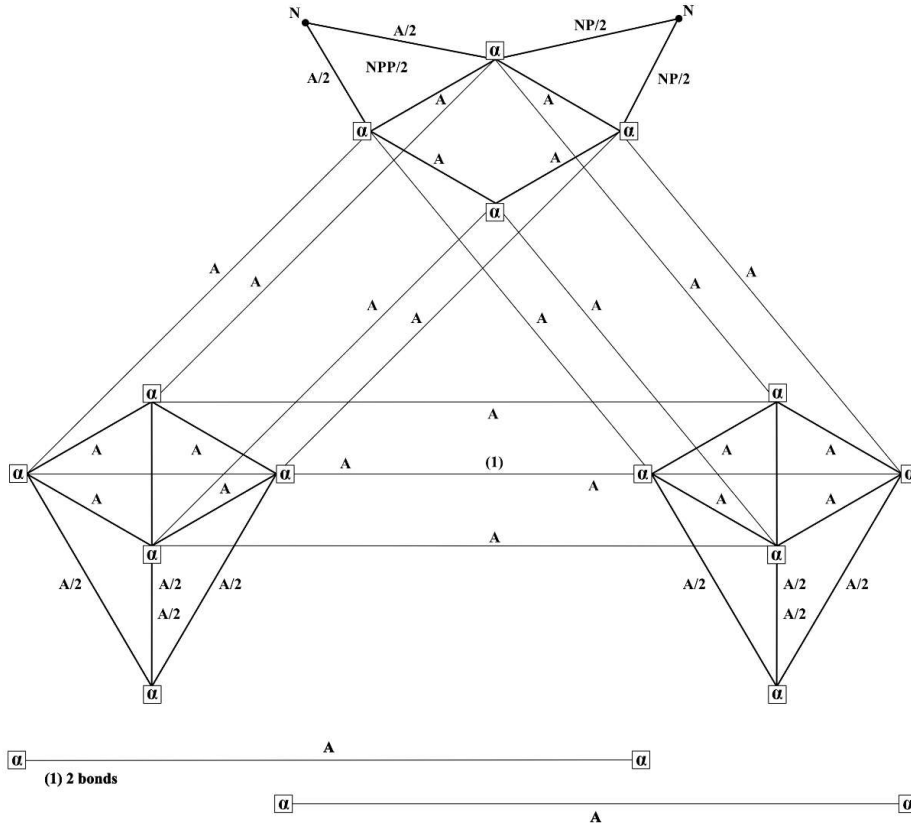
EB in MeV = 506.4594

Stable	$\left\{ \begin{array}{l} 14 \\ (7+2) \\ (7+8) \\ 2 \\ 0 \end{array} \right\}$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 44.4285 \\ 33.3690 \\ 16.9636 \\ 0 \end{array} \right\}$	MeV
Nat. abundance: 68.27 %		x	4.9365		
		x	2.2246		
		x	8.4818		
		x	7.7180		
	$\left\{ \begin{array}{l} 0.5 \\ 0.5 \\ 0 \\ 1.5 \end{array} \right\}$	x	4.9365	$\left. \begin{array}{l} 2.4683 \\ 1.1123 \\ 0 \\ 11.5770 \end{array} \right\}$	
		x	2.2246		
		x	8.4818		
		x	7.7180		
			<u>11.5770</u>	<u>506.4687</u>	MeV
				+ 0.009	

Figure 3. Binding energy distribution among ⁵⁸₂₈Ni first figure.

This nucleus is stable. Nevertheless, 6 NP bonds are still present (see first figure). Actually, there is a NPP bond binding a supplementary N to two α particles which could be transformed into a NP bond. This, together with the transformation of the two NNP bonds between the α particles into 4 A bonds liberates enough energy to transform three NP bonds into three NN bonds creating 6A bonds to be added to the 6 existing ones. On total there will be 12A bonds (see second figure).

⁵⁸₂₈Ni Second figure
 Structure: 14 α, 2 N, 0 P
 Linear and cross bonds: 28A
 N supplementary bonds: A, NP, NPP/2



⁵⁸₂₈Ni Second figure

14α, 2N, 0P supplementary

EB in MeV = 506.4594

Stable	$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
Nat. abundance: 68.27 %		69.1110	
		31.1444	
		0	
		0	
		2.4683	
		3.3369	
		0	
		3.8590	
		506.4696	MeV
	+ 0.010		

Figure 4. Binding energy distribution among ⁵⁸₂₈Ni second figure.

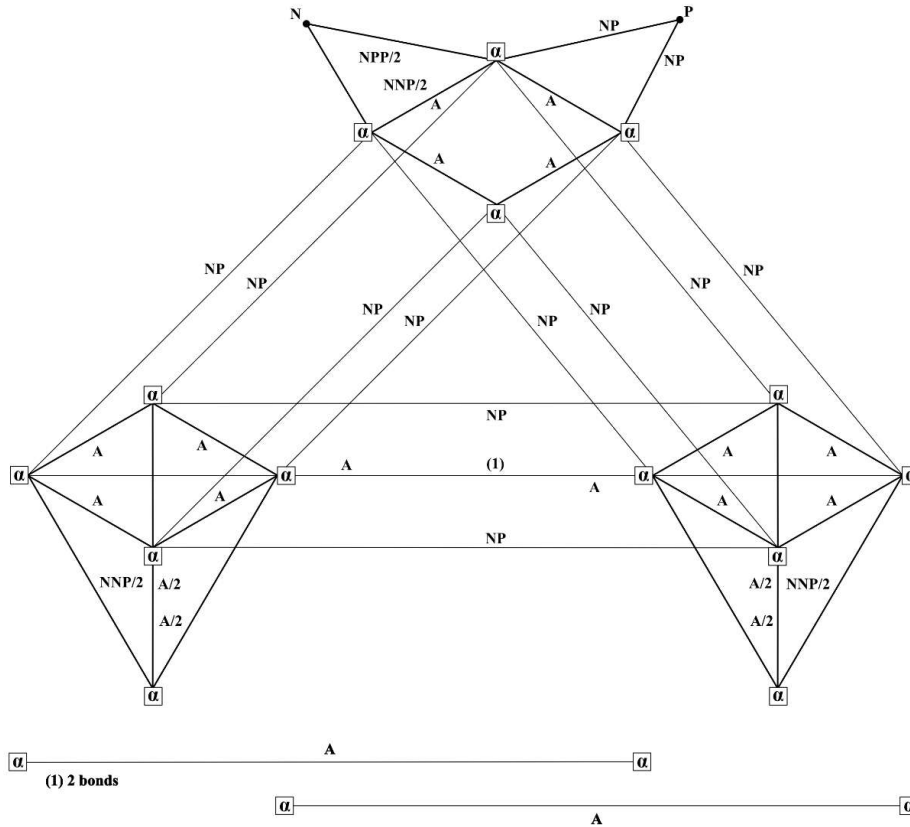
The whole core structure of Ni58 is constituted out of A type bonds. Only the 2 N supplementary are linked with different bonds to the α particles. This type of transformation is frequent within a given nucleus; when there is enough energy available, the most stable rearrangement is occurring. So Ni58 is stable.

⁵⁸₂₉ Cu

Structure: 14 α, 1 N, 1 P

Linear and cross bonds: 16A, 10 NP, 1 NNP

N, P supplementary bonds: 2 NP, NNP/2, NPP/2



⁵⁸₂₉ Cu

14α, 1N, 1P supplementary

EB in MeV = 497.1161

Lifetime: 3.2 seconds

Modes of decay: β⁺

$\left\{ \begin{array}{l} 14 \\ (7+1) \\ (7+11) \\ 1 \\ 0 \\ 0 \\ 2 \\ 0.5 \\ 0.5 \end{array} \right\}$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 39.4920 \\ 40.0428 \\ 8.4818 \\ 0 \\ 0 \\ 4.4492 \\ 4.2409 \\ 3.8590 \end{array} \right\}$	MeV
	x	4.9365		
	x	2.2246		
	x	8.4818		
	x	7.7180		
	x	4.9365		
	x	2.2246		
	x	8.4818		
	x	7.7180		
	497.1157			MeV

Figure 5. Binding energy distribution among ⁵⁸₂₉ Cu.

10 NP and only 2A bonds link the α particles, hence the lack of stability. The P outside the core structure is linked with 2 NP bonds. If one NP bond is transformed into one NN bond through β⁺ decay, Cu58 is transmuted into Ni58.

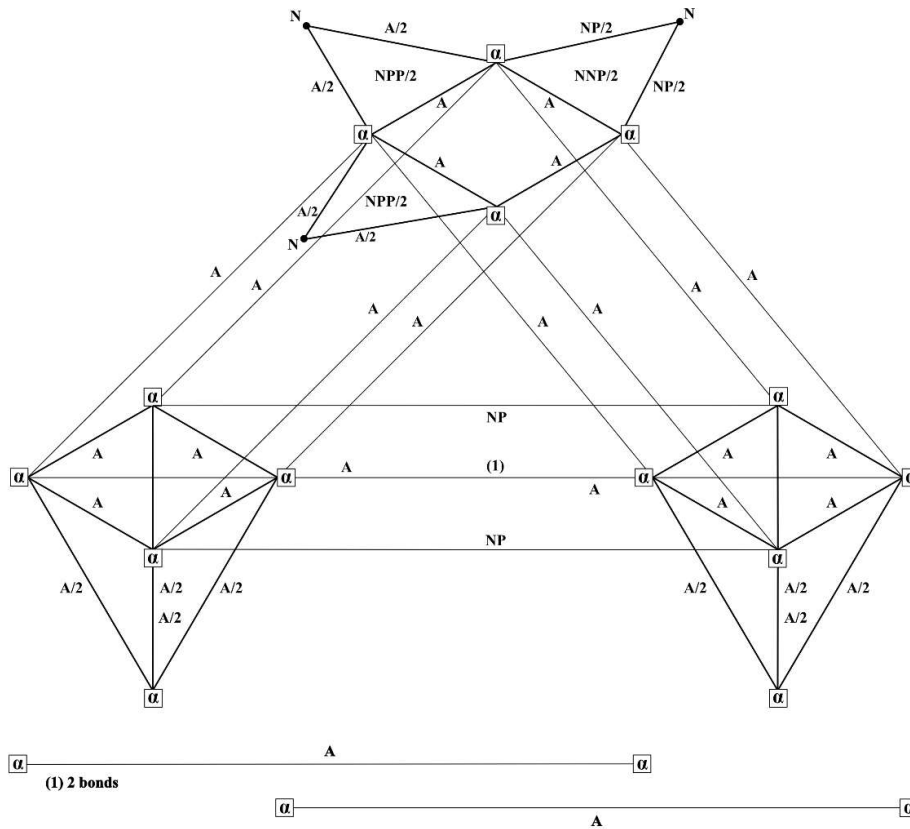
Indeed, other NP → NN transformations must occur to stabilize the nucleus.

