Statistical Research of Nuclide’s Shell Structure

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Abstract: This thesis, after a systematic and in-depth analysis of known nuclides, proposes a new model of nuclides’ shell structure and offers a table of the shell structures of 935 nuclides. With this theoretic approach, the thesis studies the shell combination with a bias towards the statistical analysis of nuclide structures. This thesis distinguishes between the basic models of nuclides and gives 7 criteria for nuclide binding, the maximal nucleonic number of each shell \( \Delta A \), combination of proton and neutron \( p/n \) and graphs of the nuclide growth. Based on magnetic moment, it also conducts a quantitative analysis of \( p/n \) on the shell. The nuclide structure has the characteristic of a shell and on every shell the combination of proton and neutron features clear regularity. Among the 106 elements from \(^1\text{H}\) to \(^{263}\text{Sg}\) the serial number of the most outside shell in structure is 7, and nuclides \(^{262}\text{Ha}\) and \(^{263}\text{Sg}\) are respectively even \( A \) and odd \( A \) 7 shells. It is not a coincidence but a reflection of the nuclide shell structure. The thesis uses the result of a statistical analysis to confirm the existence of “the magic Number” and reveals the fact that the magic number” is a reflection of \( p/n \) on nuclide shell, particularly on the outer shells. The statistical analysis reveals that the nuclide stability and its way of decay are dependent on the nucleonic combination on the most outside shell and the matching between full-filled and semi-full filled \( p/n \), thus unveiling the general law governing the stability and decay of nuclides.

Keywords: Nuclide Shell Structure, \( p/n \) (Mass Rate of Proton and Neutron), Criteria of Nuclide Binding, Graphs of Nuclide Growth, Table of Nuclide Shell Structure

1. Introduction

In 1940s M.G. Mayer discovered that the number of protons and neutrons is 2, 8, 20, 28, 50, 82, 126 and so on. This kind of nuclides has a special stability. This characteristic is called “the magic number” law. The existence of “the magic number” indicates that the nuclide is characteristic of a shell structure. Afterwards, M.G. Mayer and J.H.D Jensen proposed, with the nuclide independent motion as its theoretic basis, the shell structure of nuclides and as a result explained the “magic number” law. [1]

The Mayer’s shell structure model solved the magic numbers of 2, 8 and 20 first by using potential energy function of nuclear central force field in the model of harmonic oscillator potential well and square potential well. Then, with the analysis of splitting of energy levels, other magic numbers are obtained.

Mayer’s shell structure is good in many ways. For an example, it successfully explains the characters of double magic-number nuclides and their near-by ones in both theory and experiment. But there are many examples showing great differences between prediction and experiment such as electric quadruple moment of nucleon and magnetic moment of baryon odd-A nuclide. To solve the problem, A. Bohr B. R. Mottelson and L. J. Rainwater proposed the model of collective motion. [2] However neither of the models gave specific from of the nuclide shell structure.

We hold that circumstances inside and outside nuclear are entirely different. Inside it is similar to a free space while outside it has a powerful nuclear force. So there is no electronic orbiting motion and no steady-state distribution inside nuclear. Therefore, the model of nucleon shell structure is most likely an approximate description of the nuclide shell structure. The model we offer in this paper is different from the thought of Mayer, A. Bohr et al and it is based on classification of basic models of nuclides and on statistical analysis of nuclides.
2. Statistical Characteristics of Nuclide Shell Structure

Shell structure of a nuclear is a necessary result of direct proportion between its volume and its nucleide number. The volume $V$ of a nuclear is

$$V = \frac{4}{3} \pi r_0^3 A$$  \hspace{1cm} (1)

In which radius $r_0$ ($r_0 = 1.21 \times 10^{-15} m$) is a constant obtained from experiment.[3] It is known that each nucleon has similar mass and identical volume. Suppose the nucleon inside the nuclear takes up an average space of a sphere with a radius $r_0$, the nucleide shell structure could be composed with diameter $r_0$. Suppose the average space between shells is a sphere with diameter $r_0$, and the distance between two nearby shells is $\sim r_0$; too, the geometric space $\Delta N_i$ of No.$i$ shell is as follows, for the volume is directly proportional to nucleonic number:

$$\Delta N_i = \frac{\frac{4}{3} \pi (r_0)^3 - \frac{4}{3} \pi [i-(i-1)]r_0^3}{\frac{4}{3} \pi r_0^3} = i^3 - (i-1)^3$$  \hspace{1cm} (2)

In the formula (2), if “i” is 1, 2, 3, 4, 5, 6 or 7, $\Delta N_i$ must respectively be 1, 7, 19, 37, 61, 91 or 127, indicating geometric space of shell layers in terms of nucleide numbers. To make a distinction, nucleide with “i” shells is called $k$-shell nucleide. For instance $^{16}_8$O$_8$ could be called 3-shell nucleide and its second shell has 4 nucleons.

There is nuclear force between nucleons, so they cannot be indefinitely close to each other. Except for $i=1$, no shell can be covered with the maximal number of nucleons as given in formula (2). Nucleons do not fully occupy the geometric space of the shell either. The nucleide shell structure is shown in Fig. (1).

Suppose the actual maximal number of nucleons contained on $i$ shell structure is $A_i$, $\Delta A_i \leq \Delta N_i$. $\Delta A_i / \Delta N_i$ represents the ratio of nucleons occupation of the shell space and reflects the fullness of nucleons. The proton-neutron ratio of each shell, called $p/n$ for short, indicates the nucleonic combination on each shell. Interdigitation distribution of nucleons on shells.

It is found that, if even $A$ nuclides are “hollow” and odd $A$ nuclides are “neutron centered” except for Hydrogen (H) nuclides, the shapes of nuclide shell structures may be obtained according of the pairing characteristics of nucleons and the quantitative relationship of magnetic moment. Through statistical analysis of nuclides, we propose the 7-shell structure of known nuclides. Statistical analysis shows:

(1) There could be only one nucleon on the first shell, and it is always filled by neutron except for element H;

(2) The maximal number $\Delta A_2$ of nucleon on the second shell is 4, that is, $\Delta A_2 = 4$, so $\Delta A_2 / \Delta N_2 = 0.5714$. When the second shell is full filled, the $p/n = 2/2$;

(3) On the 3rd shell, $\Delta A_3 = 12$, $\Delta A_3 / \Delta N_3 = 0.6316$. If the 3rd shell is the most outside and full-filled, its p/n has only two combinations: $p/n = 6/6$ and $p/n = 5/7$;

(4) On the 4th shell, $\Delta A_4 = 24$, $\Delta A_4 / \Delta N_4 = 0.6486$, the $p/n$ of the full-filled shell has only two combi-nations:12/12 and 10/14;

(5) On the 5th shell, $\Delta A_5 = 48$, $\Delta A_5 / \Delta N_5 = 0.7868$, the $p/n$ of the full-filled shell has only two combinations: 20/28 and 18/30;

(6) On the 6th shell, $\Delta A_6 = 72$, $\Delta A_6 / \Delta N_6 = 0.7912$, the $p/n$ of the full-filled shell has only two combinations: 28/44 and 26/46;

(7) On the 7th shell, $\Delta A_7 = 102$, $\Delta A_7 / \Delta N_7 = 0.8031$, the $p/n$ of the full-filled shell has only two combinations: 44/58 and 42/60.

Except for the first and second shells, there are two kinds of stable combinations when the shell is full-filled. The first kind, represented by I, is full-proton combination and the second kind, represented by II, is full-neutron combination. The objectivity of $p/n$ combination on each shell is a decisive factor for determine the model quality. Further quantitative analysis will be given in the following discussion of nucleonic magnetic moment.

![Fig. 1. The Model of Nuclide Shell Structure.](image)

In the diagram, the distance between two nearby cells is “$r_0$“. Black circles stand for protons and grey ones for neutrons. Full-filled nucleon numbers of the 4th, 5th, 6th, and 7th, shells are 24, 48, 72 and 102 respectively.
3. Basic Classification of Nuclides of Determination of ∆A_i

For the maximal nucleonic number a A_i the shell can actually contain, the statistics of ∆A_i = 1, ∆A_i = 4, ∆A_i = 12, ∆A_i = 24, ∆A_i = 48, ∆A_i = 72, ∆A_i = 102 provided by us is of important significance for the statistic models of plastic shell structure. In implementation this group of statistics may be of even ratio tend to increase. Therefore, we come to the following judgment:

\[ ∆A_i/∆N_i < ∆A_2/∆N_2 < ∆A_3/∆N_3 < ∆A_4/∆N_4 < ∆A_5/∆N_5 < ∆A_6/∆N_6 < ∆A_7/∆N_7 < α \]  (3)

A being an actual number smaller than 1. [4]

The ∆A_i may be deduced from the relationship shown in Formula (3) and the stability of corresponding nuclides. Taking even A nucleus as an example, we know that the helium (He) nucleus has stable nuclides of sphere symmetry and is often used as bullet to attack other nuclei. From this we infer that 1/2 He is the even A full-filled nucleus of the second shell level and ∆A_2 = 4, ∆A_2/∆N_2 = 4/7 = 0.571.

For even A nuclides of the 3rd shell level, the abundance is

\[ ∆A_3/∆N_3 = ∆A_3/19 > 0.571 \]  (4)

So ∆A_3 > 10.894. Noticing the characteristic of even integer of even A, ∆A_3 can only be chosen from among 12, 14, 16 and 18. Since 18/19 = 1, as a matter of fact ∆A_3 can only be chosen from 12, 14 and 16. Again, because the nucleus number of full-filled nuclides of Even A of 2nd shell level is 4, the nucleus number of full-filled nuclides of even A of 3rd shell level can only be taken from 16, 18 and 20. Seeing that the nuclides have nucleus numbers are 18 and 20 lack high abundance stability, the nucleus number of even A full-filled nuclides of the 3rd shell level can be none other than 16 and the corresponding nuclide is 16\(^8\) O_8. ∆A_3 = 12, ∆A_3/∆N_3 = 12/19 = 0.6316.

For full-filled nuclides of even A of the 4th shell level, because

\[ ∆A_4/∆N_4 = ∆A_4/37 > 0.6316 \]  (5)

∆A_4 > 23.369, so ∆A_4 can only be chosen from among 24, 26, 28 and 30. The corresponding full-filled nucleus numbers of even A are respectively 40, 42, 44 and 46. We notice that none of the nucleus numbers 42, 44 and 46 have nuclides of high abundance stability while A = 40 has two nuclides of high abundance of stability: 40\(^\text{Ar}_{22}\) and 40\(^\text{Ca}_{20}\), and their natural abundance is 99.60 and 96.94. The full-filled nuclides have good stability, and from this we can judge that the full-filled nucleus number of even A of the 4th shell level is 40. ∆A_4 = 24, ∆A_4/∆N_4 = 24/37 = 0.6486.

For full-filled nuclides of even A of the 5th shell level, ∆A_5/∆N_5 = ∆A_5/61 > 0.6486  (6)

∆A_5 > 39.56, so A_5 can only be chosen from among 40, 42, 44, 46, 48 and 50. Because even A nucleus A_4 = 40, the full-filled nucleus numbers of even A of the 5th shell level are respectively 80, 82, 84, 86, 88 and 90. From the analysis of the abundance of stable nuclides, we can infer that the full-filled nucleus number of even A of the 5th shell level is 88, the corresponding nuclide is 88\(^\text{Sr}_{50}\) and the abundance is 82.60. ∆A_5 = 48, ∆A_5/∆N_5 = 48/61 = 0.7869.

For full-filled nuclides of even A of the 6th shell level, ∆A_6/∆N_6 = ∆A_6/91 > 0.7869  (7)

∆A_6 > 71.608, so ∆A_6 can only be selected from among 72, 74, 76, 78 and 80 and the corresponding the full-filled nucleus numbers of even A are respectively 160, 162, 164, 166 and 168. From the ratio between ∆A_i and ∆N_i, we can see that the ∆A_i/∆N_i values of the 3rd and 4th shell levels are close to each other and the ∆A_i/∆N_i value of the 5th shell level is clearly enlarged. Because ∆A_5/∆N_5 < α < 1, the ∆A_i/∆N_i and ∆A_i/∆N_i can not possibly maintain the increase rate of ∆A_i/∆N_i. From the analysis of the abundance of stable nuclides, it can be determined that the full-filled nucleus number of even A of the 6th shell level is 160 and the corresponding nuclides are respectively 160\(^\text{Gd}_{66}\) and 160\(^\text{Dy}_{84}\). ∆A_6 = 72, ∆A_6/∆N_6 = 72/91 = 0.7912.

Experiments reveal that the maximal nucleus number of even A nucleus is 262, which conforms to the characteristics of even A full-filled nucleus number of the 7th shell level. Since 262 is the biggest nucleus number of even A, it must be the number of full-filled nuclei. If A = 262, A_7 = 102, A_7/∆N_7 = 102/127 = 0.8031, which fully agrees to the relationship shown in Formula 3. From this we can come to the following judgment: 262 is the full-filled nucleus number of even A of...
the 7th shell level, and the corresponding nuclides are respectively $^{263}\text{Hg}_{167}$ and $^{263}\text{Bi}_{135}$.

After the full-filled nucleus number of even $A$ is determined, that of odd $A$ is at the same time determined. Because the even $A$ nuclei are hollow nuclides and the odd $A$ nuclei are neutron-star nuclides, the addition of one nucleus to even $A$ full-filled nuclei does not alter the nucleus number at various shell levels. From this we know that the full-filled nucleus numbers of odd $A$ are respectively $A1=1$, $A2=5$, $A3=17$, $A4=41$, $A5=89$, $A6=161$ and $A7=263$. The corresponding nuclides are respectively $^{1}\text{H}_1$, $^{17}\text{O}_8$, $^{41}\text{K}_{22}$, $^{89}\text{Y}_{39}$, $^{161}\text{Dy}_{66}$ and $^{263}\text{Sg}_{106}$. Here, the nucleus numbers 41, 89 and 161 correspond to the nuclides $^{41}\text{K}_{22}$, $^{89}\text{Y}_{39}$ and $^{161}\text{Dy}_{66}$. This is an important enlightenment for us to better understand the fundamental categorization of nuclides. Especially, the heaviest nuclide $^{263}\text{Sg}_{106}$ of the laboratory exactly fills up the position of odd $A$ full-filled nucleus of the 7th shell level. It provides a convincing evidence for the fundamental classification method of nuclides.

4. Magnetic Moments and Combinations of Nuclei

The nucleus number $AA_i$ of the shell level offers a general description of the nucleus of the level. To conduct an in-depth analysis of the shell-level structure, we have to probe into the combinations of the shell level nuclei, so as to find the specific forms combination between protons and neutrons. The proton-neutron combination ratio $p/n$ at the shell level is determined by the pairing characteristics of nuclei and the quantitative relation of nuclear magnetic moments.

Nuclei pairing is the basic condition for the formation of nuclides. The fact that nuclei have magnetic moments means that, apart from nuclear force, there also exists electromagnetic force. Experiments show that the force between nuclei is related to the included angle of the nucleus spin angular momentum [5].