⁵⁹₂₈ Ni

Structure: 14 α, 3 N, 0 P

Linear and cross bonds: 26A, 2 NP

N supplementary bonds: 2A, 1 NP, 0.5 NNP, 1 NPP



⁵⁹₂₈ Ni

14α, 3N, 0P supplementary

EB in MeV = 515.4587

Lifetime: 8×10^4 years

Mode of decay: EC

$\left\{ \begin{array}{l} 14 \\ (7+6) \\ (7+8) \\ 0 \\ 0 \\ 1 \\ 2 \\ 0.5 \\ 1 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			64.1745	
			33.3690	
			0	
			0	
			4.9365	
			4.4492	
			4.2409	
			7.7180	
			515.4381	MeV
- 0.020				

Figure 6. Binding energy distribution among ⁵⁹₂₈ Ni.

One observes that the configuration of that nucleus is similar to that one of Ni58. Nevertheless, an equilibrium cannot be achieved due to 2 NP bonds in its core structure, and an EC decay occurs.

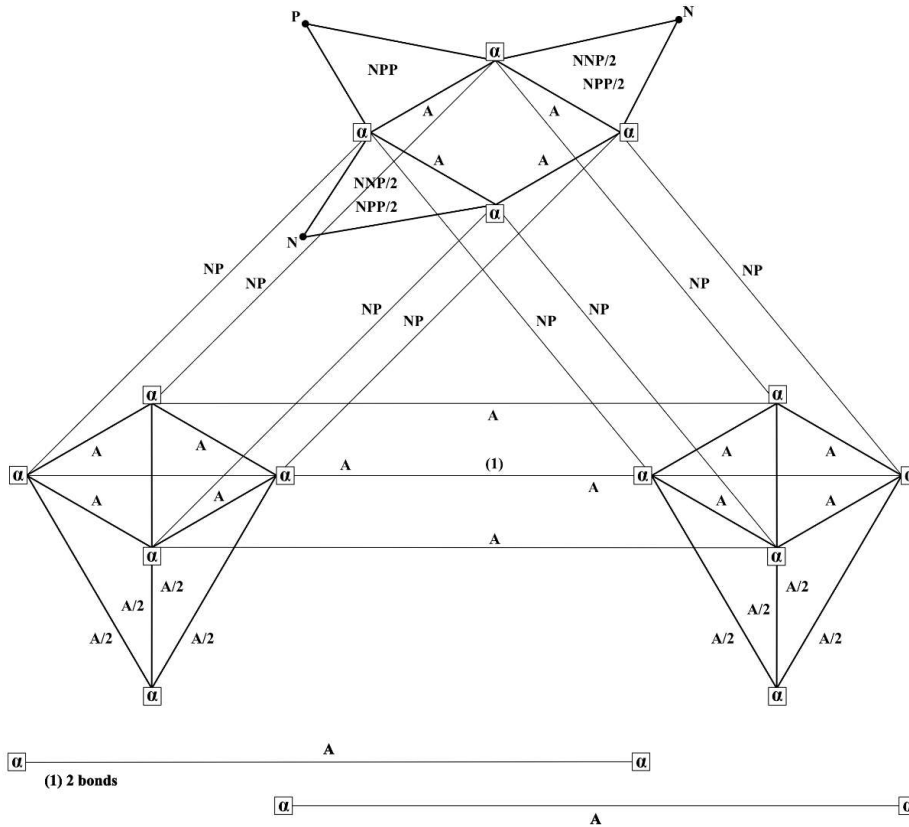
The half-life of that nucleus is important, and Ni58, Ni60 are stable and represent together nearly 95% of the Ni element. Ni61, Ni62, Ni64 are representing the remaining 5%. So, the element Ni has reached its internal equilibrium with 2 and 4 supplementary neutrons.

⁵⁹₂₉ Cu

Structure: 14 α, 2 N, 1 P

Linear and cross bonds: 20A, 8 NP

N, P supplementary bonds: NNP, 2 NPP



⁵⁹₂₉ Cu

14α, 2N, 1P supplementary

EB in MeV = 509.8780

Lifetime: 82 seconds

Modes of decay: β⁺, EC

$\left\{ \begin{array}{l} 14 \\ (7+3) \\ (7+11) \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 2 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			49.3650	
			40.0428	
			0	
			0	
			0	
			0	
			8.4818	
			15.4360	
			509.8756	MeV
	- 0.002			

Figure 7. Binding energy distribution among ⁵⁹₂₉ Cu.

8 NP bonds are linking the α particles. So, β⁺ and EC decays occur.

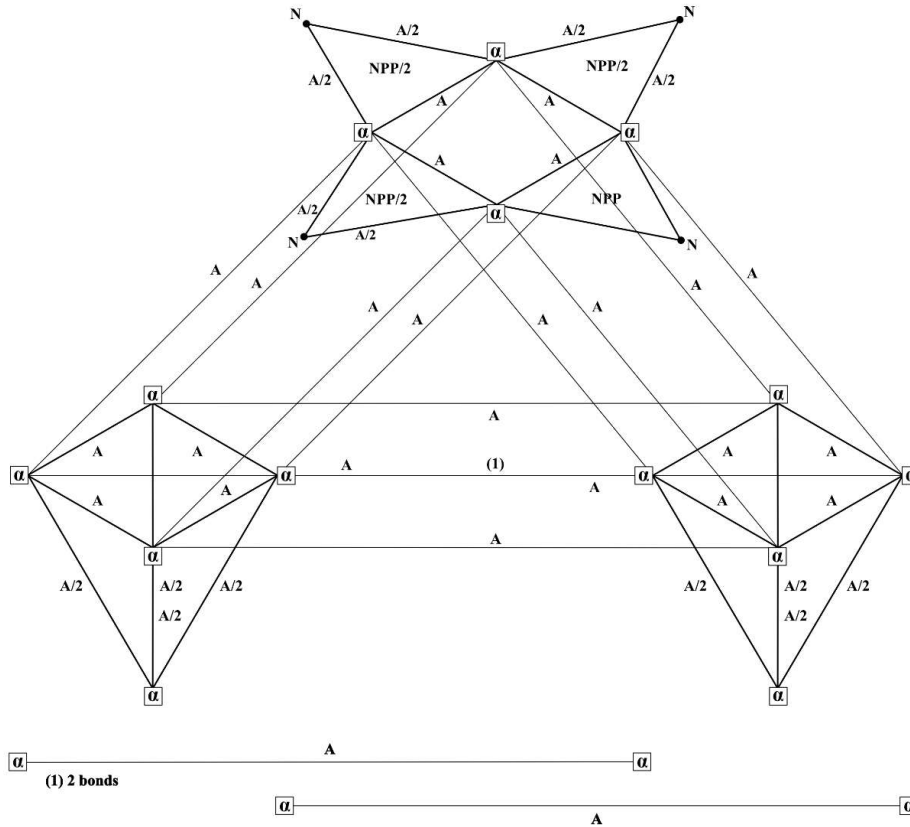
Comparing this nucleus with ⁵⁹₂₈ Ni, there are 3 NP transformed into 3 NN in the core.

⁶⁰₂₈Ni

Structure: 14 α , 4 N, 0 P

Linear and cross bonds: 28A

N supplementary bonds: 3A, 2.5 NPP



⁶⁰₂₈Ni

14 α , 4N, 0P supplementary

EB in MeV = 526.8464

Stable	$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 1.5 \\ 1.5 \\ 0 \\ 2.5 \end{array} \right\} \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV	
Nat. abundance: 26.1 %			69.1110	
			31.1444	
			0	
			0	
			7.4048	
			3.3369	
			0	
			19.2950	
			526.8421	MeV
			- 0.004	

Figure 8. Binding energy distribution among ⁶⁰₂₈Ni.

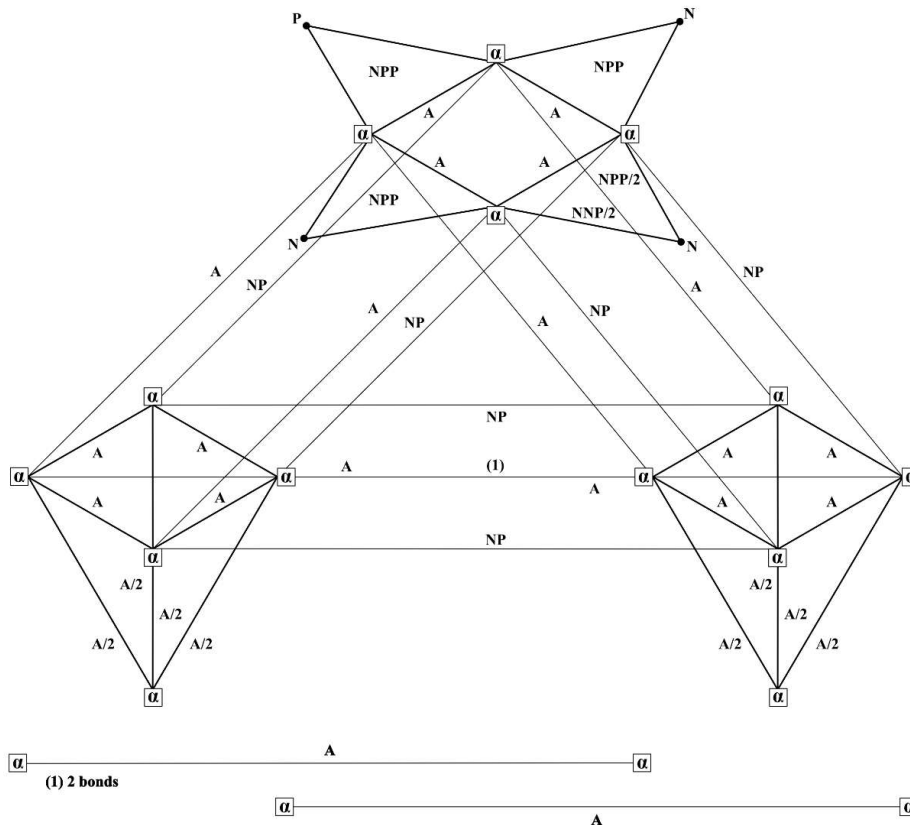
This nucleus is stable, the α particles are linked with A bonds.