Let’s take even $A$ nuclei as an example. He2 is the nuclide of full-filled 2nd shell level. The nucleus of the first shell level is vacant. The 2nd level has 4 nuclei and the proton-neutron is $p2/n2=2/2$. O8 is the nuclides of the full-filled 3rd shell level. The proton-neutron ratios of the 2nd and 3rd levels are $p2/n2=2/2$ and $p3/n3=6/6$. Ca20 refers to the nuclides of the full-filled 4th shell level and the proton-neutron ratios of the 2nd, 3rd and 4th levels are $p2/n2=2/2$, $p3/n3=6/6$ and $p4/n4=12/12$. The 3 kinds of nuclides are all highly abundant and stable. This shows that the proton-neutron ratios of the 2nd, 3rd and 4th shell levels. This type of combinations is characteristic of one-to-one pairing between protons and neutrons. Please refer to Fig. 2 for nuclide pairing.

Nucleons of the same kind expel each other when in the same direction and attract each other when in opposite directions.

Nucleons of different kinds attract each other when in the same direction and expel each other when in opposite directions.

With more shell levels and more neutrons, the nuclei of high levels no longer have conditions for one-to-one pairing between protons and neutrons. But the proton-neutron ratio $(p/n)$ can be obtained by quantitative analysis of the ratio of nucleus magnetic moments. The magnetic force of nucleons is shown in Fig. 3 [6].

Magnetic moments of the same kind of nucleons attract each other when in the same direction and expel each other when in opposite directions.

Experiment tests show that the proton magnetic moment $\mu_p = 2.792847386 (63)$ $\mu_N$, the neutron magnetic moment $\mu_n = -1.91304275 (45)$ $\mu_N$ and their relative rate is

$$\frac{\mu_p}{\mu_n} = 1.46 \quad (8)$$

This relative rate represent the strength level of the eddy field caused by proton or neutron spin. Nucleons on stable shells are in a state of balance of electromagnetic force, i. e. the eddy fields of protons and neutrons are in mutual balance. Except such nuclides as $^{16}\text{O}_8$ and $^{40}\text{Ca}_{20}$, total balance of the proton and neutron eddy fields on all shells should be maintained. Formula (8) indicates that, when the $p/n$ of all shells approaches 1/1.46, the electromagnetic force is in balance on the whole. The nucleon number is a natural one and even-even nucleons tend to be stable. With the above characteristics in mind, we can give a semi-quantitative explanation about the combinations of $p/n$’s on all shells.
Statistical analysis reveals that \( p/n = 5/7, p/n = 10/14 \) and \( p/n = 20/28 \) are respectively a stable combination of the full-filled \( p/n \) of the 3\(^{\text{rd}}\), 4\(^{\text{th}}\) and 5\(^{\text{th}}\) shell. It is no co-incidence that the \( p/n \) rate of the 3 shells is 1/1.4. It is a manifestation of the magnetic moment of protons and neutrons and also a manifestation of the strength level of the eddy field caused by a proton or neutron spin. A stable shell is in a balance state of electromagnetic force and is full-filled with neutrons. For any shell, if the quantity of protons is \( p_i \), the quantity of neutrons \( n_i \approx 1.46 p_i \). Thus, we have the following:

\[
P_i + n_i = p_i + 1.46 p_i = A_i. \tag{9}
\]

In the formula, \( A_i \) stands for the maximal number of nucleon “\( i \)” shell. If \( p_i \) is figured out, the nucleonic combination on “\( i \)” shell can be known.

For the 3\(^{\text{rd}}\) shell

\[
p_3 = 1.46 p_3 = 12, p_3 = 4.88,
\]

After rounding it off to an integer

\[
p_3 = 5, n_3 = 7, p_3/n_3 = 5/7.
\]

For the 4\(^{\text{th}}\) shell

\[
p_4 + 1.46p_4 = 24, p_4 = 9.76,
\]

After rounding it off to an integer

\[
p_4 = 10, n_4 = 14, p_4/n_4 = 10/14.
\]

For the 5\(^{\text{th}}\) shell

\[
p_5 + 1.46p_5 = 48, p_5 = 19.51,
\]

After rounding it off to an integer

\[
p_5 = 20, n_5 = 28, p_5/n_5 = 20/28.
\]

For the 6\(^{\text{th}}\) shell

\[
p_6 + 1.46 p_6 = 72, p_6 = 29.27,
\]

After rounding it off to an integer

\[
p_6 = 28, n_6 = 44, p_6/n_6 = 28/44.
\]

For the 7\(^{\text{th}}\) shell

\[
p_7 + 1.46 p_7 = 102, p_7 = 41.46,
\]

After rounding it off to an integer

\[
p_7 = 42, n_7 = 60, p_7/n_7 = 42/60.
\]

The calculated results are in agreement with the stable combination of protons and neutrons on full-filled shells and also with the growing graph of nuclides. If these results reflect the overall balance of nucleonic electromagnetic force on full-filled shells, the \( p/n \) 's \( p_2/n_2 = 2/2, p_3/n_3 = 6/6 \) and \( p_4/n_4 = 12/12 \) reflect the single balance of the nucleonic electromagnetic force. It is a manifestation of the one-to-one pairing between protons and neutrons. And the other \( p/n \)'s \( p_5/n_5 = 18/30, p_6/n_6 = 26/46 \) and \( p_7/n_7 = 44/58 \) are stable combination of dynamic balance of nucleonic electromagnetic force.

Although there is a con-firmed \( A_i \) (maximal number of nucleons) and a stable combination of protons and neutrons on each shell, the nucleons do not remain unchanged, for they keep exchanging nucleons against the background of energy exchange with the outside world. In an instant, a quasi-full-filled shell state is formed. In general, if the combination of nucleons on the 3\(^{\text{rd}}\) shell in a nuclide is a full-filled one (\( p_3/n_3 = 6/6 \)), the combination of nucleons on the 4\(^{\text{th}}\) shell is mostly a full-neutron one (\( p_4/n_4 = 10/14 \)). After a pair of nucleons are exchanged, we have \( p_5/n_5 = 5/7, p_6/n_6 = 11/13 \), of which \( p_5/n_5 = 11/13 \) is a stable combination of inside quasi-filled shell. See Fig. 4 (a) for details.

If the nucleonic combination on the 4\(^{\text{th}}\) shell is a full-proton one (\( p_4/n_4 = 12/12 \)), that on the 5\(^{\text{th}}\) shell is a full-neutron combination (\( p_5/n_5 = 18/30 \)). The exchange of two pairs of nucleons results in the combination \( p_4/n_4 = 10/14, p_5/n_5 = 20/28 \), which is shown in Fig. 4 (b). The newly-formed combination may be restored to the original state after exchange of two pairs of nucleons. Similarly, such exchange may take place between the 5\(^{\text{th}}\) and 6\(^{\text{th}}\) shells and between the 6\(^{\text{th}}\) and 7\(^{\text{th}}\) shells. To sum up, nucleons on shells fluctuate and exchange between individual balance (e. g. \( p/n = 6/6, p/n = 12/12 \)) and overall balance (e. g. \( p/n = 5/7, p/n = 10/14, p/n = 20/28 \)), which is controlled by the relative rate between the magnetic moment of protons and that of neutrons.

![Exchange of a pair of nucleons between the 3\(^{\text{rd}}\) and 4\(^{\text{th}}\) shells results in quasi-full shell combination.](image)

![Exchange of a pair of nucleons between the 4\(^{\text{th}}\) and 5\(^{\text{th}}\) shells results in switching of combinations.](image)
5. Magic Numbers and Nuclide Stability

In the preparation of the table, no particular attention is attached to the condition of magic numbers which nevertheless do exist as a natural character of the shell structures. Let’s take $^{4}_{2}$ He as an example. Its $p/n = 2/2$ and it is a 2-shelled nuclide with full-filled structure. $^{16}_{8}$ O is a 3-shelled nuclide with full-filled shell structure and its $\Sigma p/n = 8/8$. $^{40}_{20}$ Ca, its $\Sigma p/n = 20/20$, is a 4-shelled nuclide with full-filled structure. $^{88}_{36}$ Sr, its $\Sigma p/n = 38/50$, is a 5-shelled nuclide with full-filled shell structure. Nuclides with full-field structures are stable in character.

Another feature of stable nuclides is that the $p/n$ of most outside shells equals. Nuclides with $N = 20$ have 5 kinds of stable nuclides, of which 4 have their $p/n$ equal one on the most outside shells. They are, $^{37}_{17}$ Cl, $^{38}_{18}$ Ar, $^{39}_{19}$ K, and $^{40}_{20}$ Ca. Their $p/n$’s of most outside shells are respectively 10/10, 11/11, 11/12, and 12/12.

Of the 5 kinds of stable nuclides with $N = 28$, 4 have the characteristic of $p/n$ equaling one on the most outside shell. They are $^{50}_{22}$ Ti, $^{51}_{23}$ V, $^{52}_{24}$ Cr, $^{53}_{25}$ Mn, and $^{54}_{26}$ Fe. Their $p/n$’s of the most outside shells are respectively 5/5, 5/5, 6/6, and 7/7.

There are 6 kinds of stable nuclides with $N = 50$: $^{88}_{36}$ Sr, $^{89}_{37}$ Y, $^{90}_{38}$ Zr, $^{92}_{39}$ Mo, and $^{90}_{40}$ Sr. It is known from Table 1 that, of all the $p/n$’s of full-filled shells on the $5^{th}$ shell have two combinations of $p/n = 20/28$ and $p/n = 18/30$. The $p/n$’s of the most outside shells of $^{88}_{36}$ Sr, $^{87}_{37}$ Rb, $^{88}_{38}$ Sr, $^{89}_{39}$ Y, $^{90}_{40}$ Zr, and $^{92}_{41}$ Mo are 18/28 and 18/28, close to the $p/n$ of the $5^{th}$ shell. For $^{88}_{38}$ Sr, $^{89}_{39}$ Y, and $^{90}_{40}$ Zr, the $p/n$’s are both 20/28, identical with the combinations on the $5^{th}$ full-filled shell. $^{90}_{40}$ Zr and $^{92}_{42}$ Mo are 6-shelled nuclides with their $p/n$’s on the $6^{th}$ shell being 1/1 and 2/2.

Of the heavy nuclides with $N = 82$, seven are stable ones:, $^{134}_{54}$ Xe, $^{135}_{55}$ Xe, $^{136}_{56}$ Xe, $^{138}_{56}$ Ba, $^{139}_{57}$ La, $^{140}_{58}$ Ce, $^{142}_{60}$ Nd, and $^{144}_{62}$ Sm. They are all 6 shelled and their $p/n$’s of the most outside shells are respectively 18/30, 20/30, 20/30, 22/30, 22/30, 24/30 and 24/32.

Nuclides have shell structures and stable nuclides have stable $p/n$’s on the most outside shells. But with the increase of nucleonic number $A$, the filling level of neutrons grows higher and the $p/n$ of the most outside shells is smaller than one. For the 7 stable nuclides with $N = 82$, the $p/n$ value of the most outside shells changes around 1/1.5. So it is known that this characteristic is relevant to the magnetic moment of nucleons.

Nuclides with $N = 126$ are 7-shell structured and there are two stable nuclides: $^{208}_{82}$ Pb and $^{209}_{83}$ Bi. Their $p/n$’s of the most outside shells are 18/30 and 20/28, identical with the two stable combinations of the $5^{th}$ shell when it is full-filled. This shows that a nuclide may become stable when its combination of protons and neutrons of the most outside shells in consistent with the stable nucleonic combination of an inside shell.

Heavy nuclides with $Z>84$ are unstable except $^{235}_{92}$ U and $^{238}_{92}$ U. They are 7-shell structured and their $p/n$’s of the most outside shells are respectively 26/46, 28/46 and 28/50. Except even-even nucleonic combination of the most outside shells, being identical with or close to the $p/n$ of the 6th shell is also a prerequisite for the nuclide stability.

To sum up, it could be presumed that the stability of a nuclide is decided by $p/n$ combination on the most outside shells and on the $p/n$ filling level of each shell. The “magic number” is the reflection of this feature. Except the case that the numbers of protons or neutrons are 2, 8 or 20, other magic numbers reflect nucleonic number of unful-filled shells. So magic numbers reflect the combinations of protons and neutrons of stable nuclides.

Decay modes of unstable nuclides is dependent on the nucleonic combinations of outside shells. The Table of Nuclide Shell Structure (See the appendix) indicates that a nuclide decays in the $(c)$ way when its $p/n$ of the most outside shell is 2, 4 or 6 and it decays in the $(f)$ way when its outside shell $n-p$ is 2, 4 or 6. This characteristic remains true after nearly 1000 unstable nuclides are tested.

Unstable nuclides decaying in the $(c)$ way are characterized by the nucleonic numbers on outside shells being even numbers of 2, 4, 6, etc. Judging from the condition of forming a nuclide, we know from Fig. 2 (a) that pairing of protons in the abnormal (reverse) direction caused by magnetic moment is a kind of pairing style. The magnetic moment of a proton is 1.46 times more powerful than that of a pair of a neutron and the electromagnetic force of a pair of protons is 1.46 times more powerful than that of a pair of neutrons. We know that the pairing of protons and neutrons is an important pre-requisite for a nuclide to form. Therefore, a pair of protons is unstable which can distribute on the most outside shell for a short time. By absorbing an electron, a proton turns into a neutron, thus forming a stable nucleonic pair. So the nuclide becomes stable and this is the cause of $(c)$ way of decay.

The unstable nuclides which decay in the $(\beta)$ way are characterized by the even number of nucleons on the outside shells, 2, 4, 6, etc. When protons and neutrons on outside shells fail to strike individual or overall balance, superfluous neutrons pair in reverse direction caused by magnetic moment, as is shown in Fig 2 (b). But the electromagnetic force between pairs of neutrons is 1.46 greater than that between proton-neutron pairs. It is less powerful than the combination ability of proton-neutron pairs, so the neutron pair is also unstable and can only be distributed on outside shells. By the force of proton-neutron pairs in the neighboring field, one of the neutrons becomes a proton after discharging an electron. A stable nucleonic pair is formed and the nuclide is made stable. And this is the cause of “$\beta$” way of decay. It is surprising that No. 42 element Mo and No. 44 element Ru each have 7 stable isotopes while No. 43 element Tc between them has no stable nuclides at all. The Table of Nuclide Shell Structure tells us that element Tc could not form structure with suitable $p/n$ among the cells and its $p/n$ of the most outside shell is not one.

The $(\alpha)$ way of decay of heavy nuclides is a reflection of the evolution of the $p/n$ combination of most outside shells from unstable to stable. For instance, the outside shell $p/n$ of stable...
nuclide $^{209}_{83}$Bi$_{126}$ is 20/28. As for unstable nuclide $^{211}_{85}$At$_{126}$, its
outside shell p/n is 22/30 and the product after its ($\alpha$) way of
decay is $^{209}_{83}$Bi$_{126}$, tending to be stable. Let’s cite another
example, the stable nuclide $^{242}_{94}$U$_{146}$ has its outside shell p/n at
28/50. The unstable nuclide $^{242}_{94}$Pu$_{146}$ has it at 30/52, tending
to be stable after its decay in the ($\alpha$) way. Thus, the conclusion
is drawn that the decay mode depends on nucleonic
combination of the most outside shells. Unstable nuclides
which decay in the ($\beta$) way result from the imbalance of p/n’s
between shells.

The heavy nuclide confirmed by experiment is $^{262}_{105}$Sg$_{157}$. It
is a neutron-filled nuclide with a 7-shell full-filled structure.
It decays by free fission. If there exists a heavier nuclide with a
super-large N number, it must be 8-shell structured. It is
presumed from Table I about the specific value \((\Delta A/\Delta N)\)
of the shell space nucleons take up that the maximal number of
nucleons \(\Delta A_8\) which can be accommodated by the 8\(^{th}\)
full-filled shell should be 136 \([8^2-7^2]=0.81\]. If the number of
protons on the 8\(^{th}\) shell is equal to that of neutrons on the 7\(^{th}\)
shell, it is a prerequisite for the stable combination of p/n’s of the
8\(^{th}\)shell. The p/n’s of full-field 8\(^{th}\) shell are 60/76 and 58/78.
From this we may calculate that the nucleonic number A of an
even-A nuclide with 8 full-filled shells is 398.

M. G. Mayer predicted the existence of Z=114 supper-heavy nuclide. At the end of last century, scientists of
Joint Institute for Nuclear Research announced that they had
successfully produced Z=114 nuclide, its atomic weight being
289 and its half of decay being 30 seconds which is much
longer than other nearby nuclides.[8] Our theory on nuclide
shell structure tells us that, if the nuclide with Z=114 and
A=287 tends to be stable, it structure should be as follows:

\[ Z/2\ 6/6\ 10/14\ 18/30\ 26/46\ 42/60\ 10/14\ \Sigma:114/173 \]

6. Binding Energy of a Nuclear and
Characteristics of Nuclear Force

The mass average of a nuclear is lighter than the mass sum
of free nucleons of the nuclear. The difference between the
two is called mass loss. Take \(\Delta m\) \((Z, A)\) for an example,

\[ \Delta m(Z, A) = m_p + (A-Z)m_n - m(Z, A), \] \hspace{1cm} (10)

In the formula, \(m(Z, A)\) is the mass of the nuclide. All
nuclear suffer mass loss, i.e. \(\Delta m( Z, A) > 0\).

When the nuclear mass is represented by \(M\) \((Z, A)\),

\[ \Delta m(Z, A) = \Delta M( Z, A), \] \hspace{1cm} (11)

In the formula, \(\Delta M\) stands for the mass of atom hydrogen.
According to the relationship between mass and energy in
relativity theory, the binding energy of an atom is

\[ B( Z, A) = \frac{\Delta m(Z, A)c^2}{}, \] \hspace{1cm} (12)

The nucleonic radium calculated by the mass formula is \(R =

1. 21\ (F)\), but it is \(R = 0. 8\ (F)\) according to the test conducted
by R. Hofstadter in his experiment on electronic scattering.
This proves that in the nucleon is a rim with a thickness of t =
0. 4\ (F). [9]

The binding energy of a nuclide increases as the nucleonic
number grows larger. The binding energy difference between
different nuclides is great, but no regularity is discovered.
Theoretically, the average bind- ing energy of each nuclide is
used to represent the level of tightness of the binding energy.
The specific binding energy is

\[ \varepsilon (Z, A) = \frac{B( Z, A)}{A} \] \hspace{1cm} (13)

It represents the average work done on each nucleon when
the nuclear with mass number \(A\) and electric charge number \(Z\)
is fragmented into free nucleons. Graph of specific binding
energy obtained from experiments is shown in Fig. 5. [10]

(from Evans. R. D.; The Atomic Nucleus, 1995)

Fig. 5. \(\varepsilon - A\) Curve ( Note the change of coordinate scale after \(a\geq30)\)

Both theory and experiments prove that the binding energy
\(\varepsilon\) value of an even-\(A\) nuclide with full-filled shells is relatively
high at its peak value. This rule can be confirmed by working
out the binding energy of the last nucleon. The significance of
the last nucleon’s binding energy refers to the energy released
when a free nucleon and other nucleons of the nuclear
combine into a nuclide. In other words, it is the energy needed
to separate a nucleon from the nuclear.

The binding energy of the last proton is

\[ S_p( Z, A) = B( Z, A) - (Z-1, A-1), \] \hspace{1cm} (14)

The binding energy of the last neutron is

\[ S_n( Z, A) = B( Z, A) - B( Z, A-1). \] \hspace{1cm} (15)

From the value surplus in \(\Delta ( Z, A)\) in Table of Nuclide Shell
Structure, the definition of \(\Delta ( Z, A)\) and Formula

\[ \Delta ( Z, A) = [M( Z, A) - A]c^2, \] \hspace{1cm} (16)

can be used to work out the binding energy of a nuclide and
that of the last nucleon.

\(^{16}\)O is a 3-shell full-filled nuclide of “○”category. From the
definition of \(S_p, S_n\) we can work out the following:

\[ S_p( ^{16}\text{O}) = 12.12\text{MeV}, S_n( ^{16}\text{O}) = 15.66\text{MeV} \]
$S_p \left(^{17}_8 F\right) = 0.61 \text{MeV}, S_n \left(^{17}_8 O\right) = 4.15 \text{MeV}

$^{20}_{20}$ Ca is a 4-shelled nuclide of "$O$" category. $S_p, S_n$ values of neighboring nuclides are:

$S_p \left(^{20}_{20} \text{Ca}\right) = 8.38 \text{MeV}, S_n \left(^{20}_{20} \text{Ca}\right) = 15.68 \text{MeV}

$S_p \left(^{42}_{21} \text{Sc}\right) = 4.27 \text{MeV}, S_n \left(^{41}_{20} \text{Ca}\right) = 8.32 \text{MeV}

$^{88}_{38} \text{Sr} \text{50} is a 5-shelled full-filled nuclide of the "$O" category.

$S_p, S_n$ values of neighboring nuclides are:

$S_p \left(^{88}_{38} \text{Sr}\right) = 9.94 \text{MeV}, S_n \left(^{88}_{38} \text{Sr}\right) = 10.45 \text{MeV}

$S_p \left(^{89}_{39} \text{Y}\right) = 7.74 \text{MeV}, S_n \left(^{89}_{39} \text{Y}\right) = 7.03 \text{MeV}

$^{160}_{64} \text{Gd} \text{ and }^{160}_{66} \text{Dy} \text{ are 6-shelled full-filled nuclides of the } "O" \text{ category.}

$S_p, S_n$ values of neighboring nuclides are:

$S_p \left(^{160}_{64} \text{Gd}\right) = 8.51 \text{MeV}, S_n \left(^{160}_{64} \text{Gd}\right) = 7.45 \text{MeV}

$S_p \left(^{161}_{66} \text{Tb}\right) = 6.81 \text{MeV}, S_n \left(^{161}_{66} \text{Tb}\right) = 5.63 \text{MeV}

$S_p \left(^{161}_{66} \text{Dy}\right) = 7.43 \text{MeV}, S_n \left(^{161}_{66} \text{Dy}\right) = 6.45 \text{MeV}

The above results show that the peak values of $S_p$ and $S_n$ appear on full-filled nuclides.

Table 2 shows the binding energy of some isotopes $S_n (Z, A)$ of nuclides with full-field shells. We can see that nuclides $^{16}_{8} \text{O},^{20}_{20} \text{Ca},^{88}_{38} \text{Sr},^{89}_{39} \text{Y}$, and $^{160}_{66} \text{Dy}$ show their peak values of $S_n (Z, A)$ when full-filled.

| Nuclides   | $B (Z, A)$ (MeV) | $S_n$ (MeV) | Nuclides   | $B (Z, A)$ (MeV) | $S_n$ (MeV) |
|------------|------------------|-------------|------------|------------------|-------------|
| $^{14}_{8} \text{O}$ | 98.73            |             | $^{86}_{39} \text{Y}$ | 742.87            |             |
| $^{15}_{8} \text{O}$ | 111.96           | 13.23       | $^{87}_{35} \text{Y}$ | 754.72           | 11.85**     |
| $^{16}_{8} \text{O}$ | 127.62           | 15.66*      | $^{88}_{35} \text{Y}$ | 764.07           | 9.35        |
| $^{17}_{8} \text{O}$ | 131.77           | 4.15        | $^{89}_{35} \text{Y}$ | 775.54           | 11.47*      |
| $^{18}_{8} \text{O}$ | 139.81           | 8.04        | $^{90}_{35} \text{Y}$ | 782.40           | 6.86        |
| $^{19}_{8} \text{O}$ | 143.77           | 3.96        | $^{91}_{35} \text{Y}$ | 790.34           | 7.74        |
| $^{20}_{8} \text{O}$ | 154.37           | 7.60        | $^{92}_{35} \text{Y}$ | 796.88           | 6.54        |
| $^{38}_{20} \text{Ca}$ | 313.13           |             | $^{137}_{66} \text{Dy}$ | 1285.00          |             |
| $^{39}_{20} \text{Ca}$ | 362.42           | 13.29       | $^{158}_{66} \text{Dy}$ | 1294.06          | 9.06**      |
| $^{40}_{20} \text{Ca}$ | 342.06           | 15.64*      | $^{159}_{66} \text{Dy}$ | 1300.89          | 6.83        |
| $^{41}_{20} \text{Ca}$ | 350.32           | 8.26        | $^{160}_{66} \text{Dy}$ | 1309.47          | 8.58*       |
| $^{42}_{20} \text{Ca}$ | 361.90           | 11.58       | $^{161}_{66} \text{Dy}$ | 1315.92          | 6.45        |
| $^{43}_{20} \text{Ca}$ | 369.83           | 7.93        | $^{162}_{66} \text{Dy}$ | 1324.12          | 8.20        |
| $^{44}_{20} \text{Ca}$ | 380.96           | 11.13       | $^{163}_{66} \text{Dy}$ | 1330.39          | 6.27        |
| $^{83}_{38} \text{Sr}$ | 716.86           |             |             |                  |             |
| $^{84}_{38} \text{Sr}$ | 728.91           | 12.05**     |             |                  |             |
| $^{85}_{38} \text{Sr}$ | 737.44           | 8.53        |             |                  |             |
| $^{86}_{38} \text{Sr}$ | 748.92           | 11.48       |             |                  |             |
| $^{87}_{38} \text{Sr}$ | 757.44           | 8.52        |             |                  |             |
| $^{88}_{38} \text{Sr}$ | 768.47           | 11.03*      |             |                  |             |
| $^{89}_{38} \text{Sr}$ | 774.83           | 6.36        |             |                  |             |
| $^{90}_{38} \text{Sr}$ | 782.63           | 7.80        |             |                  |             |
| $^{91}_{38} \text{Sr}$ | 788.44           | 5.81        |             |                  |             |

* The nuclide with full-filled shells in high in binding energy.
** Such as nuclides have protons with high filling level and are strong in electromagnetic force and high in binding energy. With the increase of the filling level of protons, the binding energy decreases.
7. Criteria of Nuclide Shell Structure and the Graph of Its Growth

Table 1 shows that the ratio \( \Delta A_i/\Delta N_i \) is between 0.571 and 0.803 and increases as the number of shells becomes larger, which is consistent with the fact that the distance between nearby nucleons decreases as the radius of curvature becomes larger.

The full-filled shell nuclide refers to the nuclide, each of whose shells has been filled with \( \Delta A_i \). Only after the inside shells are fully filled, will the outside ones begin to full fill. Therefore, the unfull - filled shells only refer to those outside ones whose proton is smaller than \( \Delta A_i \).

The statistical analysis shows that, except for \( ^{40} \text{Ar} \), in the stable nuclides of the 2\(^{nd} \), 3\(^{rd} \) and 4\(^{th} \) shells, the \( p/n \) is 1 and the protons and neutrons are very likely to pair with each other. If the shells are naturally stable, the \( \circ \) kind and the odd exception of element H. The nucleonic number of the most outside shells is even with the full-filled, its stable nuclide is invariably 1, but its shells are full-filled or unfull-filled alternatively in the II kind of nuclides.

To determine values of \( \Delta A_i \) and the \( p/n \) combinations is the principal basis for the preparation of the nuclide shell structure table. The regularity shown in \( \Delta A_i \) and \( p/n \) is embedded in the graph of nuclide growth. The developing route of full-filled nuclides is shown in Fig. 6 (a) (b). Fig. (a) is the route of the development of even A full-filled nuclides and Fig. (b) is that of odd A full-filled nuclides. The 1\(^{st} \), 2\(^{nd} \), 3\(^{rd} \) and 4\(^{th} \) shells are the same as the shell structure proposed by Mayer, but the 5\(^{th} \), 6\(^{th} \) and 7\(^{th} \) shells are obviously different in the number of nucleons.

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**Fig. 6 (a). Developing Route of Even A nuclides.**

Even A nuclide belongs to “\( \circ \)” category and its first shell is vacant. With the second shell full-filled, its stable nuclide is \( ^{2} \text{He} \); with the third shell full-filled, its stable nuclide is \( ^{16} \text{O} \); with the fourth shell full-filled, its stable nuclides are \( ^{40} \text{Ar} \) and \( ^{40} \text{Ca} \) with the fifth shell full-filled, its stable nuclide is \( ^{88} \text{Sr} \); with the sixth shell full-full ed, its stable nuclides are \( ^{160} \text{Gd} \) and \( ^{160} \text{Dy} \) with the seventh shell full-filled, its stable nuclides are \( ^{262} \text{Hg} \) and \( ^{262} \text{Bk} \). This figure derives from Table I.
Odd nuclide belongs to “⊙” category. Except for Element H, the first shell is invariably filled with neutrons. With the second shell full-filled, its nuclide $^2_\text{He}$ is unstable; with the third shell full-filled, it is the isotope $^{17}_8\text{O}$ of the lowly full-filled O; with the fourth shell full-field, the nuclides include stable nuclide $^{41}_{19}\text{K}$ and unstable nuclide $^{41}_{20}\text{Ca}$; with the fifth shell full-filled, the nuclide is $^{89}_{39}\text{Y}$ stable; with the sixth shell full-filled, the nuclide $^{161}_{66}\text{Dy}$ is stable. $^{263}_{106}\text{Sg}$ is exactly the odd nuclide of the full-filled seventh shell. The figure derives from Table I.

Any nuclide is first of all categorized according to the nature of nucleon $A$, i.e. whether it is odd or even in number, and then it is filled with nucleons one shell after another from inside to outside. The $p/n$ of each shell is determined by the afore-mentioned 7 criteria. For an example, $^{35}_{17}\text{Cl}$ is an odd $A$ nuclide belonging to “⊙” kind. So its first shell is filled with one neutron and its $p/n$’s on the 2nd, 3rd, 4th and the most outside shells are respectively 2/2, 6/6, 9/9 and 1. It is therefore identified as a stable nuclide.

The second example is $^{60}_{28}\text{Ni}_{32}$. It is an even $A$ nuclide belonging to “○” kind. Its first shell is not filled. Its $p/n$’s of the 2nd, 3rd, 4th and 5th shells are respectively 2/2, 6/6, 10/10 and 10/10. It is a stable nuclide because $p/n$ on the most outside shell is 1. The third example is the even $A$ nuclide $^{238}_{92}\text{Th}_{142}$ belonging to “○” kind. Its first shell is not filled. Its $p/n$’s of the 2nd, 3rd, 4th, 5th and 6th shells are respectively 2/2, 6/6, 10/10, 20/28 and 26/46. The 7th shell is not full-filled, but its $p/n$ (26/46) is the same as that of the 6th shell. So it is presumed to be stable.