⁶⁰₂₉ Cu

Structure: 14 α , 3 N, 1 P

Linear and cross bonds: 22A, 6 NP

N, P supplementary bonds: NNP/2, 3.5 NPP



⁶⁰₂₉ Cu

14 α , 3N, 1P supplementary

EB in MeV = 519.9361

Lifetime: 23 minutes

Modes of decay: β^+ , EC

$\left\{ \begin{array}{l} 14 \\ (7+4) \\ (7+10) \\ 0 \\ 0 \\ 0 \\ 0 \\ 0.5 \\ 3.5 \end{array} \right\}$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 54.3015 \\ 37.8182 \\ 0 \\ 0 \\ 0 \\ 0 \\ 4.2409 \\ 27.0130 \\ \hline 519.9236 \\ - 0.013 \end{array} \right\}$	MeV
	x	4.9365		
	x	2.2246		
	x	8.4818		
	x	7.7180		
	x	4.9365		
	x	2.2246		
	x	8.4818		
	x	7.7180		

Figure 9. Binding energy distribution among ⁶⁰₂₉ Cu.

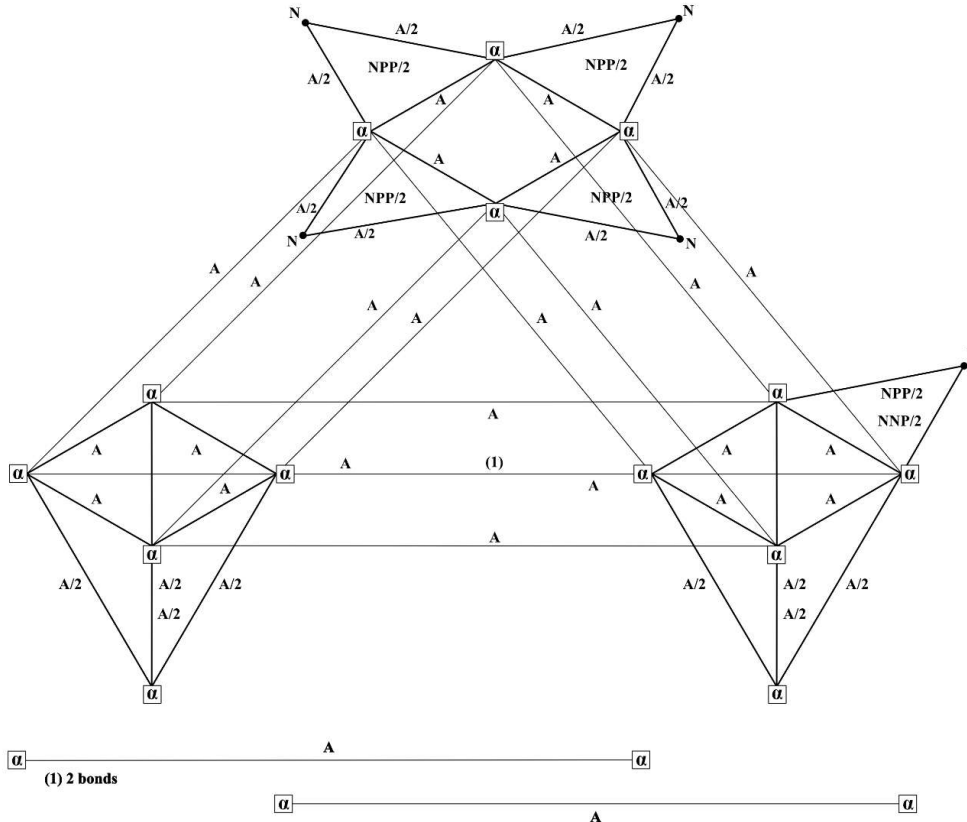
6 NP bonds are present in that nucleus, there is no stability.

⁶¹₂₈Ni

Structure: 14 α, 5 N, 0 P

Linear and cross bonds: 28A

N supplementary bonds: 4A, NNP/2, 2.5 NPP



⁶¹₂₈Ni

14α, 5N, 0P supplementary

EB in MeV = 534.6665

Stable

Nat. abundance: 1.13 %

$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 2 \\ 2 \\ 0.5 \\ 2.5 \end{array} \right\}$	x	28.325	$\left. \begin{array}{r} 396.5500 \\ 69.1110 \\ 31.1444 \\ 0 \\ 0 \\ 9.8730 \\ 4.4492 \\ 4.2409 \\ 19.2950 \\ \hline 534.6635 \\ - 0.003 \end{array} \right\}$	MeV	
	x	4.9365			
	x	2.2246			
	x	8.4818			
	x	7.7180			
	x	4.9365			
	x	2.2246			
	x	8.4818			
	x	7.7180			
				MeV	
				- 0.003	

Figure 10. Binding energy distribution among ⁶¹₂₈Ni.

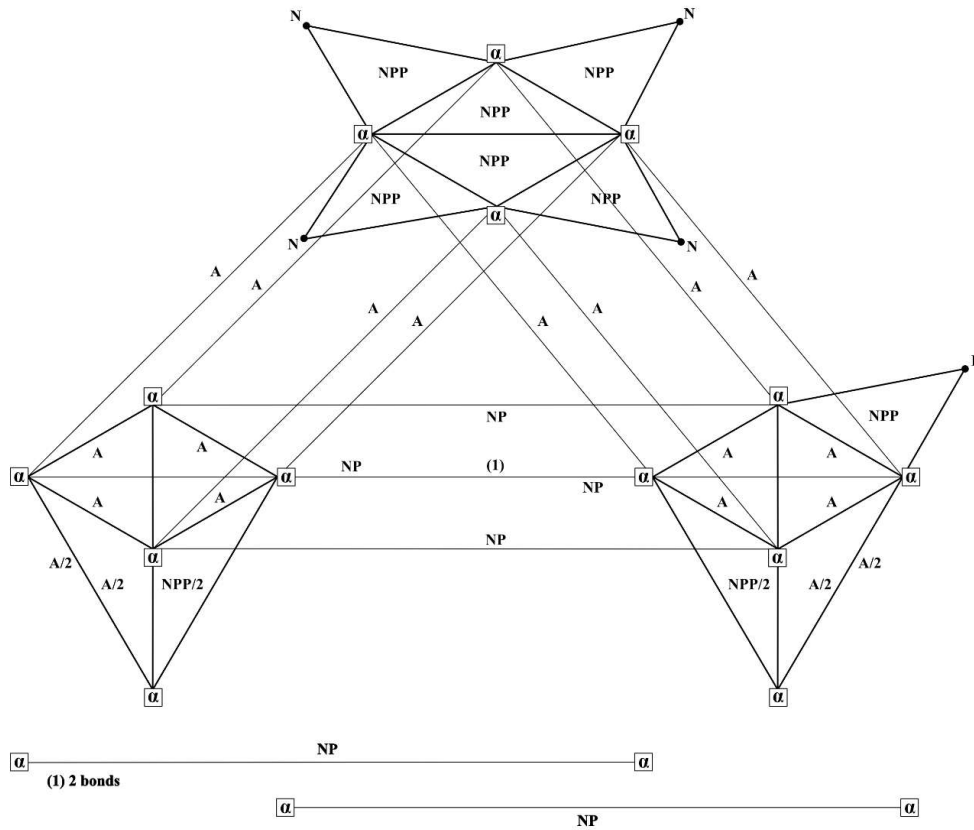
This nucleus is stable. EB Ni61 = EB Ni60 + A + NNP/2. So, the addition of one N has yield a binding energy of A + NNP/2.

⁶¹₂₉ Cu

Structure: 14 α, 4 N, 1 P

Linear and cross bonds: 18A, 4 NP, 3 NPP

N, P supplementary bonds: 5 NPP



⁶¹₂₉ Cu

14α, 4N, 1P supplementary

EB in MeV = 531.6464

Lifetime: 3.41 hours

Modes of decay: β⁺, EC

$\left\{ \begin{array}{l} 14 \\ (7+2) \\ (7+6) \\ 0 \\ 3 \\ 0 \\ 0 \\ 0 \\ 0 \\ 5 \end{array} \right.$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 44.4285 \\ 28.9198 \\ 0 \\ 23.1540 \\ 0 \\ 0 \\ 0 \\ 0 \\ 38.5900 \end{array} \right\}$	MeV		
	x	4.9365				
	x	2.2246				
	x	8.4818				
	x	7.7180				
	x	4.9365				
	x	2.2246				
	x	8.4818				
	x	7.7180				
				531.6423	MeV	
				- 0.004		

Figure 11. Binding energy distribution among ⁶¹₂₉ Cu.

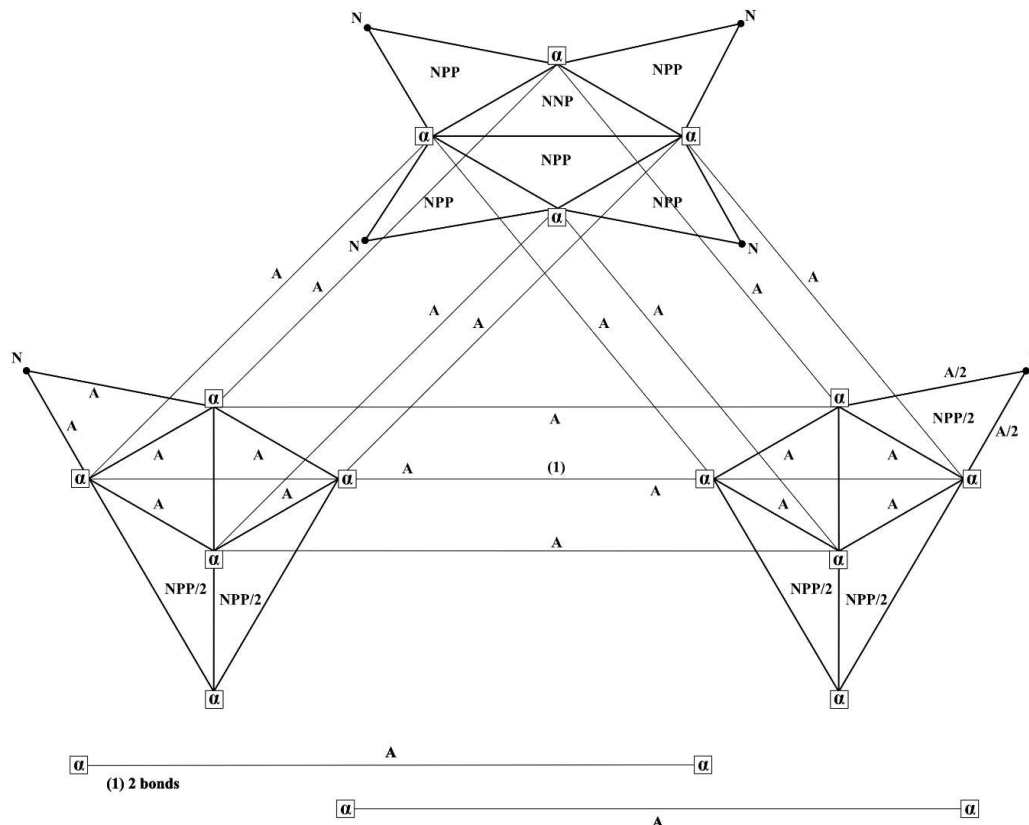
4 NP bonds are still present in that nucleus. There is no stability possible.