Nuclide shell structures may either be directly indicated or shown in a table. For instance, the shell structures of $^{17}_8\text{O}$, $^{88}_{38}\text{Sr}$ and $^{238}_{92}\text{U}$ are illustrated as follows:

Shell structures of stable nuclides are illustrated in Table II which is prepared in accordance with the afore-mentioned criteria. All the stable nuclides are included and special nuclides are marked with an asterisk “*”. The clear regularity shown in the shell structures of stable nuclides is the basis for the preparation of this table.

The Table of Nuclide Shell Structure is completed on the basis of The Table of Shell Structures of Stable Nuclide, giving consideration to the stability and decay modes of nuclides and even to the above-mentioned 7 criteria. Consideration should be given to matching between full-level and unfull level of $p/n$’s between shells and to decay modes of unstable nuclides in the combination of nucleons on the most outside shells. The Table of Nuclide Shell Structures prepared in this way can very well explain and predict the stability of nuclides and the decay patterns of unstable nuclides. Please refer to the appendix for the shell structures, with special nuclides marked with asterisks. Tables of Shell Structure of Stable Nuclides are included in Appendix One. Tables of Shell Structure of Nuclides are included in Appendix Two.

8. Conclusion

We’ve arrived at the following conclusions after statistics and analysis of nuclides.

The known highest position of nuclides is a structure of 7 shell levels and the structure is composed with the nucleus ratios $r_0$ as its unit. Nuclides are categorized into two: odd and even nuclides. Except for hydrogen nuclides, even $A$ are hollow and odd $A$ are neutron-star type. The statistic model based on the fundamental categorization of nuclides and the tables of shell structure of nuclides prepared on the basis of the model reveal the general law governing the stability and decay of nuclides. This law is both the effect and a proof of the fundamental categorization method of nuclides.
## Appendix

**Table 1. Shell Structure of Stable Nuclides [11] [12].**

| nuclide | Z  | A  | Shell structure of nucleon (p/n) | Binding energy (MeV) | Fulling level (%) |
|---------|----|----|---------------------------------|----------------------|-------------------|
| H       | 1  | 1  | 1/1                             | 7.289                | 1/2 99.985        |
|         | 2  | /1 | /1                             | 13.136               | 1 0.015           |
| He      | 2  | 3  | 1/1                             | 14.931               | 1/2 0.000138      |
|         | 4  | /2 | /2                             | 2.425                | 0 99.99986*       |
| Li      | 3  | 6  | 2/1                             | 14.087               | 1 7.50***         |
|         | 7  | /1 | /1                             | 14.908               | 3/2 92.50         |
| Be      | 4  | 9  | 2/2 2/2                        | 11.348               | 3/2 100.0         |
| B       | 5  | 10 | 2/2 3/3                        | 12.052               | 3 98.89           |
|         | 11 | /1 | 2/2 3/3                        | 8.668                | 3/2 80.20         |
| C       | 6  | 12 | 2/2 4/4                        | 3/2 1.11            |
| N       | 7  | 14 | 2/2 5/5                        | 2.863                | 1 99.63           |
|         | 15 | /1 | 2/2 5/5                        | 0.102                | 1/2 0.366         |
| O       | 8  | 16 | 2/2 6/6                        | -4.737               | 0 99.76***        |
|         | 17 | /1 | 2/2 6/6                        | -0.810               | 5/2 0.038         |
|         | 18 | /1 | 2/2 5/7 1/1                    | -0.783               | 0 0.204****       |
| F       | 9  | 19 | 2/2 6/6 1/1                    | -1.487               | 1/2 100.0         |
| Ne      | 10 | 20 | 2/2 6/6 2/2                    | -7.043               | 0 90.51           |
|         | 21 | /1 | 2/2 6/6 2/2                    | -5.733               | 3/2 0.27         |
|         | 22 | /1 | 2/2 5/7 3/3                    | -8.026               | 0 9.22           |
| Na      | 11 | 23 | 2/2 6/6 3/3                    | -9.530               | 3/2 100.0         |
| Mg      | 12 | 24 | 2/2 6/6 4/4                    | -13.931              | 0 78.99           |
|         | 25 | /1 | 2/2 6/6 4/4                    | -13.191              | 5/2 10.0          |
|         | 26 | /2 | 2/2 5/7 5/5                    | -16.212              | 0 11.01           |
| AI      | 13 | 27 | 2/2 6/6 5/5                    | -17.194              | 5/2 100.0         |
| Si      | 14 | 28 | 2/2 6/6 6/6                    | -21.491              | 0 92.23           |
|         | 29 | /2 | 2/2 6/6 6/6                    | -21.894              | 1/2 4.67         |
|         | 30 | /2 | 2/2 5/7 7/7                    | -24.092              | 0 3.10           |
| P       | 15 | 31 | 2/2 6/6 7/7                    | -24.440              | 1/2 100.0         |

* ¹²He² is two-shelled full-filled nuclide of the "○"category. Its p/n is 2/2. There is only one combination for its full-filled p/n on the 2nd shell.

* * The proton-neutron pairing on the outside shell is an important prerequisite for a stable nuclide. Most of the stable nuclides bear this characteristic.

***¹⁶O⁸, ¹⁷O are full-filled nuclides of 3 shells. The 3rd shell p/n is 6/6; the 3rd shell p/n of ¹⁸O is 5/7. The stable isotope of oxygen shows that p/n = 6/6 and p/n = 5/7 are the stable combinations of the 3rd shell.

****¹⁸O is a 4-shelled nuclide.
### Shell Structure of Stable Nuclides.

| Nuclide | Z  | A  | Shell structure of nucleon (p/n) | King of structure | Binding energy (MeV) | 1° Fulling level (%) |
|---------|----|----|----------------------------------|-------------------|---------------------|----------------------|
| S       | 16 | 32 | 2/2 6/6 8/8                       | 16/16             | -26.015             | 0° 95.02             |
|         | 33 | /1 | 2/2 6/6 8/8                       | 16/17             | -26.586             | 3/2 0.75             |
|         | 34 |  2/2 5/7 9/9                      | 16/18             | -29.931             | 0° 4.21              |
|         | 36 |  2/2 6/6 8/12                     | 16/20             | 930.666             | 0° 0.017*            |
| Cl      | 17 | 35 | 2/2 6/6 9/9                       | 17/18             | -29.014             | 3/2 75.77            |
|         | 37 | /1 | 2/2 6/6 10/10                     | 17/20             | -31.762             | 3/2 24.23            |
| Ar      | 18 | 36 | 2/2 6/6 10/10                     | 18/18             | -30.321             | 0° 0.337             |
|         | 38 |  2/2 5/7 11/11                    | 18/20             | -34.715             | 0° 0.063             |
|         | 40 |  2/2 6/6 10/14                    | 18/22             | -35.040             | 0° 99.60**           |
| K       | 19 | 39 | 2/2 6/6 11/11                     | 19/20             | -33.806             | 3/2 93.26            |
|         | 41 | /1 | 2/2 5/7 12/12                     | 19/22             | -35.560             | 3/2 6.73             |
| Ca      | 20 | 40 | 2/2 6/6 12/12                     | 20/20             | -34.847             | 0° 96.94**           |
|         | 42 |  2/2 5/7 12/12 1/1                | 20/22             | -38.544             | 0° 0.647***          |
|         | 43 | /1 | 2/2 5/7 12/12 1/1                 | 20/23             | -38.405             | 7/2 0.135            |
|         | 44 |  2/2 6/6 10/14 2/2                | 20/24             | -41.466             | 0° 2.09***           |
|         | 46 |  2/2 5/7 10/14 3/3                | 20/26             | -43.138             | 0° 3.5×10⁻³          |
|         | 48 |  2/2 6/6 10/14 2/6                | 20/28             | -44.216             | 0° 0.187***          |
| Sc      | 21 | 45 | 2/2 5/7 12/12 2/2                 | 21/24             | -41.066             | 7/2 100.0            |
| Ti      | 22 | 46 | 2/2 5/7 12/12 3/3                 | 22/24             | -44.123             | 0° 8.20              |
|         | 47 | /1 | 2/2 5/7 12/12 3/3                 | 22/25             | -44.931             | 5/2 7.40             |
|         | 48 |  2/2 6/6 10/14 4/4                | 22/26             | -48.488             | 0° 73.70             |
|         | 49 | /1 | 2/2 6/6 10/14 4/4                 | 22/27             | -48.599             | 7/2 5.40             |
|         | 50 |  2/2 5/7 10/14 5/5                | 22/28             | -51.432             | 0° 5.20              |
| V       | 23 | 50 | 2/2 6/6 10/14 5/5                 | 23/27             | -49.219             | 6° 0.250             |
|         | 51 | /1 | 2/2 6/6 10/14 5/5                 | 23/28             | -52.199             | 7/2 99.750           |
| Cr      | 24 | 50 | 2/2 5/7 12/12 5/5                 | 24/26             | -50.258             | 0° 4.35              |
|         | 52 |  2/2 6/6 10/14 6/6                | 24/28             | -55.415             | 0° 83.79             |
|         | 53 | /1 | 2/2 6/6 10/14 6/6                 | 24/29             | -55.284             | 3/2 9.50             |
|         | 54 |  2/2 5/7 10/14 7/7                | 24/30             | -56.931             | 0° 2.36              |
| Mu      | 25 | 55 | 2/2 6/6 10/14 7/7                 | 25/30             | -57.710             | 5/2 100.0            |

* For a full-folled proton, the p/n=1 on the most outside shell is not a neceessary pre-requisite for a stable nuclide. However, the stability of $^{36}_{19}K_{20}$ indicates that the nucleons whose p/n's on all shells are even combinations are more and more stable.

** $^{40}_{20}Ca_{20}$ and $^{46}_{20}Ca_{20}$ show that p/n=10/14, p/n=12/12 are the two stable combinations of the p/n's on the 4th shell.

*** $^{42}_{20}Ca_{22}$ and $^{44}_{20}Ca_{24}$ bear obvious characteristics of the 5th shell.

****The proton-neutron pairing is the necessary prerequisite for the formation of nuclides. After the proton and neutron of $^{36}_{16}Ca_{28}$ have paved on the outside shell the remaining 4 neutrons and the inside-shell neutrons become pairs, showing that the nucleons of neighboring shells may also pair. The nuclides whose nucleons are all even-even combinations are more stable.
### Shell Structure of Stable Nuclides

| Nuclide | Z | A | Shell structure of nucleon (p/n) | King of structure | Binding energy (Δ(MeV)) | J* | Filling Level (%) |
|---------|---|---|----------------------------------|-------------------|------------------------|----|------------------|
| Fe 26   | 54 | 1 | 2/2 5/7 12/12 7/7 26/28 | -56.251 | 0° | 5.80 |
|         | 56 | 2/2 6/6 10/14 8/8 26/30 | -60.604 | 0° | 91.80 |
|         | 57 | /1 2/2 6/6 10/14 8/8 26/31 | -60.179 | 1/2 | 2.15 |
|         | 58 | 2/2 5/7 10/14 9/9 26/32 | -62.152 | 0° | 0.29 |
| Co 27   | 59 | /1 2/2 6/6 10/14 9/9 27/32 | -62.226 | 7/2 | 100.0 |
| Ni 28   | 58 | 2/2 5/7 12/12 9/9 28/30 | -60.224 | 0° | 68.30 |
|         | 60 | 2/2 5/7 10/14 10/10 28/32 | -64.470 | 0° | 26.10 |
|         | 61 | /1 2/2 6/6 10/14 10/10 28/33 | -64.219 | 3/2 | 1.13 |
|         | 62 | 2/2 5/7 10/14 11/11 28/34 | -66.745 | 0° | 3.59 |
|         | 64 | 2/2 6/6 10/14 10/14 28/36 | -67.098 | 0° | 0.91* |
| Cu 29   | 63 | /1 2/2 6/6 10/14 11/11 29/34 | -65.578 | 3/2 | 69.20 |
|         | 65 | /1 2/2 5/7 10/14 12/12 29/36 | -67.262 | 3/2 | 30.80 |
| Zn 30   | 64 | 2/2 6/6 10/14 12/12 30/34 | -66.001 | 0° | 48.60 |
|         | 66 | 2/2 5/7 10/14 13/13 30/36 | -68.898 | 0° | 27.90 |
|         | 67 | /1 2/2 5/7 10/14 13/13 30/37 | -67.880 | 5/2 | 4.10 |
|         | 68 | 2/2 6/6 10/14 12/16 30/38 | -70.006 | 0° | 18.80 |
|         | 70 | 2/2 6/6 10/14 12/18 30/40 | -69.560 | 0° | 0.62 |
| Ga 31   | 69 | /1 2/2 5/7 10/14 14/14 31/38 | -69.322 | 3/2 | 60.10 |
|         | 71 | /1 2/2 5/7 12/12 12/18 31/40 | -70.142 | 3/2 | 39.90 |
| Ge 32   | 70 | 2/2 5/7 10/14 15/15 32/38 | -70.561 | 0° | 20.50 |
|         | 72 | 2/2 6/6 10/14 14/18 32/40 | -72.583 | 0° | 27.40 |
|         | 73 | /1 2/2 6/6 10/14 14/18 32/41 | -71.294 | 9/2 | 7.80 |
|         | 74 | 2/2 6/6 10/14 14/20 32/42 | -73.422 | 0° | 36.50 |
|         | 76 | 2/2 6/6 10/14 14/22 32/42 | -73.214 | 0° | 7.80 |
| As 33   | 75 | /1 2/2 5/7 12/12 14/20 33/42 | -73.034 | 3/2 | 100.0 |
| Se 34   | 74 | 2/2 5/7 10/14 17/17 34/40 | -72.213 | 0° | 0.87 |
|         | 76 | 2/2 6/6 10/14 16/20 34/42 | -75.259 | 0° | 9.0 |
|         | 77 | /1 2/2 6/6 10/14 16/20 34/43 | -74.606 | 1/2 | 7.60 |
|         | 78 | 2/2 6/6 10/14 16/22 34/44 | -77.032 | 0° | 23.50 |
|         | 80 | 2/2 6/6 10/14 16/24 34/46 | -77.761 | 0° | 49.80 |
|         | 82 | 2/2 6/6 10/14 16/26 34/48 | -77.586 | 0° | 9.20 |
| Br 35   | 79 | /1 2/2 5/7 12/12 16/22 35/44 | -76.070 | 3/2 | 50.69 |

*The outside-shell p/n = 10/14 of 56Ni is a stable combination of the p/n on the 3rd shell. p/n = 5/7, p/n = 10/14 and p/n = 20/28 are respectively the stable combinations of the 3rd, 4th and 5th shell, the ratio being invariably 1/1.4. The nuclides whose outside-shell p/n is 1/1.4 are more likely to be stable.*
**Shell Structure of Stable Nuclides.**

| Nuclide | Z  | A  | Shell structure of nucleon (p/n) | King of structure | Binding energy (MeV) | Fulling level (%) |
|---------|----|----|---------------------------------|-------------------|---------------------|-------------------|
|         |    |    | 1     | 2     | 3     | 4     | 5     | 6     | 7     | ΣP/n |            |                  |                  |
| Kr      | 36 | 88 | /1    | 2/2   | 5/7   | 12/12 | 16/24 | 35/56 | 37/46 | 77.976 | 3/2  | 49.31      |                  |
| Sr      | 38 | 90 | /1    | 2/2   | 6/5   | 10/14 | 19/22 | 36/42 | 74.150 | 0°    | 0.356 | 2.77       |                  |
| O       | 38 | 84 | /1    | 2/2   | 6/5   | 10/14 | 18/24 | 36/42 | 77.897 | 0°    | 11.60 | 17.30      |                  |
| Y       | 39 | 89 | /1    | 2/2   | 5/7   | 12/12 | 18/26 | 36/48 | 82.432 | 0°    | 57.0  | 72.17      |                  |
| Zr      | 40 | 90 | /1    | 2/2   | 5/7   | 12/12 | 20/28 | 37/50 | 84.596 | 0°    | 27.83 | 82.60      |                  |
| Nb      | 41 | 93 | /1    | 2/2   | 5/7   | 12/12 | 20/28 | 38/50 | 87.911 | 0°    | 82.60 | 100.0***   |                  |
| Mo      | 42 | 96 | /1    | 2/2   | 6/6   | 10/14 | 18/28 | 39/50 | 87.695 | 1/2   | 100.0*** |                  |

* 88 38 Sr and 89 39 Y show that the p/n=20/28 is a stable p/n combination on the 5th shell. The element Y has only one stable nuclide 89 39 Y. The filling level of the isotope 88 38 Sr of element is 82.6, for lower than other isotopes, showing that 88 38 Sr and 89 39 Y are 5-shelled nuclides of even A and odd A. Their stability depends on the outside-shell p/n=20/28. That is to say, it depends on “the magic numbers” 20, 28 instead of “magic number” 50.