⁶²₂₈ Ni

Structure: 14 α, 6 N, 0 P

Linear and cross bonds: 20A, 1 NNP, 3 NPP

N supplementary bonds: 3A, 4.5 NPP



⁶²₂₈ Ni

14α, 6N, 0P supplementary

EB in MeV = 545.2623

Stable	$\left\{ \begin{array}{l} 14 \\ (7+3) \\ (7+3) \end{array} \right.$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 49.3650 \\ 22.2460 \end{array} \right\}$	MeV
Nat. abundance: 3.59 %			4.9365		
			2.2246		
	$\left\{ \begin{array}{l} 1 \\ 3 \end{array} \right.$	x	8.4818	$\left. \begin{array}{l} 8.4818 \\ 23.1540 \end{array} \right\}$	
			7.7180		
			4.9365		
	$\left\{ \begin{array}{l} 1.5 \\ 1.5 \\ 0 \end{array} \right.$	x	2.2246	$\left. \begin{array}{l} 7.4048 \\ 3.3369 \\ 0 \end{array} \right\}$	
			8.4818		
			7.7180		
		x	34.7310		
			545.2695		MeV
			+ 0.007		

Figure 12. Binding energy distribution among ⁶²₂₈ Ni.

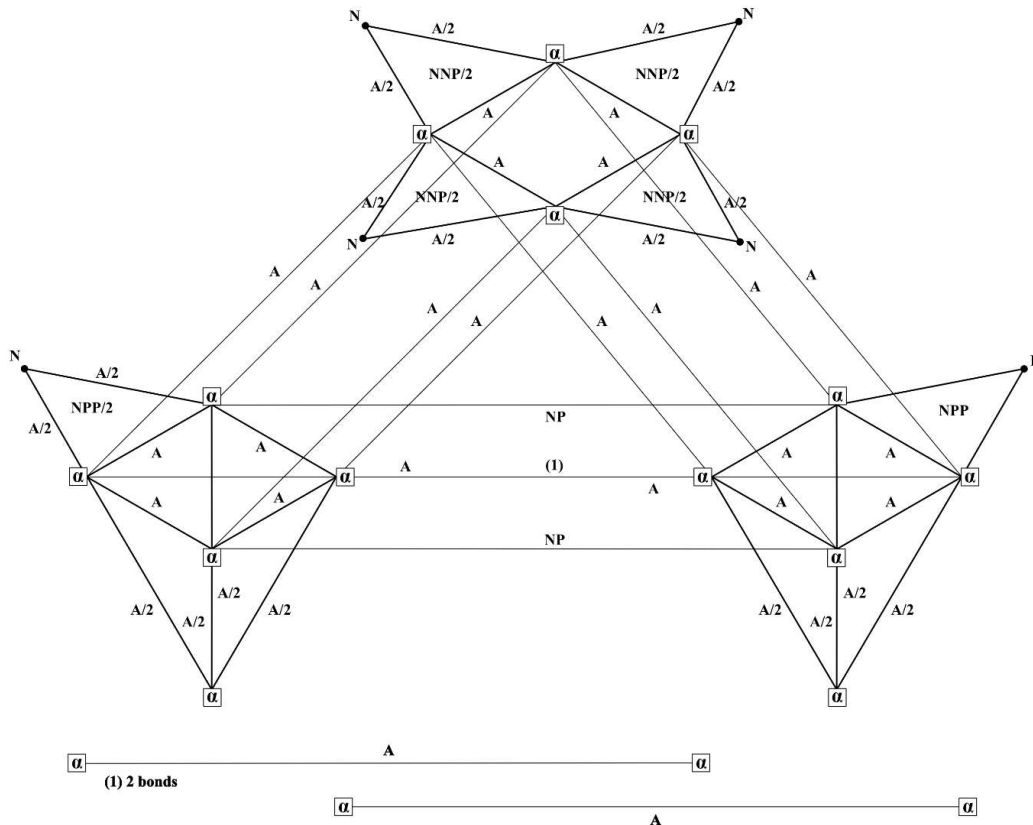
This nucleus is stable.

⁶²₂₉ Cu

Structure: 14 α, 5 N, 1 P

Linear and cross bonds: 26A, 2 NP

N, P supplementary bonds: 5A, 2 NNP, 1.5 NPP



⁶²₂₉ Cu

14α, 5N, 1P supplementary

EB in MeV = 540.5210

Lifetime: 9.8 min

Modes of decay: β⁺, EC

$\left\{ \begin{array}{l} 14 \\ (7+6) \\ (7+8) \\ 0 \\ 0 \\ 2.5 \\ 2.5 \\ 2 \\ 1.5 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			64.1745	
			33.3690	
			0	
			0	
			12.3413	
			5.5615	
			16.9636	
			<u>11.5770</u>	
			540.5369	MeV
+ 0.016				

Figure 13. Binding energy distribution among ⁶²₂₉ Cu.

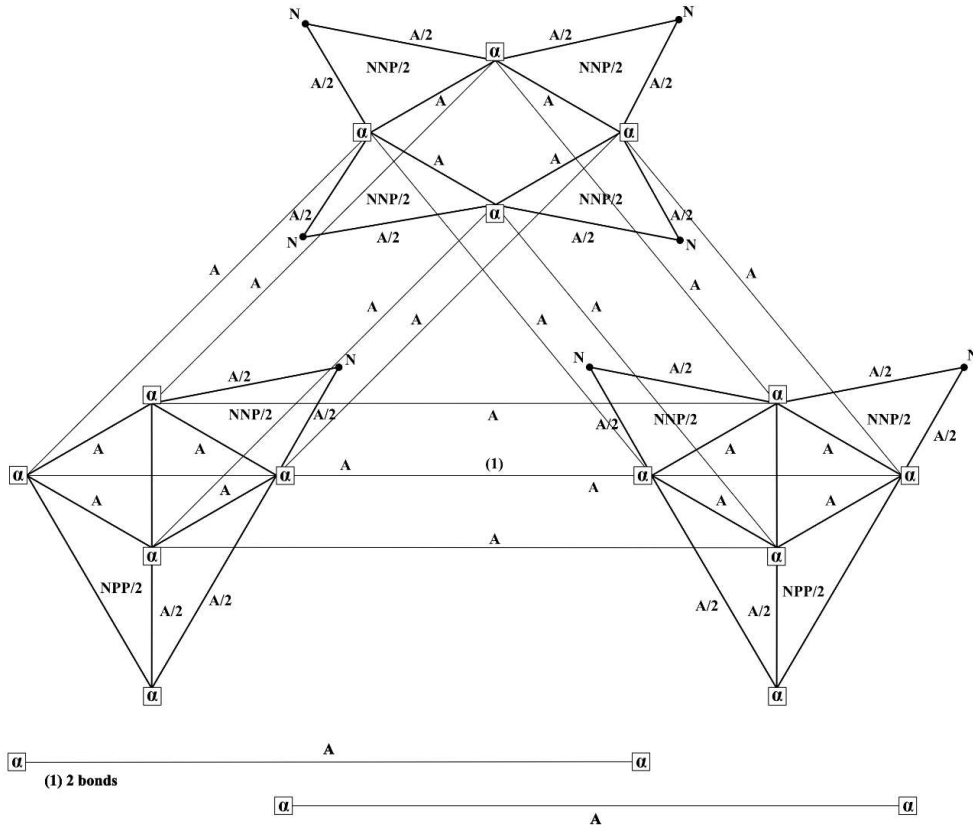
2 NP bonds are remaining in the core of the nucleus, this nucleus is not stable.

⁶³₂₈ Ni

Structure: 14 α, 7 N, 0 P

Linear and cross bonds: 26A, 1 NPP

N supplementary bonds: 7A, 3.5 NNP



⁶³₂₈ Ni

14α, 7N, 0P supplementary

EB in MeV = 552.1001

Lifetime: 92 years

Mode of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+6) \\ (7+6) \\ 0 \\ 1 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV			
			64.1745				
			28.9198				
			0				
			7.7180				
			$\left\{ \begin{array}{l} 3.5 \\ 3.5 \\ 3.5 \\ 0 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	17.2778	
						7.7861	
						29.6863	
0							
			552.1125	MeV			
			+ 0.012				

Figure 14. Binding energy distribution among ⁶³₂₈ Ni.

The core is stable. There are 7 N supplementary. This nucleus is submitted to β⁻ decay which transforms a N into P; in the present case Ni 63 is transmuted into Cu 63. On the contrary of β⁺ decay which concerns the core of the nucleus the β⁻ decay concerns the supplementary neutrons transformed one by one into protons since a new equilibrium is found within a nucleus.

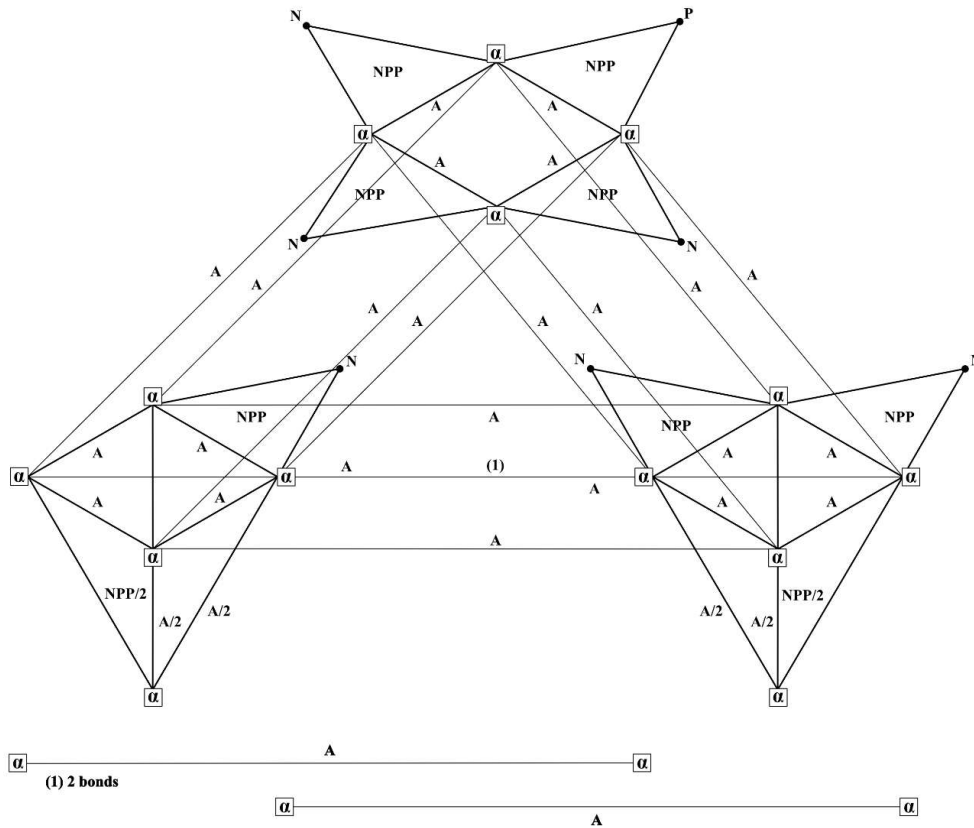
The 7 N supplementary are bound to the α particles with 7A (3.5 NN + 3.5 NP) + 3.5 NNP bonds.

⁶³₂₉ Cu

Structure: 14 α, 6 N, 1 P

Linear and cross bonds: 26A, 1 NPP

N, P supplementary bonds: 7 NPP



⁶³₂₉ Cu

14α, 6N, 1P supplementary

EB in MeV = 551.3847

Stable	$\left\{ \begin{array}{l} 14 \\ (7+6) \\ (7+6) \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 7 \end{array} \right\} \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV	
Nat. abundance: 69.2 %			64.1745	
			28.9198	
			0	
			7.7180	
			0	
			0	
			0	
		54.0260		
		551.3883	MeV	
		+ 0.004		

Figure 15. Binding energy distribution among ⁶³Cu.

This nucleus is stable. Its structure is comparable to that one of Ni 63.

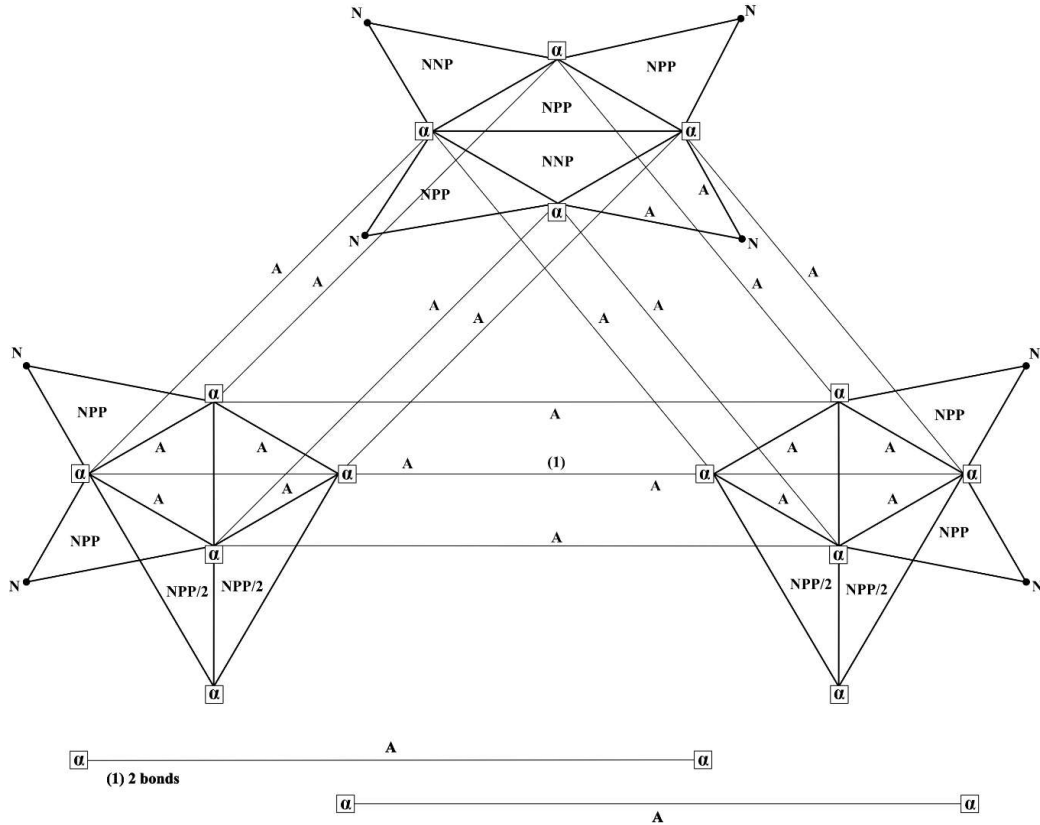
Actually, 7A bonds (3.5NN + 3.5NP) + 3.5 NNP bonds are transformed into 7 NPP bonds.

⁶⁴₂₈Ni

Structure: 14 α, 8 N, 0 P

Linear and cross bonds: 20A, 1 NNP, 3 NPP

N supplementary bonds: 2A, 1 NNP, 6 NPP



⁶⁴₂₈Ni

14α, 8N, 0P supplementary

EB in MeV = 561.7575

Stable	$\left\{ \begin{array}{l} 14 \\ (7+3) \\ (7+3) \\ 1 \\ 3 \end{array} \right\}$	x	28.325	$\left. \begin{array}{l} 396.5500 \\ 49.3650 \\ 22.2460 \\ 8.4818 \\ 23.1540 \end{array} \right\}$	MeV
Nat. abundance: 0.91 %		x	4.9365		
		x	2.2246		
		x	8.4818		
		x	7.7180		
		x	7.7180		
	$\left\{ \begin{array}{l} 1 \\ 1 \\ 1 \\ 6 \end{array} \right\}$	x	4.9365	$\left. \begin{array}{l} 4.9365 \\ 2.2246 \\ 8.4818 \\ 46.3080 \end{array} \right\}$	
		x	2.2246		
		x	8.4818		
		x	7.7180		
				<u>561.7477</u>	MeV
				-0.010	

Figure 16. Binding energy distribution among ⁶⁴₂₈Ni.

This nucleus is stable. It is comparable to ⁶²₂₈Ni. (See figure 12).

EB Ni64 = EB Ni62 + NNP + 1.5 NPP - A.

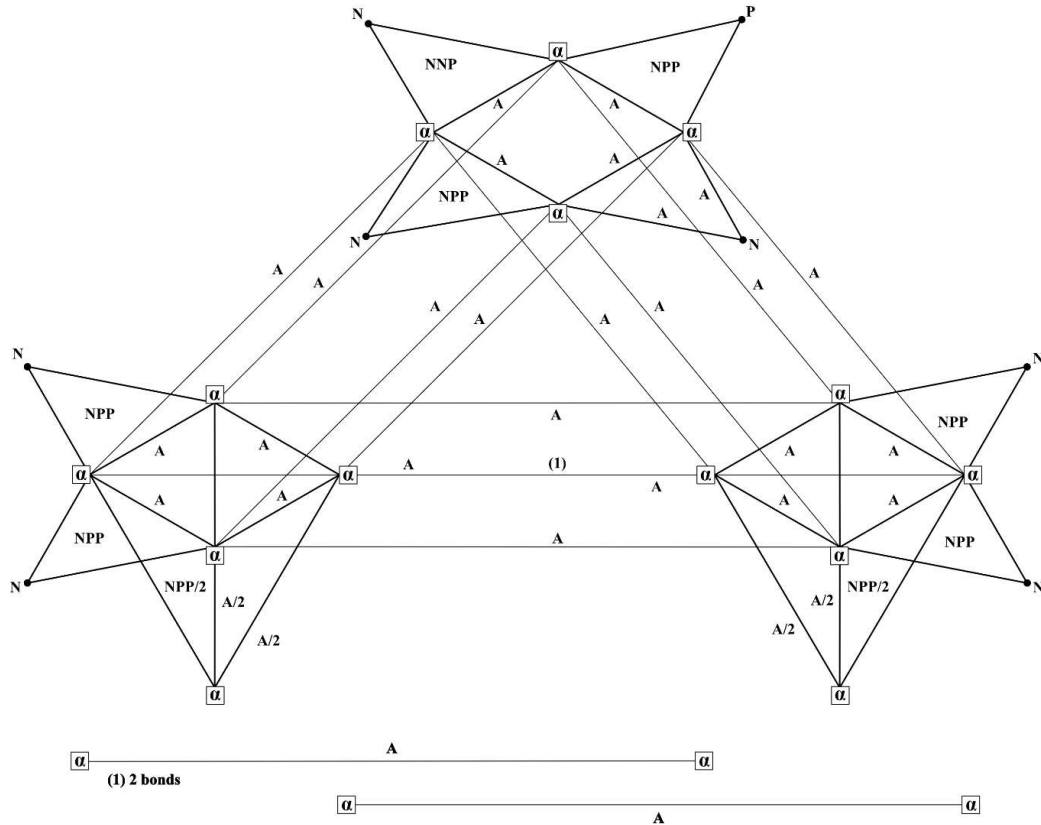
The addition of 2 N has yield a binding energy of NNP + 1.5 NPP - A.

⁶⁴₂₉Cu

Structure: 14 α, 7 N, 1 P

Linear and cross bonds: 26A, NPP

N, P supplementary bonds: 2A, 1 NNP, 6 NPP



⁶⁴₂₉Cu

14α, 7N, 1P supplementary

EB in MeV = 559.3008

Lifetime: 12.9 hours

Modes of decay: β⁺, EC

$\left. \begin{array}{l} 14 \\ (7+6) \\ (7+6) \\ 0 \\ 1 \\ 1 \\ 1 \\ 1 \\ 6 \end{array} \right\}$	$\begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array}$	$\left. \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			64.1745	
			28.9198	
			0	
			7.7180	
			4.9365	
			2.2246	
			8.4818	
			46.3080	
			559.3132	MeV
			+ 0.012	

Figure 17. Binding energy distribution among ⁶⁴₂₉Cu.