** 90 40 Zr and 91 40 Zr show the structural characteristics of the 6th shell.

*** 94 40 Zr and 96 40 Zr show that p/n=18/30 is a stable combination of the 5th shell p/n.

**** 94 41 Nb₂ shows that the nuclides who alternate between “full-filled” and “unfulfilled” in the two kinds of 1 and 2 p/n enjoy a high filling level. Most of the nuclides bear such a feature.
### Shell Structure of Stable Nuclides

| Nuclide | Z  | Λ | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | 1° | Fulling level (%) |
|---------|----|---|----------------------------------|-------------------|---------------------|----|------------------|
|         |    | Σp/n | 1 | 2 | 3 | 4 | 5 | 6 | 7 |            |          |          |          |
|         |    |      |   |   |   |   |   |   |   |            |          |          |          |
| 98      | 2/2| 5/7 | 12/12 | 20/28 | 5/5 | 44/54 | ❌ | -88.226 | 0° | 1.86 |
| 99      | /1 | 2/2 | 5/7 | 12/12 | 20/28 | 5/5 | 44/55 | ❌ | -87.620 | 5/2° | 12.70 |
| 100     | 2/2 | 6/6 | 10/14 | 20/28 | 6/6 | 44/56 | ❌ | -89.222 | 0° | 12.60 |
| 101     | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 6/6 | 44/57 | ❌ | -87.952 | 5/2° | 17.0 |
| 102     | 2/2 | 5/7 | 12/12 | 18/30 | 7/7 | 44/58 | ❌ | -89.100 | 0° | 31.60 |
| 104     | 2/2 | 6/6 | 10/14 | 18/30 | 8/8 | 44/60 | ❌ | -88.099 | 0° | 18.70 |
| Rh 45   | 103 | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 7/7 | 45/58 | ❌ | -88.024 | 1/2° | 100.0 |
| Pd 46   | 102 | 2/2 | 5/7 | 12/12 | 20/28 | 7/7 | 46/56 | ❌ | -87.925 | 0° | 1.0 |
|         | 104 | 2/2 | 6/6 | 10/14 | 20/28 | 8/8 | 46/58 | ❌ | -89.400 | 0° | 11.0 |
|         | 105 | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 8/8 | 46/59 | ❌ | -88.422 | 5/2° | 22.20 |
|         | 106 | 2/2 | 5/7 | 12/12 | 18/30 | 9/9 | 46/60 | ❌ | -89.913 | 0° | 27.30 |
|         | 108 | 2/2 | 6/6 | 10/14 | 18/30 | 10/10 | 46/62 | ❌ | -89.523 | 0° | 26.70 |
|         | 110 | 2/2 | 5/7 | 10/14 | 18/30 | 11/11 | 46/64 | ❌ | -88.335 | 0° | 11.80 |
| Ag 47   | 107 | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 9/9 | 47/60 | ❌ | -88.404 | 1/2° | 51.83 |
|         | 109 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 10/10 | 47/62 | ❌ | -88.722 | 1/2° | 48.17 |
| Cd 48   | 106 | 2/2 | 5/7 | 12/12 | 18/30 | 10/10 | 48/58 | ❌ | -87.131 | 0° | 1.25 |
|         | 108 | 2/2 | 6/6 | 10/14 | 20/28 | 9/9 | 48/58 | ❌ | -89.251 | 0° | 0.89 |
|         | 110 | 2/2 | 5/7 | 12/12 | 18/30 | 11/11 | 48/62 | ❌ | -90.349 | 0° | 12.50 |
|         | 111 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 11/11 | 48/63 | ❌ | -89.254 | 1/2° | 12.80 |
|         | 112 | 2/2 | 6/6 | 10/14 | 18/30 | 12/12 | 48/64 | ❌ | -90.570 | 0° | 24.10 |
|         | 113 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 12/12 | 48/65 | ❌ | -89.050 | 1/2° | 12.20 |
|         | 114 | 2/2 | 5/7 | 10/14 | 18/30 | 13/13 | 48/66 | ❌ | -90.020 | 0° | 28.70 |
|         | 116 | 2/2 | 6/6 | 10/14 | 18/30 | 12/16 | 48/68 | ❌ | -88.718 | 0° | 7.50* |
| In 49   | 113 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 12/12 | 49/64 | ❌ | -89.372 | 9/2° | 4.30 |
|         | 115 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 13/13 | 49/66 | ❌ | -89.541 | 9/2° | 95.70 |
| Sn 50   | 112 | 2/2 | 6/6 | 10/14 | 20/28 | 12/12 | 50/62 | ❌ | -88.658 | 0° | 1.01 |
|         | 114 | 2/2 | 5/7 | 12/12 | 18/30 | 13/13 | 50/64 | ❌ | -90.560 | 0° | 0.67 |
|         | 115 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 13/13 | 50/65 | ❌ | 90.035 | 1/2° | 0.38 |
|         | 116 | 2/2 | 6/6 | 10/14 | 18/30 | 14/14 | 50/66 | ❌ | -91.526 | 0° | 14.60 |
|         | 117 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 14/14 | 50/67 | ❌ | -90.399 | 1/2° | 7.75 |
|         | 118 | 2/2 | 5/7 | 10/14 | 18/30 | 15/15 | 50/68 | ❌ | -91.654 | 0° | 24.30 |
|         | 119 | /1 | 2/2 | 5/7 | 10/14 | 18/30 | 15/15 | 50/69 | ❌ | -90.067 | 1/2° | 8.60 |
|         | 120 | 2/2 | 6/6 | 10/14 | 18/30 | 14/18 | 50/70 | ❌ | -91.102 | 0° | 32.4 |
|         | 122 | 2/2 | 6/6 | 10/14 | 18/30 | 14/20 | 50/72 | ❌ | -89.946 | 0° | 4.56 |

*In the stable nuclides whose p/n’s on outside shells do not equal 1, the nucleons of all shells are mostly even-even combinations, except for the first shell.
| nuclide | Z | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | Filling level (%) |
|---------|---|---------------------------------|------------------|--------------------|-----------------|
|        |   | 1 2 3 4 5 6 7                 |                  |                    |                 |
|        |   | 1/2 2/2 6/6 10/14 18/30 14/22 | 50/74            | -88.240            | 0%              |
| Sb     | 51| /1 2/2 5/7 10/14 18/30 16/16  | 51/70            | -89.589            | 5/2+ 57.30%     |
|        |   | /1 2/2 5/7 12/12 18/30 14/20   | 51/72            | -89.218            | 5/2+ 42.70%     |
| Te      | 52| 2/2 6/6 10/14 18/30 16/16     | 52/68            | -89.404            | 0%              |
|        |   | /1 2/2 5/7 10/14 18/30 17/17   | 52/71            | -89.166            | 1/2+ 0.89%      |
|        |   | /1 2/2 6/6 10/14 18/30 16/20   | 52/72            | -90.518            | 0%              |
|        | 52| /1 2/2 6/6 10/14 18/30 16/20   | 52/73            | -89.019            | 1/2+ 7.0%       |
| I      | 53| /1 2/2 5/7 12/12 18/30 16/22   | 53/74            | -88.980            | 5/2+ 100.0%     |
| Xe     | 54| /1 2/2 6/6 10/14 18/30 18/18   | 54/70            | -87.45             | 0%              |
|        |   | /1 2/2 6/6 10/14 18/30 18/18   | 54/72            | -89.162            | 0%              |
|        |   | 2/2 6/6 10/14 20/28 16/24     | 54/74            | -89.861            | 0%              |
|        |   | /1 2/2 6/6 10/14 20/28 16/24   | 54/75            | -88.698            | 1/2+ 26.40%     |
|        |   | /1 2/2 6/6 10/14 20/28 16/26   | 54/77            | -88.421            | 3/2+ 21.20%     |
|        |   | 2/2 6/6 10/14 20/28 18/26     | 54/78            | -89.286            | 0%              |
| Cs      | 55| /1 2/2 6/6 10/14 18/30 18/30   | 54/80            | -88.125            | 0%              |
| Ba      | 56| /1 2/2 5/7 12/12 18/30 18/30   | 55/78            | -88.089            | 7/2+ 100.0%     |
|        |   | 2/2 5/7 10/14 18/30 21/21     | 56/74            | -87.303            | 0%              |
|        |   | 2/2 6/6 10/14 20/28 18/26     | 56/76            | -88.453            | 0%              |
|        |   | 2/2 6/6 10/14 18/30 20/26     | 56/78            | -88.968            | 0%              |
|        |   | /1 2/2 6/6 10/14 18/30 20/26   | 56/79            | -87.870            | 3/2+ 6.59%      |
|        |   | /1 2/2 6/6 10/14 18/30 20/28   | 56/80            | -88.906            | 0%              |
|        |   | /1 2/2 6/6 10/14 18/30 20/28   | 56/81            | -87.733            | 3/2+ 11.20%     |
|        | 57| 2/2 6/6 10/14 18/30 20/30     | 56/82            | -88.273            | 0%              |
| La      | 58| 2/2 5/7 12/12 18/30 20/30     | 57/81            | -86.524            | 5%              |
|        |   | 2/2 5/7 12/12 18/30 20/30     | 57/82            | -87.231            | 7/2+ 99.911%    |
|        | 58| 2/2 6/6 10/14 20/28 20/28     | 58/78            | -86.50             | 0%              |
| Ce      | 59| /1 2/2 5/7 12/12 18/30 22/30   | 58/80            | -87.565            | 0%              |
|        |   | 2/2 6/6 10/14 18/30 22/30     | 58/82            | -88.081            | 0%              |
| Pr      | 60| /1 2/2 5/7 12/12 18/30 22/30   | 59/82            | -86.018            | 5/2+ 100.0%     |
## Shell Structure of Stable Nuclides

| Nuclide | Z | A | 1  | 2  | 3  | 4  | 5  | 6  | 7  | $\Sigma P/n$ | $\Delta$(MeV) | $I^*$ | Fulling level (%) |
|---------|---|---|----|----|----|----|----|----|----|-------------|-------------|------|------------------|
| Nd 60  | 142 | 2/2 | 6/6 | 10/14 | 18/30 | 24/30 | 60/82 | 0 | 0 | -85.949 | 0 | 27.2 |
|        | 143 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 24/30 | 60/83 | 0 | 0 | -84.000 | 7/2 | 12.2 |
|        | 144 | 2/2 | 6/6 | 10/14 | 18/30 | 24/32 | 60/84 | 0 | 0 | -83.746 | 0 | 23.8 |
|        | 145 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 24/32 | 60/85 | 0 | 0 | -81.430 | 7/2 | 8.3 |
|        | 146 | 2/2 | 6/6 | 10/14 | 18/30 | 24/34 | 60/86 | 0 | 0 | -80.923 | 0 | 17.2 |
|        | 148 | 2/2 | 6/6 | 10/14 | 18/30 | 24/36 | 60/88 | 0 | 0 | -77.407 | 0 | 5.7 |
|        | 150 | 2/2 | 6/6 | 10/14 | 18/30 | 24/38 | 60/90 | 0 | 0 | -73.682 | 0 | 5.6 |
| Pm 61  | 144 | 2/2 | 6/6 | 10/14 | 20/28 | 24/32 | 62/82 | 0 | 0 | -81.964 | 0 | 3.1 |
|        | 147 | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 24/34 | 62/85 | 0 | 0 | -79.265 | 7/2 | 15.1 |
|        | 148 | 2/2 | 6/6 | 10/14 | 20/28 | 24/36 | 62/86 | 0 | 0 | -79.335 | 0 | 11.3 |
|        | 149 | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 24/36 | 62/87 | 0 | 0 | -77.135 | 7/2 | 13.9 |
|        | 150 | 2/2 | 6/6 | 10/14 | 18/30 | 26/36 | 62/88 | 0 | 0 | -77.049 | 0 | 7.4 |
|        | 152 | 2/2 | 6/6 | 10/14 | 18/30 | 26/38 | 62/90 | 0 | 0 | -74.761 | 0 | 26.6 |
|        | 154 | 2/2 | 6/6 | 10/14 | 18/30 | 26/40 | 62/92 | 0 | 0 | -72.454 | 0 | 22.6 |
| Eu 63  | 151 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 26/36 | 63/88 | 0 | 0 | -74.650 | 5/2 | 47.9 |
|        | 153 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 26/38 | 63/90 | 0 | 0 | -73.363 | 5/2 | 52.1 |
| Cd 64  | 152 | 2/2 | 6/6 | 10/14 | 18/30 | 28/36 | 64/88 | 0 | 0 | -74.703 | 0 | 0.20 |
|        | 154 | 2/2 | 6/6 | 10/14 | 18/30 | 28/38 | 64/90 | 0 | 0 | -73.704 | 0 | 2.1 |
|        | 155 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 28/38 | 64/91 | 0 | 0 | -72.071 | 3/2 | 14.8 |
|        | 156 | 2/2 | 6/6 | 10/14 | 18/30 | 28/40 | 64/92 | 0 | 0 | -72.536 | 0 | 26.6 |
|        | 157 | /1 | 2/2 | 6/6 | 10/14 | 18/30 | 28/40 | 64/93 | 0 | 0 | -70.071 | 3/2 | 15.7 |
|        | 158 | 2/2 | 6/6 | 10/14 | 18/30 | 28/42 | 64/94 | 0 | 0 | -70.691 | 0 | 24.8 |
|        | 160 | 2/2 | 6/6 | 10/14 | 20/28 | 26/46 | 64/96 | 0 | 0 | -67.943 | 0 | 21.8* |
| Tb 65  | 159 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/42 | 65/94 | 0 | 0 | -69.536 | 3/2 | 100.0 |
| Dy 66  | 156 | 2/2 | 6/6 | 10/14 | 20/28 | 28/40 | 66/90 | 0 | 0 | -70.527 | 0 | 0.057 |
|        | 158 | 2/2 | 6/6 | 10/14 | 20/28 | 28/42 | 66/92 | 0 | 0 | -70.410 | 0 | 0.10 |
|        | 160 | 2/2 | 6/6 | 10/14 | 20/28 | 28/44 | 66/94 | 0 | 0 | -69.674 | 0 | 2.3** |
|        | 161 | /1 | 2/2 | 6/6 | 10/14 | 20/28 | 28/44 | 66/95 | 0 | 0 | -68.056 | 5/2 | 19.09 |
|        | 162 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 1/1 | 66/96 | 0 | 0 | -68.181 | 0 | 25.5 |
|        | 163 | /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 1/1 | 66/97 | 0 | 0 | -66.382 | 5/2 | 24.9 |
|        | 164 | 2/2 | 6/6 | 10/14 | 18/30 | 28/44 | 2/2 | 66/98 | 0 | 0 | -65.967 | 0 | 28.1 |

* $^{164}_{64}$Gd shows that $p/n = 26/46$ is a stable combination of the full-filled shell $p/n$'s on the 6th shell.