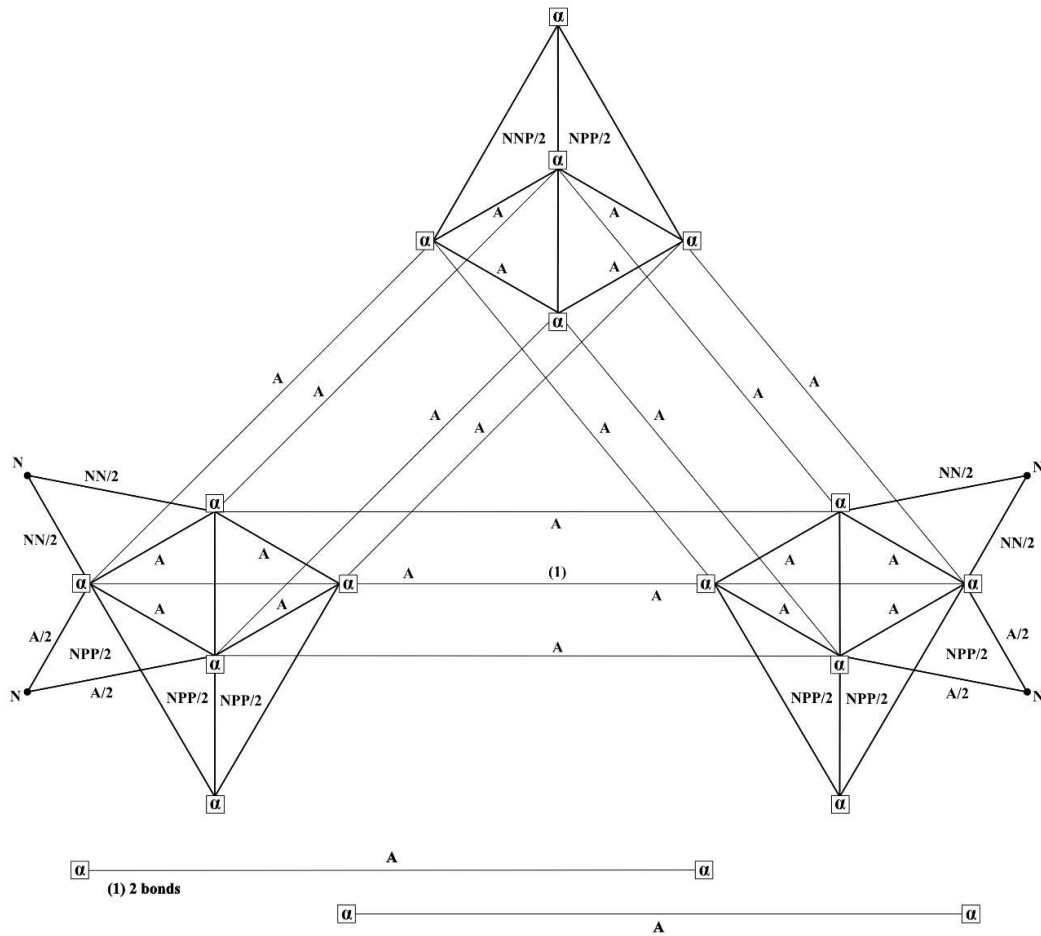
Cu 64 has the same core structure as Cu63 and the same outside core structure as Ni64. A β⁺, EC decay occurs: the P is modified into N and 6A (3NN + 3NP) are transformed into one NNP and two NPP. Cu64 is transmuted into Ni64.

⁶⁴₃₀Zn

Structure: 15 α , 4 N, 0 P

Linear and cross bonds: 24A, 0.5 NNP, 2.5 NPP

N supplementary bonds: 2A, 2 NN, 1 NPP



⁶⁴₃₀Zn

15 α , 4N, 0P supplementary

EB in MeV = 559.0979

Stable	$\left\{ \begin{array}{l} 15 \\ (7.5+4.5) \\ (7.5+4.5) \\ 0.5 \\ 2.5 \\ 3 \\ 1 \\ 0 \\ 1 \end{array} \right\} \left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\} \left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	424.8750	MeV
Nat. abundance: 48.6%		59.2380	
		26.6952	
		4.2409	
		19.2950	
		14.8095	
		2.2246	
		0	
		7.7180	
		559.0962	MeV
	- 0.002		

Figure 18. Binding energy distribution among ⁶⁴₃₀Zn.

Cu64 is also submitted to β^- decay, together with β^+ , EC decays.

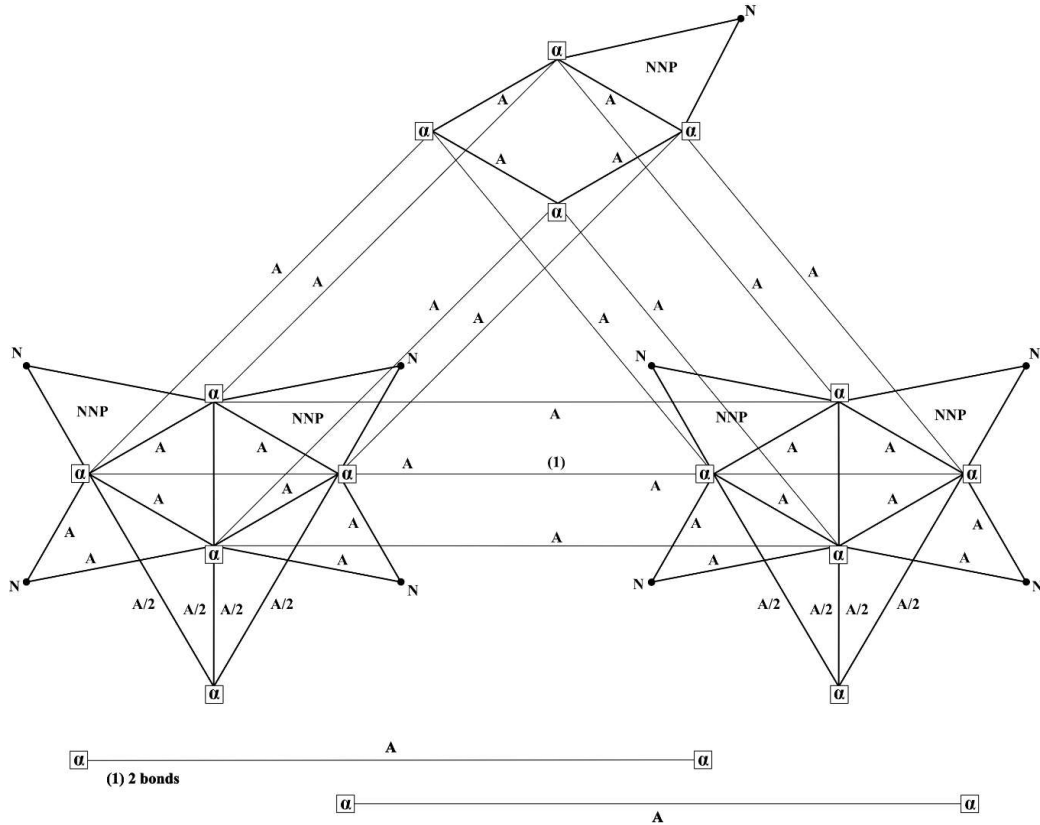
So, a β^- decay occurs within ⁶⁴₂₉Cu and a α particle is created. ⁶⁴₂₉Cu is transmuted into ⁶⁴₃₀Zn.

⁶⁵₂₈Ni

Structure: 14 α, 9 N, 0 P

Linear and cross bonds: 28A

N supplementary bonds: 8A, 5 NNP



⁶⁵₂₈Ni

14α, 9N, 0P supplementary

EB in MeV = 567.8556

Lifetime: 2.52 hours

Mode of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 4 \\ 4 \\ 5 \\ 0 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			69.1110	
			31.1444	
			0	
			0	
			19.7460	
			8.8984	
			42.4090	
			0	
			<u>567.8588</u>	MeV
+ 0.003				

Figure 19. Binding energy distribution among ⁶⁵₂₈Ni.

Too many supplementary N are occurring a β⁻ decay, Ni65 is transformed into Cu65.

1 NNP is transformed into NPP/2 + NP, N becoming a P.

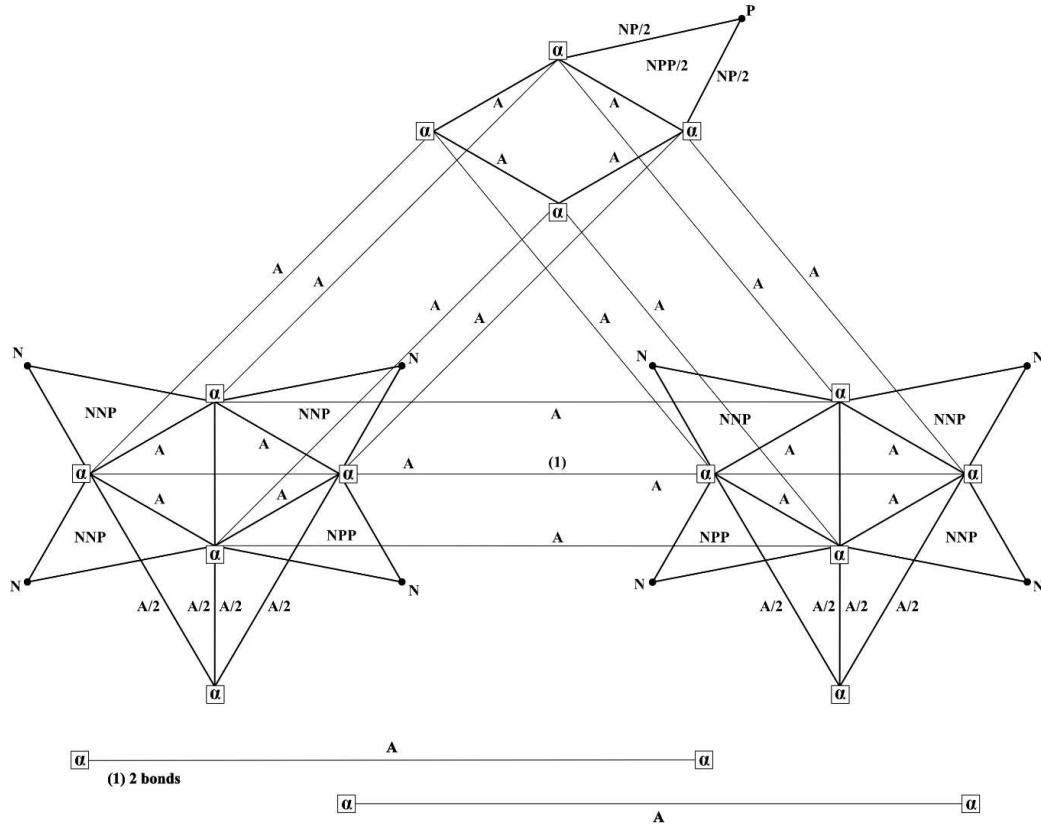
8A (4 NN + 4 NP) are transformed into 2 NNP + 2 NPP.

⁶⁵₂₉ Cu

Structure: 14 α, 8 N, 1 P

Linear and cross bonds: 28A

N, P supplementary bonds: 1 NP, 6 NNP, 2.5 NPP



⁶⁵₂₉ Cu

14α, 8N, 1P supplementary

EB in MeV = 569.2112

Stable	$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 0 \\ 1 \\ 6 \\ 2.5 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
Nat. abundance: 30.8 %				69.1110	
				31.1444	
				0	
				0	
				0	
				2.2246	
				50.8908	
	19.2950				
	569.2158	MeV			
	+ 0.005				

Figure 20. Binding energy distribution among ⁶⁵Cu.

This nucleus is stable.

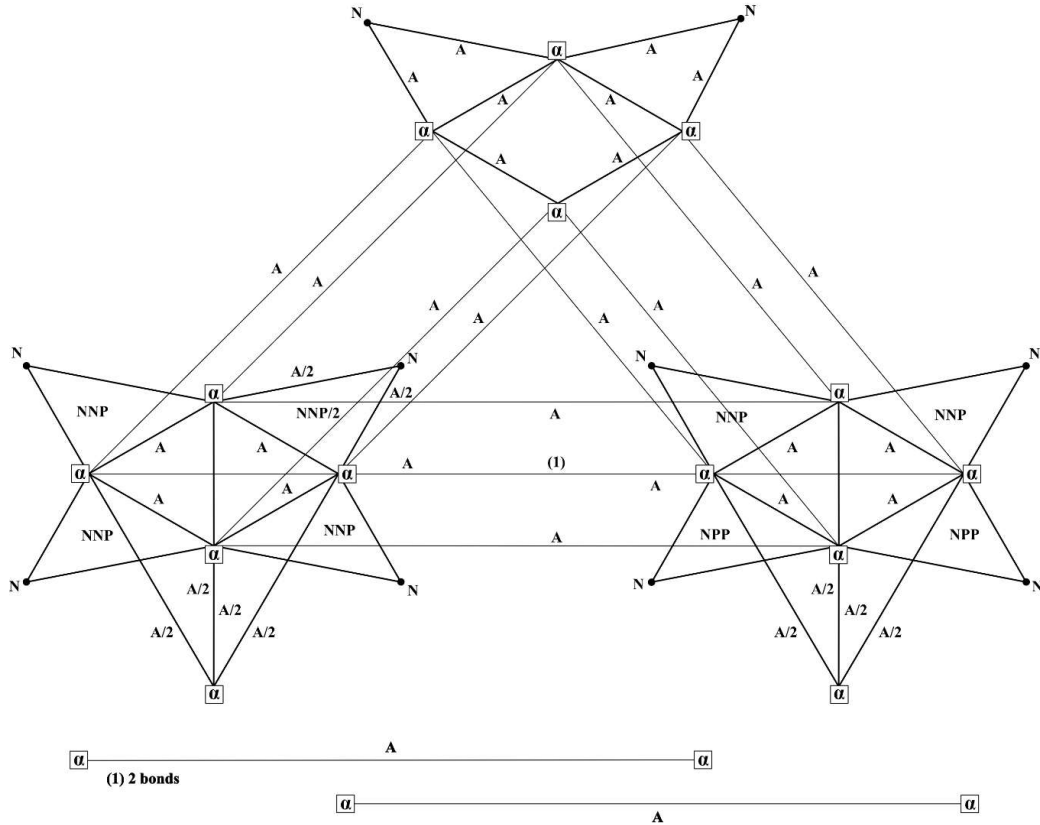
This nuclide is the last stable one as far as Nickel and Copper are concerned. Beyond the nuclides are submitted to β⁻ decay.

⁶⁶₂₈Ni

Structure: 14 α, 10 N, 0 P

Linear and cross bonds: 28A

N supplementary bonds: 5A, 5.5 NNP, 2 NPP



⁶⁶₂₈Ni

14α, 10N, 0P supplementary

EB in MeV = 576.8075

Lifetime: 54.6 hours

Mode of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 2.5 \\ 2.5 \\ 5.5 \\ 2 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			69.1110	
			31.1444	
			0	
			0	
			12.3413	
			5.5615	
			46.6499	
			15.4360	
			<u>576.7941</u>	MeV
-0.013				

Figure 21. Binding energy distribution among ⁶⁶₂₈Ni.

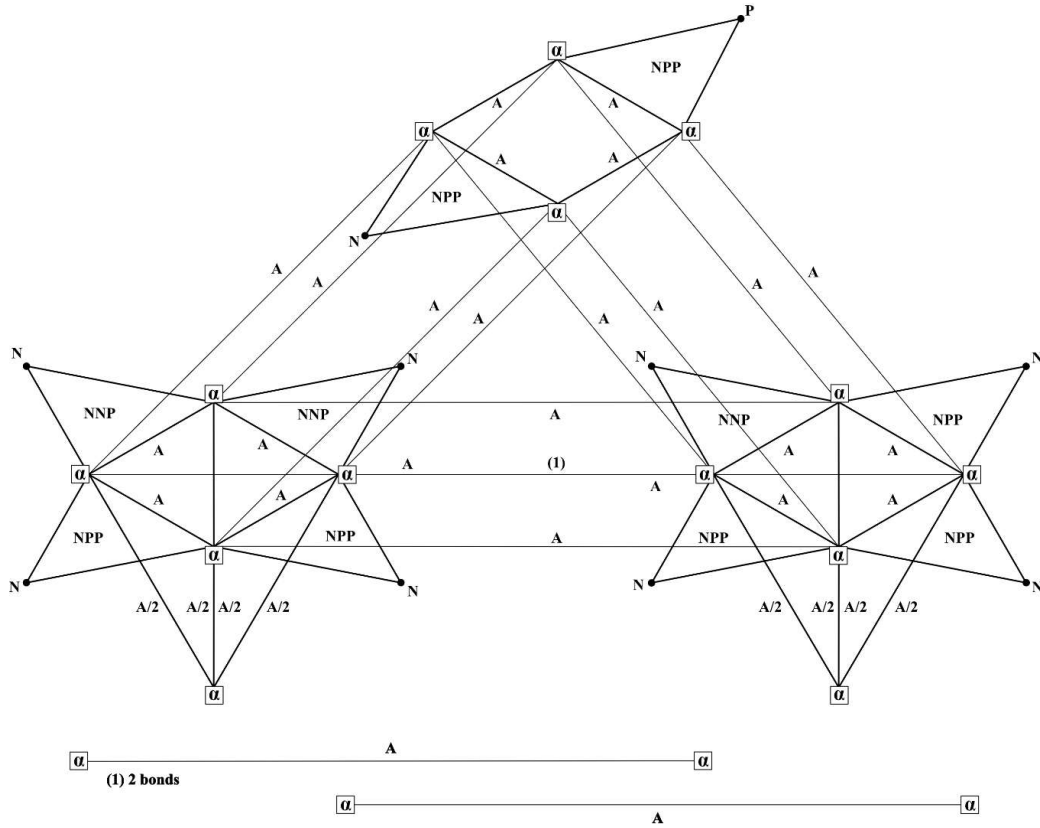
As for Ni65 there are too many supplementary N, Ni66 is transmuted into Cu66.

⁶⁶₂₉ Cu

Structure: 14 α, 9 N, 1 P

Linear and cross bonds: 28A

N, P supplementary bonds: 3 NNP, 7 NPP



⁶⁶₂₉ Cu

14α, 9N, 1P supplementary

EB in MeV = 576.2772

Lifetime: 5.10 minutes

Modes of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 0 \\ 0 \\ 3 \\ 7 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			69.1110	
			31.1444	
			0	
			0	
			0	
			0	
			25.4454	
			54.0260	
			<u>576.2768</u>	MeV
				/

Figure 22. Binding energy distribution among ⁶⁶₂₉ Cu.