** $^{166}_{66}$Dy shows that $p/n = 28/44$ is a stable combination of the full-filled shell $p/n$'s on the 6th shell. The neighboring shells exchange nucleons instantly. The $p/n$'s of the 4th and 5th shells fluctuate between $p/n = 10/14$, $p/n = 20/28$ and $p/n = 18/30$. But the quasi-full filled combinations on inside shells do not affect the stability of nuclides.
### Shell Structure of Stable Nuclides

| nuclide | Z  | $A$  | Shell structure of nucleon (p/n) | King of structure | Binding energy $\Delta$(MeV) | $I^*$ | Fulling Level (%) |
|---------|----|------|----------------------------------|------------------|-----------------------------|------|------------------|
| Ho      | 67 | 165  | /1                               |                  | -64.896                     | 7/2  | 100.0           |
| Er      | 68 | 162  | 2/2                              |                  | -66.335                     | 0    | 0.14*           |
|         |    |      | 164 /1                           |                  | -65.940                     | 0    | 1.56            |
|         |    |      | 166 /1                           |                  | -64,921                     | 0    | 33.4            |
|         |    |      | 167 /1                           |                  | -63.286                     | 7/2  | 22.9            |
|         |    |      | 168 /1                           |                  | -62.985                     | 0    | 21.8            |
|         |    |      | 170 /1                           |                  | -60.104                     | 0    | 14.9            |
| Tm      | 69 | 169  | 2/2                              |                  | -61.269                     | 1/2  | 100.0           |
| Yb      | 70 | 168  | 2/2                              |                  | -61.565                     | 0    | 0.135           |
|         |    |      | 170 /1                           |                  | -60.759                     | 0    | 3.1             |
|         |    |      | 171 /1                           |                  | -59.302                     | 1/2  | 14.4            |
|         |    |      | 172 /1                           |                  | -59.250                     | 0    | 21.9            |
|         |    |      | 173 /1                           |                  | -57.546                     | 5/2  | 16.2            |
|         |    |      | 174 /1                           |                  | -56.940                     | 0    | 31.6            |
|         |    |      | 176 /1                           |                  | -53.490                     | 0    | 12.6            |
| Lu      | 71 | 175  | 2/2                              |                  | -55.159                     | 7/2  | 97.39           |
|         |    |      | 176 /1                           |                  | -53.381                     | 7    | 2.61            |
| Hf      | 72 | 174  | 2/2                              |                  | -55.830                     | 0    | 0.16            |
|         |    |      | 176 /1                           |                  | -54.567                     | 0    | 5.2             |
|         |    |      | 177 /1                           |                  | -52.879                     | 7/2  | 18.6            |
|         |    |      | 178 /1                           |                  | -52.434                     | 0    | 27.1            |
|         |    |      | 179 /1                           |                  | -50.462                     | 9/2  | 13.7            |
|         |    |      | 180 /1                           |                  | -49.779                     | 0    | 35.2            |
| Ta      | 73 | 180  | 2/2                              |                  | -48.941                     | 1/2  | 0.0123          |
|         |    |      | 181 /1                           |                  | -48.425                     | 7/2  | 99.9877         |
| W       | 74 | 180  | 2/2                              |                  | -49.624                     | 0    | 0.13            |
|         |    |      | 182 /1                           |                  | -48.228                     | 0    | 26.3            |
|         |    |      | 183 /1                           |                  | -46.347                     | 1/2  | 14.3            |
|         |    |      | 184 /1                           |                  | -45.687                     | 0    | 30.7            |
|         |    |      | 186 /1                           |                  | -42.498                     | 0    | 28.6            |
| Re      | 75 | 185  | 2/2                              |                  | -43.802                     | 5/2  | 37.40           |
|         |    |      | 187 /1                           |                  | -41.205                     | 5/2  | 62.60           |
| Os      | 76 | 184  | 2/2                              |                  | -44.233                     | 0    | 0.018           |
|         |    |      | 186 /1                           |                  | -42.987                     | 0    | 1.6             |

* $^{162}_{66}$ Dy and $^{162}_{68}$ Er show the characteristics of nuclides on the 7th shell.
The outside shell p/n’s are p/n = 20/28 and p/n = 18/30, which happen to be the 2 stable combinations of the full-filled shell p/n’s on the 5\textsuperscript{th} shell.

*\(^{208}\)\textsubscript{82}Pd\textsubscript{126}. The outside shell p/n’s are p/n = 20/28 and p/n = 18/30, which happen to be the 2 stable combinations of the full-filled shell p/n’s on the 5\textsuperscript{th} shell.

\[^{209}\textsubscript{83}Bi\textsubscript{126} is astable nuclide and the p/n of the outside shell is p/n = 20/28. The specific value of p/n = 5/7, p/n = 10/14, p/n = 20/28 is 1/1.4 and it a stable combination. The number of neutrons of this nuclide is n = 126 and its stability does not depend on “the magic number”126, but on the matching of filling level between shells. So is. \(^{208}\textsubscript{82}Pd\textsubscript{126}.\]
Shell Structure of Stable Nuclides.

| Nuclide | Z  | A   | Shell structure of nucleon (p/n) | 1  | 2  | 3  | 4  | 5  | 6  | 7  | ΣP/n | Binding energy (MeV) | t* | Filling level (%) |
|---------|----|-----|---------------------------------|----|----|----|----|----|----|----|------|---------------------|----|-------------------|
| Ra      | 88 | 228 | 2/6 | 10/14 | 20/28 | 26/46 | 26/46 | 90/142 | ○   | 35.447 | 0'  | 100.0*            |
| Th      | 90 | 232 | 2/6 | 10/14 | 20/28 | 26/46 | 26/46 | 92/143 | ○   | 40.916 | 7/2 | 0.720            |
| U       | 92 | 238 | 2/6 | 10/14 | 20/28 | 26/46 | 26/46 | 92/146 | ○   | 47.307 | 0'  | 99.275**          |

* 232_90Th is a stable nuclide and its outside shell $p/n=26/46$, identical with the full-filled shell p/n=son the 6th shell.

** 238_92U is the heaviest stable nuclide in the natural world. Its outside shell $p/n=28/50$ and its protons and neutrons are all “magic number”. However, the nuclide stability do not depend on such “magic numbers” as 28, 50, but on the $p/n$ combinations on outside shells and the matching of filling levell between shells.

Notes: [11] The fundamental data of the table comefrom: V. S. Shirley et al, Nuclear Wallet Cards, 1979. K. S. Crane, Introductory Nuclear Physics, 1987. [12] The fundamental data of the table come from: Nuclear Physics, P390~P405, Xu Side, published by Qinghua university Press, 1992.

Table 2. Shell Structure of Nuclides.

| Nuclide | Z  | A   | Shell structure of nucleon (p/n) | 1  | 2  | 3  | 4  | 5  | 6  | 7  | ΣP/n | Binding energy (MeV) | t* | Filling level (%) |
|---------|----|-----|---------------------------------|----|----|----|----|----|----|----|------|---------------------|----|-------------------|
| N       | 0  | 1   | 1/1                             | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 1/1 | 8.071              | 1/2 | 10.6min (β^+)     |
| H       | 1  | 1   | 1/1                             | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 1/1 | 7.289              | 1/2 | 99.985%          |
| Li      | 3  | 6   | 2/2                             | 3/3 | 3/3 | 3/3 | 3/3 | 3/3 | 3/3 | 2/2 | 14.087             | 1/2 | 1.38×10^3%        |
| Be      | 4  | 7   | 2/2                             | 4/3 | 4/3 | 4/3 | 4/3 | 4/3 | 4/3 | 2/2 | 15.770             | 1/2 | 53.3d             |
| B       | 5  | 8   | 2/2                             | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 2/2 | 4.942              | 0'  | 0.076 (α)^***     |
| C       | 6  | 9   | 2/2                             | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 2/2 | 12.052             | 3/2 | 19.8%            |
| N       | 7  | 12  | 2/2                             | 6/6 | 6/6 | 6/6 | 6/6 | 6/6 | 6/6 | 2/2 | 17.338             | 1/2 | 11ms (α)          |

* 4/2He is a 2 – filled full-filled nuclide with its p/n being 2/2. The p/n on 2nd full-filled shell has only one combination.

** It is an important characteristic of a stable nuclide for the p/n on outside shells to be equal to one. The nuclides of n–p = 2, 4, 6, ... decay in the way of (β^+) radiation.
Shell Structure of Nuclides.

| Nuclide | Z | A | Shell structure of nucleon (p/n) | King of structure | Binding energy (MeV) | T1/2 |
|---------|---|---|----------------------------------|------------------|---------------------|------|
|         |   |   | 1 2 3 4 5 6 7 | Σp/n |                        |      |
| Be5     | 4 | 9 | 2/2 5/3 | 7/6 | ○ | 5.346 | 1/2 | 9.96min (c) |
| Be6     | 4 | 10| 2/2 5/5 | 7/7 | ○ | 2.863 | 1/2 | 99.63% |
| Be7     | 4 | 11| 2/2 5/6 | 7/8 | ○ | 0.102 | 1/2 | 0.366% |
| Be8     | 4 | 12| 2/2 5/7 | 7/9 | ○ | 5.682 | 2/2 | 7.13s (β⁻) |
| Ne9     | 10| 17| 2/2 5/7 | 7/10| ○ | 7.870 | 1/2-| 4.17s (β⁻) |
| Ne10    | 10| 18| 2/2 5/8 | 7/11| ○ | 13.274 | 1/2 | 0.63s (β⁻) |
| O8      | 8 | 14| 2/2 6/4 | 8/6 | ○ | 8.008 | 0' | 71s (c) |
| O9      | 8 | 15| 2/2 6/4 | 8/7 | ○ | 2.855 | 1/2 | 122s (c) |
| O10     | 8 | 16| 2/2 6/6 | 8/8 | ○ | -4.737 | 0' | 99.76% |
| Ne11    | 10| 17| 2/2 6/6 | 8/9 | ○ | -0.810 | 5/2 | 0.038% |
| Ne12    | 10| 18| 2/2 6/7 | 8/10| ○ | -0.783 | 0' | 0.204%** |
| Ne13    | 10| 19| 2/2 6/7 | 8/11| ○ | 3.331 | 5/2 | 26.9s (β⁻) |
| Ne14    | 10| 20| 2/2 6/7 | 8/12| ○ | 3.799 | 0' | 13.5s (β⁻) |
| F9      | 9 | 17| 2/2 5/5 | 9/8 | ○ | 1.952 | 5/2 | 64.5s |
| F10     | 9 | 18| 2/2 5/7 | 9/8 | ○ | 0.872 | 0' | 110min |
| F11     | 9 | 19| 2/2 6/6 | 9/9 | 0' | -1.487 | 1/2 | 100% |
| F12     | 9 | 20| 2/2 6/6 | 9/10| ○ | -0.017 | 2' | 11s (β⁻) |
| F13     | 9 | 21| 2/2 6/6 | 9/12| ○ | -0.047 | 5/2 | 4.3s (β⁻) |
| Ne15    | 10| 17| 2/2 5/7 | 9/13| ○ | 2.826 | (3, 4)’ | 4.2s (β⁻) |
| Ne16    | 10| 18| 2/2 5/7 | 9/14| ○ | 3.35 | (3/2, 5/2)’ | 2.2s (β⁻) |
| Ne17    | 10| 19| 2/2 6/4 | 10/7| ○ | 16.478 | 1/2 | 0.11s (c)** |
| Ne18    | 10| 20| 2/2 6/6 | 10/8| ○ | 5.319 | 0' | 1.7s (c) |
| Ne19    | 10| 21| 2/2 6/6 | 10/9| ○ | 1.751 | 1/2' | 17.3s (c) |
| Ne20    | 10| 22| 2/2 6/6 | 10/10| ○ | -7.043 | 0' | 90.51% |
| Ne21    | 10| 23| 2/2 6/6 | 10/11| ○ | -5.733 | 3/2 | 0.27% |
| Ne22    | 10| 24| 2/2 5/7 | 10/12| ○ | -8.026 | 0' | 9.22% |
| Ne23    | 10| 25| 2/2 5/7 | 10/13| ○ | -5.155 | 5/2 | 37.6s (β⁻) |
| Ne24    | 10| 26| 2/2 5/7 | 10/14| ○ | -5.949 | 0' | 3.4min (β⁻) |
| Ne25    | 10| 27| 2/2 5/7 | 10/15| ○ | -2.15 | (1/2, 3/2)’ | 0.60s (β⁻) |
| Na11    | 11| 20| 2/2 6/6 | 11/9| ○ | 6.844 | 2’ | 0.45s (c) |
| Na12    | 11| 21| 2/2 6/6 | 11/10| ○ | -2.186 | 3/2 | 22.5s (c) |
| Na13    | 11| 22| 2/2 5/7 | 11/11| ○ | -5.184 | 3’ | 2.60y (c) |

* 16O is a 3-shelled nuclide with full-filled shells, with its p/n on the 3rd shell being 6/6. We know from the Table of Development Route of Nuclides that p/n=6/6 is a relatively stable combination of full-filled p/n on the 3rd shell.

** Although there is such a nuclide as one whose p/n is 5/7 when the 3rd shell is the most outside, p/n=5/7 is a combination when the 3rd shell is inside. Such stable nuclide as Ne15, Si16, and S17 all indicate that p/n=5/7 is a combination when the 3rd shell is full-filled.