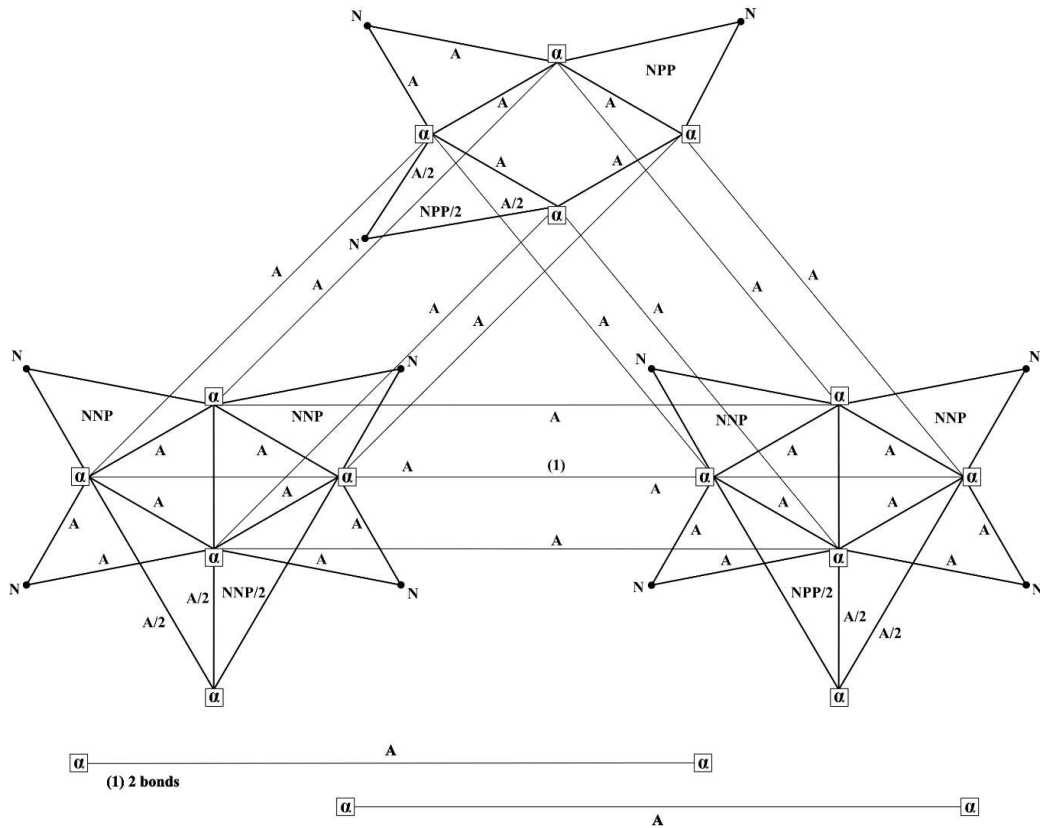
Compared with ⁶⁶₂₈ Ni (see figure 21), 5A bonds and 2.5 NNP bonds are transformed into 5 NPP bonds. There are too many supplementary N. Note the similarity between ⁶⁴₂₉ Cu and ⁶⁶₂₉ Cu. EB ⁶⁴₂₉ Cu + 2 NNP = EB ⁶⁶₂₉ Cu. The addition of 2 N has yield 2 NNP.

⁶⁷₂₈Ni

Structure: 14 α, 11 N, 0 P

Linear and cross bonds: 26A, NNP/2, NPP/2

N supplementary bonds: 11A, 4 NNP, 1.5 NPP



⁶⁷₂₈Ni

14α, 11N, 0P supplementary

EB in MeV = 582.6153

Lifetime: 50 seconds

Mode of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+6) \\ (7+6) \\ 0.5 \\ 0.5 \\ 5.5 \\ 5.5 \\ 4 \\ 1.5 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			64.1745	
			28.9198	
			4.2409	
			3.8590	
			27.1508	
			12.2353	
			33.9272	
			11.5770	
			<u>582.6345</u>	MeV
+ 0.019				

Figure 23. Binding energy distribution among ⁶⁷₂₈Ni.

There are too many supplementary N, a β⁻ decay occurs.

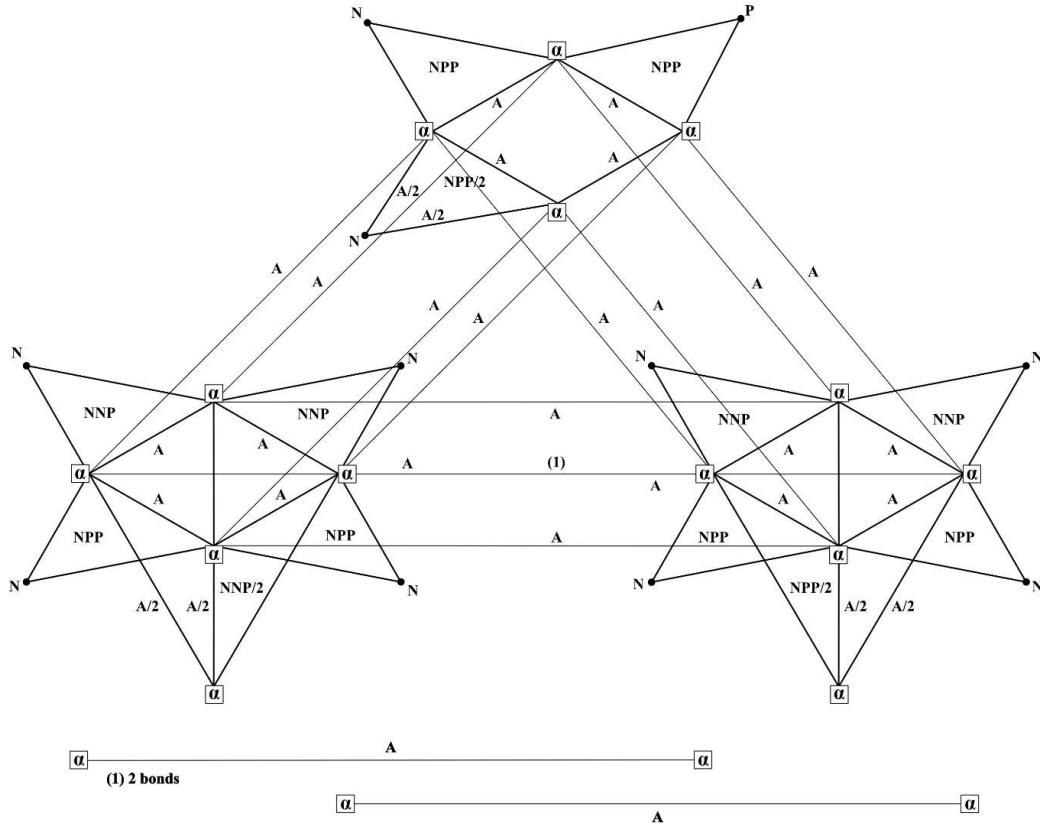
EB Ni67 = EB Ni66 + 4A - NNP.

⁶⁷₂₉ Cu

Structure: 14 α, 10 N, 1 P

Linear and cross bonds: 26A, NNP/2, NPP/2

N, P supplementary bonds: A, 4 NNP, 6.5 NPP



⁶⁷₂₉ Cu

14α, 10N, 1P supplementary

EB in MeV = 585.4097

Lifetime: 61.88 hours

Modes of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+6) \\ (7+6) \\ 0.5 \\ 0.5 \\ 0.5 \\ 0.5 \\ 4 \\ 6.5 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			64.1745	
			28.9198	
			4.2409	
			3.8590	
			2.4683	
			1.1123	
			33.9272	
			50.1670	
			<u>585.4190</u>	MeV
+ 0.009				

Figure 24. Binding energy distribution among ⁶⁷Cu.

Compared with ⁶⁷₂₈ Ni, 10A (5 NN + 5 NP) are transformed into 5 NPP.

Here also there are too many supplementary N.

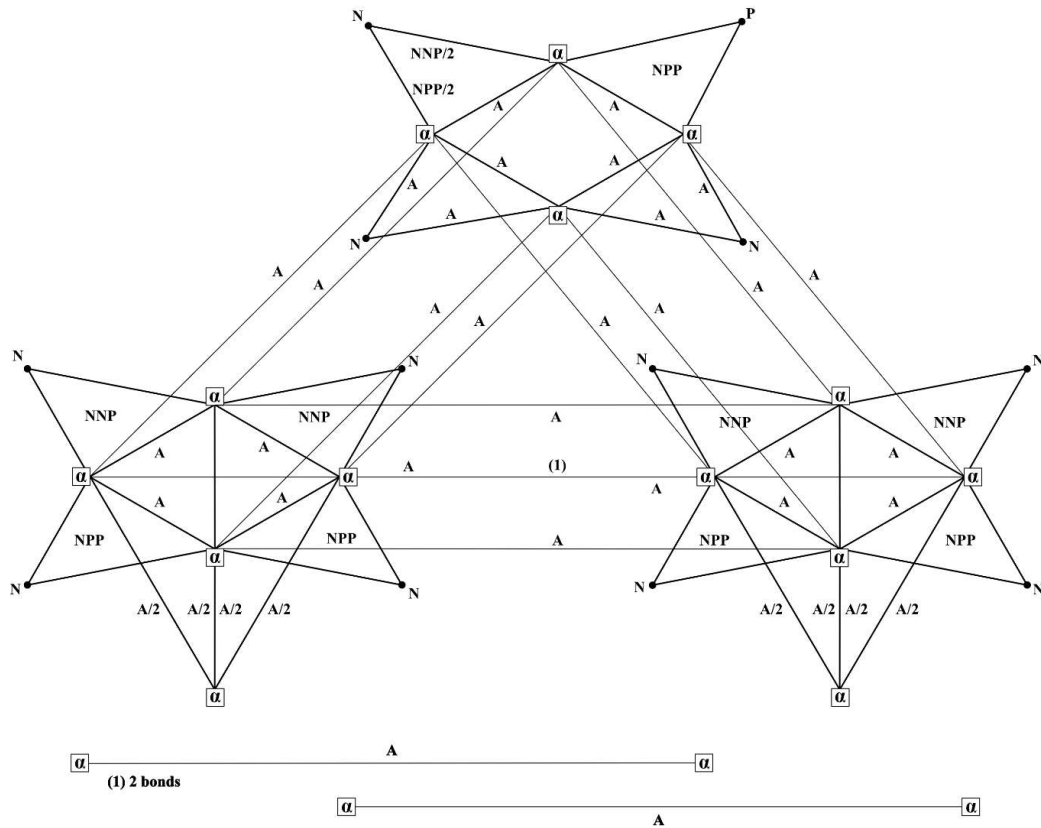
Also, EB Cu67 = EB Cu66 - A + 1.5 NNP.

⁶⁸₂₉Cu

Structure: 14 α, 11 N, 1 P

Linear and cross bonds: 28A

N supplementary bonds: 4A, 4.5 NNP, 5.5 NPP



⁶⁸₂₉Cu

14α, 11N, 1P supplementary

EB in MeV = 591.7285

Lifetime: 30 seconds

Modes of decay: β⁻

$\left\{ \begin{array}{l} 14 \\ (7+7) \\ (7+7) \\ 0 \\ 0 \\ 2 \\ 2 \\ 4.5 \\ 5.5 \end{array} \right\}$	$\left\{ \begin{array}{l} x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \\ x \end{array} \right\}$	$\left\{ \begin{array}{l} 28.325 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \\ 4.9365 \\ 2.2246 \\ 8.4818 \\ 7.7180 \end{array} \right\}$	396.5500	MeV
			69.1110	
			31.1444	
			0	
			0	
			9.8730	
			4.4492	
			38.1681	
			42.4490	
			<u>591.7447</u>	MeV
+ 0.016				

Figure 25. Binding energy distribution among ⁶⁸Cu.

There are too many N supplementary, hence a β⁻ decay.

$${}^{68}_{29}\text{Cu} = {}^{67}_{29}\text{Cu} + 5A - 1.5\text{NPP}.$$