*** Restricted by the proton number p≤6 of the 3rd shell, the two extra protons line on the 4th shell. After two (c)decays, they form the 3-shelled nuclide 17O.)
### Shell Structure of Nuclides

| Nuclide | Z | A | Shell structure of nucleon (p/n) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ΣP/n | Binding energy (MeV) | T° | %T° |
|---------|---|---|---------------------------------|---|---|---|---|---|---|---|---|---------------------|----|------|
| Mg      | 12 | 21 | 6/6 4/7                        | 12/9 | ○ | 10.912 | (3/2, 5/2) | 0.123s (ε) |
|         |    |   | 6/6 4/7                        | 12/10 | ○ | -0.394 | 0° | 3.86s (ε) |
|         |    |   | 6/6 4/7                        | 12/11 | ○ | -5.471 | 3° | 11.3s (ε) |
|         |    |   | 6/6 4/7                        | 12/12 | ○ | -13.931 | 0° | 78.99%* |
|         |    |   | 6/6 4/7                        | 12/13 | ○ | -13.191 | 5° | 10.00% |
|         |    |   | 6/6 4/7                        | 12/14 | ○ | -16.212 | 0° | 11.01% |
|         |    |   | 6/6 4/7                        | 12/15 | ○ | -14.585 | 1/2° | 9.46min (β⁻) |
|         |    |   | 6/6 4/7                        | 12/16 | ○ | -15.016 | 0° | 21.0h (β⁻) |
|         |    |   | 6/6 4/7                        | 12/17 | ○ | -38.405 | 3° | 1.4s (β⁻) |
| Al      | 13 | 24 | 6/6 5/3                        | 13/11 | ○ | -0.052 | 4° | 2.07s (ε) |
|         |    |   | 6/6 5/3                        | 13/12 | ○ | -8.913 | 5/2° | 7.18s (ε) |
|         |    |   | 6/6 5/3                        | 13/13 | ○ | -12.208 | 5° | 0.72My (ε) |
|         |    |   | 6/6 5/3                        | 13/14 | ○ | -17.194 | 5/2° | 100% |
|         |    |   | 6/6 5/3                        | 13/15 | ○ | -16.848 | 3° | 2.24min (β⁻) |
|         |    |   | 6/6 5/3                        | 13/16 | ○ | -18.212 | 5/2° | 6.6min (β⁻) |
|         |    |   | 6/6 5/3                        | 13/17 | ○ | -15.89 | 3° | 3.7s (β⁻) |
| Si      | 14 | 26 | 6/6 6/4                        | 14/12 | ○ | -7.143 | 0° | 2.21s (ε) |
|         |    |   | 6/6 6/4                        | 14/13 | ○ | -12.385 | 5/2° | 4.13s (ε) |
|         |    |   | 6/6 6/4                        | 14/14 | ○ | -21.491 | 0° | 92.23% |
|         |    |   | 6/6 6/4                        | 14/15 | ○ | -21.894 | 1/2° | 4.67% |
|         |    |   | 6/6 6/4                        | 14/16 | ○ | -24.432 | 0° | 3.10% |
|         |    |   | 6/6 6/4                        | 14/17 | ○ | -22.949 | 3° | 2.62h (β⁻) |
|         |    |   | 6/6 6/4                        | 14/18 | ○ | -24.092 | 0° | 105y (β⁻) |
|         |    |   | 6/6 6/4                        | 14/19 | ○ | -20.57 | (3/2)° | 6.5s (β⁻) |
| P       | 15 | 29 | 6/6 7/5                        | 15/14 | ○ | -16.949 | 1/2° | 4.1s (ε) |
|         |    |   | 6/6 7/5                        | 15/15 | ○ | -20.204 | 1° | 2.5min (ε) |
|         |    |   | 6/6 7/5                        | 15/16 | ○ | -24.440 | 1° | 100% |
|         |    |   | 6/6 7/5                        | 15/17 | ○ | -24.305 | 1° | 14.3d (β⁻) |
|         |    |   | 6/6 7/5                        | 15/18 | ○ | -26.337 | 1/2° | 25.3d (β⁻) |
**Shell Structure of Nuclides.**

| Nuclide | Z  | A  | Shell structure of nucleon (p/n) | ΣP/n | King of structure | Binding energy (MeV) | I* | T½ |
|---------|----|----|---------------------------------|------|------------------|---------------------|----|-----|
| 34      | 16 | 30 | 2/2 6/6 8/6                    | 16/14|                   | -14.062             | 0'   | 1.2s (e) |
| 31      | 16 | 30 | 2/2 6/6 8/6                    | 16/15|                   | -19.044             | 1/2' | 2.6s (e) |
| 32      | 16 | 30 | 2/2 6/6 8/8                    | 16/16|                   | -26.015             | 0'   | 95.02%  |
| 33      | 16 | 30 | 2/2 6/6 8/8                    | 16/17|                   | -26.586             | 3/2' | 0.75%   |
| 34      | 16 | 30 | 2/2 5/7 9/9                    | 16/18|                   | -29.931             | 0'   | 4.21%   |
| 35      | 16 | 30 | 2/2 6/6 8/10                   | 16/19|                   | -28.846             | 3/2' | 87.4d (β⁺) |
| 34      | 16 | 30 | 2/2 5/7 9/9                    | 16/20|                   | -30.666             | 0'   | 0.017%  |
| 37      | 17 | 33 | 2/2 5/7 9/11                   | 16/21|                   | -26.908             | 7/2' | 5.0min (β⁺) |
| 38      | 17 | 33 | 2/2 5/7 9/13                   | 16/22|                   | -26.862             | 0'   | 170min (β⁺) |
| 36      | 16 | 30 | 2/2 5/7 6/12                   | 16/20|                   | -24.438             | 0'   | 1.53s (e) |
| 35      | 16 | 30 | 2/2 5/7 7/2                    | 16/21|                   | -29.798             | 2'   | 37.3min (β⁺) |
| 39      | 16 | 30 | 2/2 5/7 10/12                  | 16/22|                   | -29.803             | 3/2' | 56min (β⁺) |
| 40      | 17 | 33 | 2/2 5/7 7/2                    | 16/23|                   | -27.54              | 2'   | 1.35min (β⁺) |
| 41      | 17 | 33 | 2/2 5/7 10/14                  | 16/24|                   | -27.40              | (1/2, 3/2)' | 31s (β⁺) |
| 43      | 18 | 34 | 2/2 6/6 10/8                   | 18/16|                   | -18.379             | 0'   | 0.844s (e) |
| 36      | 18 | 34 | 2/2 6/6 10/8                   | 18/17|                   | -23.049             | 3/2' | 1.78s (e) |
| 37      | 18 | 34 | 2/2 6/6 10/9                   | 18/18|                   | -30.231             | 0'   | 0.337%  |
| 38      | 18 | 34 | 2/2 5/7 7/2                    | 18/19|                   | -30.948             | 3/2' | 35.0d (e) |
| 39      | 18 | 34 | 2/2 5/7 10/9                   | 18/20|                   | -34.715             | 0'   | 0.063%  |
| 40      | 18 | 34 | 2/2 5/7 10/12                  | 18/21|                   | -33.241             | 7/2' | 269y (β⁻) |
| 41      | 18 | 34 | 2/2 5/7 10/14                  | 18/22|                   | -35.040             | 0'   | 99.6%*** |
| 42      | 19 | 35 | 2/2 6/6 10/14                  | 18/23|                   | -33.068             | 7/2' | 1.83h (β⁻) |
| 43      | 19 | 35 | 2/2 6/6 10/14                  | 18/24|                   | -34.42              | 0'   | 33y (β⁻)*** |
| 44      | 19 | 35 | 2/2 6/6 10/14                  | 18/25|                   | -31.98              | 5.4min (β⁻) |
| 45      | 19 | 35 | 2/2 6/6 10/14 1/3              | 18/26|                   | -32.271             | 0'   | 11.9min (β⁻) |

* When the protons are full, the p/n on outside shells of stable nuclides are not always equal to one, but $^{36}_{16}$S₃₀ shows that those nuclides in which nucleons on all shells are even-even combinations tend to be stable.

** Non-stable nuclides between two isotopes with high filling levels generally have two styles of decay, e.g. $^{36}_{17}$Diₙ with p/n = 9/11 on outside shells. It decays into $^{36}_{16}$S₃₀ after absorbing on electron and decays into $^{36}_{18}$Arₙₐ after discharging on electron, tending to be stable.

*** $^{40}_{18}$Arₙ₀ shows that p/n = 10/14 is a stable p/n combination on the 4th full-filled shell.

**** $^{40}_{18}$Arₙ₀ is obviously a 5-shelled nuclide. Only when it is included into 5-shelled nuclides can the nuclide nature be reflected. Likewise, $^{40}_{19}$Krₙ₀ also shows the characteristics of a 5-shelled nuclide.
### Shell Structure of Nuclides.

| nuclide | Z | A | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | 1* | T_{1/2} |
|---------|---|---|----------------------------------|-------------------|---------------------|----|--------|
| K       | 19| 37| 1/1 2/2 6/6 11/9 19/18          | 0                 | -24.799             | 3/2' | 1.23s  |
|         | 38| 2/2 5/7 12/10 19/19            | 0                 | -28.802             | 3'    | 7.61min (e) |
|         | 39| 2/2 6/6 11/11 19/20            | 0                 | -33.806             | 3/2'  | 93.26% |
|         | 40| 2/2 6/6 11/13 19/21            | 0                 | -33.535             | 4'    | 1.28×10^9(\beta^+)) |
|         | 41| 2/2 5/7 12/12 19/22            | 0                 | -35.560             | 3/2'  | 6.73%* |
|         | 42| 2/2 5/7 12/12 1/2 19/23        | 0                 | -35.023             | 2'    | 12.4h (\beta^-) |
|         | 43| 2/2 5/7 12/12 2/2 19/24        | 0                 | -36.588             | 3/2'  | 22.3h (\beta^-) |
|         | 44| 2/2 6/6 10/14 1/3 19/25        | 0                 | -35.807             | 2'    | 22.1min (\beta^-) |
|         | 45| 2/2 6/6 10/14 1/3 19/26        | 0                 | -36.611             | 3/2'  | 17min (\beta^-) |
|         | 46| 2/2 5/7 10/14 2/4 19/27        | 0                 | -35.420             | (2')  | 115s (\beta^-) |
|         | 47| 2/2 5/7 10/14 2/4 19/28        | 0                 | -35.698             | 1/2'  | 17.5s (\beta^-) |
| Ca      | 20| 38| 2/2 6/6 12/10 20/18            | 0                 | -22.060             | 0'   | 0.44s (e) |
|         | 39| 2/2 6/6 12/10 20/19            | 0                 | -27.282             | 3/2'  | 0.86s (e) |
|         | 40| 2/2 6/6 12/12 20/20            | 0                 | -34.847             | 0'    | 96.94%** |
|         | 41| 2/2 6/6 12/12 20/21            | 0                 | -35.138             | 7/2'  | 1.0×10^8 (e)** |
|         | 42| 2/2 5/7 12/12 1/1 20/22        | 0                 | -38.544             | 0'    | 0.647% |
|         | 43| 2/2 5/7 12/12 1/1 20/23        | 0                 | -38.405             | 7/2'  | 0.135% |
|         | 44| 2/2 6/6 10/14 2/2 20/24        | 0                 | -41.466             | 0'    | 2.09% |
|         | 45| 2/2 5/7 12/12 1/3 20/25        | 0                 | -40.810             | 7/2'  | 165d (\beta^-) |
|         | 46| 2/2 5/7 10/14 3/3 20/26        | 0                 | -43.138             | 0'    | 0.0035% |
|         | 47| 2/2 6/6 10/14 2/4 20/27        | 0                 | -42.343             | 7/2'  | 4.54d (\beta^-) |
|         | 48| 2/2 6/6 10/14 2/6 20/28        | 0                 | -44.216             | 0'    | 0.187%*** |
|         | 49| 2/2 5/7 10/14 3/5 20/29        | 0                 | -41.286             | 3/2'  | 8.72min (\beta^-) |
|         | 50| 2/2 5/7 10/14 3/7 20/30        | 0                 | -39.572             | 0'    | 14s (\beta^-) **** |
| Sc      | 21| 42| 2/2 5/7 12/12 2/ 21/21         | 0                 | -32.121             | 0'    | 0.68s (e) |
|         | 43| 2/2 5/7 12/12 2/ 21/22         | 0                 | -36.185             | 7/2'  | 3.89h (e) |
|         | 44| 2/2 6/6 10/14 3/1 21/23        | 0                 | -37.811             | 2'    | 3.93h (e) |
|         | 45| 2/2 5/7 12/12 2/2 21/24        | 0                 | -41.066             | 7/2'  | 100% |
|         | 46| 2/2 5/7 12/12 2/4 21/25        | 0                 | -41.756             | 4'    | 83.8d (\beta^-) |
|         | 47| 2/2 5/7 12/12 2/4 21/26        | 0                 | -44.330             | 7/2'  | 3.35d (\beta^-) |

* $^{41}_{19}$K$_{22}$ and $^{40}_{20}$Ca$_{20}$ show that p/n=12/12 is a stable combination of the 4th full-filled shell.  
** $^{41}_{20}$Ca$_{20}$ show that the nuclide stability not merely depends on the outside shell structure. Both of $^{41}_{20}$Ca$_{20}$ and $^{40}_{20}$Ca$_{20}$ have their outside shell p/n equai to 12/12, but their different structure categories makes different stability. $^{41}_{20}$Ca$_{20}$+e+$^{41}_{19}$K$_{22}$, tending to be stable.  
*** The proton-neutron pairing is a fundamental pre-requisite for the forming of a stable nuclide. The remaining 4 neutrons, after the protons and neutrons pair on outside shell of $^{41}_{20}$Ca$_{20}$ pair with the superfluous neutrons on inside shells. This show that nucleons of neighboring shells also may pair. The nuclides whose protons and neutrons of all shells are even numbered have a bigger tendency to be stable.  
**** The p/n of outside sheiis of $^{50}_{20}$Ca$_{20}$p/n=3/7. Such nuclides cannot become stable until after several (\beta^-) radiations. Thier decay procedure is: $^{50}_{20}$Ca$_{20}$−e→$^{50}_{21}$Sc$_{21}$→$^{50}_{22}$Tl$_{22}$. There are many nuclide which decay in the similar way.
## Shell Structure of Nuclides

| nuclide | Z | A | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | $\Sigma P/n$ | $T_{1/2}$ |
|---------|---|---|-------------------------------|------------------|---------------------|------------|----------|
|        |   | 48 | 2/2 6/6 10/14 3/5 | 21/27 | 0 | -44.498 | $6^+$ | 43.7b ($\beta^-$) |
|        |   | 49 | 2/2 6/6 10/14 3/5 | 21/28 | 0 | -46.555 | $7^2$ | 57.0min ($\beta^-$) |
|        |   | 50 | 2/2 5/7 10/14 4/6 | 21/29 | 0 | -44.539 | $5^+$ | 1.71min ($\beta^-$) |
| Ti     | 22 | 43 | 2/2 5/7 10/14 3/1 | 22/22 | 0 | -37.546 | $0^+$ | 54y ($\alpha$) |
|        |   | 44 | 2/2 5/7 10/14 3/1 | 22/21 | 0 | -29.324 | $7^2$ | 0.51s ($\alpha$) |
|        |   | 45 | 2/2 5/7 10/14 3/1 | 22/23 | 0 | -39.004 | $7^2$ | 3.09h ($\alpha$) |
|        |   | 46 | 2/2 5/7 10/14 3/1 | 22/24 | 0 | -44.123 | $0^+$ | 8.2% |
|        |   | 47 | 2/2 5/7 10/14 3/1 | 22/25 | 0 | -44.931 | $5^2$ | 7.4% |
|        |   | 48 | 2/2 5/7 10/14 4/4 | 22/26 | 0 | -48.488 | $0^+$ | 73.7% |
|        | 49 | 49 | 2/2 6/6 10/14 4/4 | 22/27 | 0 | -48.559 | $7^2$ | 5.4% |
|        | 50 | 50 | 2/2 6/6 10/14 4/4 | 22/28 | 0 | -51.432 | $0^+$ | 5.2% |
|        |   | 51 | 2/2 6/6 10/14 4/4 | 22/29 | 0 | -49.733 | $3^2$ | 5.80min ($\beta^-$) |
|        |   | 52 | 2/2 6/6 10/14 4/4 | 22/30 | 0 | -49.469 | $0^+$ | 1.7min ($\beta^-$) |
|        |   | 53 | 2/2 5/7 10/14 5/7 | 22/31 | 0 | 46.84 | $3^2$ | $33^+$ ($\beta^+$) |
| V      | 23 | 46 | 2/2 5/7 12/12 4/2 | 23/23 | 0 | -37.071 | $0^+$ | 0.42 ($\alpha$) |
|        |   | 47 | 2/2 5/7 12/12 4/2 | 23/24 | 0 | -42.001 | $3^2$ | 32.6min ($\alpha$) |
|        |   | 48 | 2/2 6/6 10/14 5/3 | 23/25 | 0 | -44.473 | $4^+$ | 16.0d ($\alpha$) |
|        | 49 | 49 | 2/2 6/6 10/14 5/3 | 23/26 | 0 | -47.957 | $7^2$ | 330d ($\alpha$) |
|        | 50 | 50 | 2/2 6/6 10/14 5/3 | 23/27 | 0 | -49.219 | $6^+$ | 0.250% |
|        |   | 51 | 2/2 6/6 10/14 5/3 | 23/28 | 0 | -5.199 | $7^2$ | 99.750% |
|        |   | 52 | 2/2 6/6 10/14 5/7 | 23/29 | 0 | -51.439 | $3^2$ | 3.76min ($\beta^+$) |
|        |   | 53 | 2/2 6/6 10/14 5/7 | 23/30 | 0 | -51.863 | $7^2$ | 1.6min ($\beta^+$) |
|        |   | 54 | 2/2 6/6 10/14 6/8 | 23/31 | 0 | -49.93 | $(3, 4, 5)^+$ | 50s ($\beta^+$) |
| Cr     | 24 | 46 | 2/2 6/6 12/12 4/2 | 24/22 | 0 | -29.461 | $0^+$ | 0.26s ($\alpha$) |
|        |   | 47 | 2/2 6/6 12/12 4/2 | 24/23 | 0 | -34.618 | $3^2$ | 0.51s ($\alpha$) |
|        |   | 48 | 2/2 5/7 12/12 5/3 | 24/24 | 0 | -42.818 | $0^+$ | 21.6h ($\alpha$) |
|        | 49 | 49 | 2/2 5/7 12/12 5/3 | 24/25 | 0 | -45.329 | $5^2$ | 41.9min ($\alpha$) |
|        | 50 | 50 | 2/2 5/7 12/12 5/5 | 24/26 | 0 | -50.258 | $0^+$ | 4.35% |
|        | 51 | 51 | 2/2 6/6 10/14 6/4 | 24/27 | 0 | -51.448 | $7^2$ | 27.7d ($\alpha$) |
|        | 52 | 52 | 2/2 6/6 10/14 6/4 | 24/28 | 0 | -55.415 | $0^+$ | 83.79% |
|        | 53 | 53 | 2/2 6/6 10/14 6/6 | 24/29 | 0 | -55.284 | $3^2$ | 9.5% |
|        | 54 | 54 | 2/2 5/7 10/14 7/7 | 24/30 | 0 | -56.931 | $0^+$ | 2.36% |
|        | 55 | 55 | 2/2 6/6 10/14 6/8 | 24/31 | 0 | -55.106 | $3^2$ | 3.5min ($\beta^+$) |
| Mn     | 25 | 50 | 2/2 5/7 12/12 6/4 | 25/25 | 0 | -42.626 | $0^+$ | 0.28s ($\alpha$) |

* It is an obvious that $^{55}_{24}$Cr is listed as ($\alpha$) decay in the original table. This nuclide should be in the ($\beta^-$) decay. The unstable isotopes after nuclides with high filling levels all belong to ($\beta^-$) decay.
| Nuclide | Z | A | Shell structure of nucleon (p/n) | ΣP/n | king of structure | Binding energy (MeV) | 1° | T½  |
|---------|---|---|---------------------------------|-------|------------------|----------------------|----|-----|
| 51      | /1| 2/2| 5/7                              | 12/12 | 6/4              | 25/26                | O  | -48.240 | 5/2  | 46.2min (e) |
| 52      | 2/2| 6/6| 10/14                            | 7/5   | 25/27            | -50.704              | 6° | 5.59d (e) |
| 53      | /1| 2/2| 6/6                              | 10/14 | 7/5              | 25/28                | O  | -54.687 | 7/2  | 3.7×10²y (e) |
| 54      | 2/2| 5/7| 10/14                            | 8/6   | 25/29            | -55.554              | 3° | 312d (e) |
| 55      | /1| 2/2| 6/6                              | 10/14 | 7/7              | 25/30                | O  | -57.710 | 5/2  | 100% |
| 56      | 2/2| 6/6| 10/14                            | 7/9   | 25/31            | -56.909              | 3° | 2.58h (β⁺) |
| 57      | /1| 2/2| 6/6                              | 10/14 | 7/9              | 25/32                | O  | -57.487 | 5/2  | 1.6min (β⁻) |
| 58      | 2/2| 5/7| 10/14                            | 8/10  | 25/33            | -55.802              | 3° | 65s (β⁻) |
| Fe      | 26| 2/2| 6/6                              | 12/12 | 6/4              | 26/25                | O  | -40.228 | (5/2) | 0.25s (e) |
| 55      | /1| 2/2| 6/6                              | 12/12 | 7/5              | 26/26                | O  | -48.332 | 0°   | 8.27h (e) |
| 53      | /1| 2/2| 6/6                              | 12/12 | 7/5              | 26/27                | O  | -50.994 | 7/2  | 8.51min (e) |
| 54      | 2/2| 5/7| 10/14                            | 7/7   | 26/28            | -56.251              | 0° | 5.8% |
| 55      | /1| 2/2| 6/6                              | 10/14 | 8/6              | 26/29                | O  | -57.479 | 3/2  | 2.7y (e) |
| 56      | 2/2| 6/6| 10/14                            | 8/8   | 26/30            | 60.604               | 0° | 91.8% |
| 57      | /1| 2/2| 6/6                              | 10/14 | 8/8              | 26/31                | O  | -60.179 | 1/2  | 2.15% |
| 58      | 2/2| 5/7| 10/14                            | 9/9   | 26/32            | -62.152              | 0° | 0.29% |
| 59      | /1| 2/2| 5/7                              | 10/14 | 8/10             | 26/33                | O  | -60.661 | 3/2  | 44.6d (β⁻) |
| 60      | 2/2| 5/7| 10/14                            | 9/11  | 26/34            | -61.437              | 0° | 1.5×10³y (β⁺) |
| 61      | /1| 2/2| 5/7                              | 10/14 | 9/11             | 26/35                | O  | -59.01  | (3/2, 5/2) | 6.0min (β⁻) |
| Co      | 27| 54 | 2/2                              | 5/7    | 12/12            | 8/6                  | 27/27 | -48.010 | 0°   | 0.19h (e) |
| 55      | /1| 2/2| 5/7                              | 12/12 | 8/6              | 27/28                | O  | -54.024 | 7/2  | 17.5h (e) |
| 56      | 2/2| 6/6| 10/14                            | 9/7   | 27/29            | -56.037              | 4° | 78.8d (e) |
| 57      | /1| 2/2| 6/6                              | 10/14 | 9/7              | 27/30                | O  | -59.342 | 7/2  | 271d (e) |
| 58      | 2/2| 5/7| 10/14                            | 10/8  | 27/31            | -59.844              | 2° | 70.8d (e) |
| 59      | /1| 2/2| 6/6                              | 10/14 | 9/9              | 27/32                | O  | -62.226 | 7/2  | 100% |
| 60      | 2/2| 6/6| 10/14                            | 9/11  | 27/33            | -61.647              | 5° | 5.27y (β⁻) |
| 61      | /1| 2/2| 6/6                              | 10/14 | 9/11             | 27/34                | O  | -62.897 | 7/2  | 1.65h (β⁻) |
| 62      | 2/2| 5/7| 10/14                            | 10/12 | 27/35            | -61.630              | 2° | 1.5min (β⁻) |
| 63      | /1| 2/2| 5/7                              | 10/14 | 10/12            | 27/36                | O  | -61.850 | (7/2) | 27.5s (β⁻) |
| Ni      | 28| 55 | 2/2                              | 6/6    | 12/12            | 8/6                  | 28/27 | -45.334 | 0°   | 6.10d (e)* |
| 55      | /1| 2/2| 6/6                              | 12/12 | 9/7              | 28/28                | O  | -53.902 | 0°   | 6.10d (e) |
| 56      | 2/2| 5/7| 12/12                            | 9/7   | 28/29            | -56.077              | 3/2 | 36.0h (e) |
| 57      | /1| 2/2| 5/7                              | 12/12 | 9/7              | 28/30                | O  | -60.224 | 0°   | 68.3% |
| 58      | 2/2| 5/7| 12/12                            | 9/9   | 28/31            | -61.153              | 3/2 | 7.5×10²y (e) |
| 59      | /1| 2/2| 6/6                              | 10/14 | 10/8             | 28/31                | O  | -61.153 | 3/2  | 7.5×10²y (e) |

* The 3rd and 4th shells of ⁵⁵Ni are all of p/n structure of full protons. After 3 consecutive (e) decays, it becomes stable. Its decay procedure is ⁵⁵Co⁻→²⁵⁵Mn(1/2)↑.
**The nucides with $p/n$ on outside shells not being equal tone and the protons and shells bring in even number tend to be stable. Similar nucides include $^{70}_{28}$ Zn, $^{72}_{28}$ Ge, $^{74}_{28}$ Ge, $^{80}_{34}$ Se, etc.**

| Nuclide | Z   | A      | $\Sigma P/n$ | Binding energy (MeV) | $\delta T_e$ |
|---------|-----|--------|--------------|----------------------|-------------|
| Cu 60   | 29  | 2/2    | 6/6 10/14 10/10 | -64.470 0' | 26.1% |
| Cu 61   | 29  | 2/2    | 6/6 10/14 10/10 | -64.219 3/2 | 1.13% |
| Cu 62   | 29  | 2/2    | 5/7 10/14 11/11 | -66.745 0' | 3.59% |
| Cu 63   | 29  | 2/2    | 5/7 10/14 11/12 | -65.513 1/2 | 100y (β') |
| Cu 64   | 29  | 2/2    | 5/7 10/14 11/13 | -67.098 0' | 0.91% |
| Cu 65   | 29  | 2/2    | 5/7 10/14 11/15 | -66.201 5/2 | 2.52h (β') |
| Cu 66   | 29  | 2/2    | 5/7 10/14 11/15 | -63.47 3/2 | 21s (β) |
| Cu 67   | 29  | 2/2    | 5/7 10/14 11/15 | -56.352 3/2 | 82s (c) |
| Zn 60   | 28  | 2/2    | 6/6 10/14 11/9 | -58.343 2' | 23.4min (c) |
| Zn 61   | 28  | 2/2    | 6/6 10/14 11/9 | -61.981 3/2 | 82s (c) |
| Zn 62   | 28  | 2/2    | 5/7 10/14 12/10 | -62.796 1' | 9.73min (c) |
| Zn 63   | 28  | 2/2    | 5/7 10/14 11/11 | -65.578 3/2 | 69.2% |
| Zn 64   | 28  | 2/2    | 5/7 10/14 11/13 | -65.423 1' | 12.7h (c)** |
| Zn 65   | 28  | 2/2    | 5/7 10/14 12/12 | -67.262 3/2 | 30.8% |
| Zn 66   | 28  | 2/2    | 5/7 10/14 12/14 | -66.257 1' | 5.10min (β') |
| Zn 67   | 28  | 2/2    | 5/7 10/14 12/14 | -67.305 3/2 | 61.9h (β') |
| Zn 68   | 28  | 2/2    | 6/6 10/14 11/17 | -65.39 1' | 31s (β') |

* The (β) decay feature of $^{67}_{28}$ Ni is not confirmed in the original table. From its shell structure, we know it should decay in the (β') way.

** Cu-63 decays into $^{64}_{28}$ Ni. In (α) decay, it absorbs an electron and into $^{64}_{28}$ Ni. In (β) decay, it releases an electron and decays into $^{64}_{30}$ Zn.**

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# Shell Structure of Nuclides

| nuclide | Z  | A    | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | 1°   | T_{1/2} |
|---------|----|------|----------------------------------|-------------------|---------------------|------|---------|
|         |    |      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ΣP/n |               |       |         |
| 65      | /1 | 2/2 | 6/6 | 10/14 | 13/11 | 31/34 | ☀ | -62.654 | 3/2 | 15.2min (c) |
| 66      | 2/2 | 5/7 | 10/14 | 14/12 | 31/35 | ☀ | -63.723 | 0° | 9.4h (c)   |
| 67      | /1 | 2/2 | 5/7 | 10/14 | 14/12 | 31/36 | ☀ | -66.878 | 3/2 | 78.3h (c)  |
| 68      | 2/2 | 6/6 | 10/14 | 13/15 | 31/37 | ☀ | -67.085 | 1° | 68.1min (c) |
| 69      | /1 | 2/2 | 5/7 | 10/14 | 14/14 | 31/38 | ☀ | -69.322 | 3/2 | 60.1%      |
| 70      | 2/2 | 5/7 | 12/12 | 12/18 | 31/39 | ☀ | -68.905 | 1° | 21.1min (β) |
| 71      | /1 | 2/2 | 5/7 | 12/12 | 12/18 | 31/40 | ☀ | -70.142 | 3/2 | 39.9%      |
| 72      | 2/2 | 6/6 | 10/14 | 13/19 | 31/41 | ☀ | -68.591 | 3° | 141h (β)   |
| 73      | /1 | 2/2 | 6/6 | 10/14 | 13/19 | 31/42 | ☀ | -69.73  | 3/2 | 4.87h (β') |
| 74      | 2/2 | 6/6 | 10/14 | 13/21 | 31/43 | ☀ | -68.02  | (4)° | 8.1min (β') |
| 75      | /1 | 2/2 | 6/6 | 10/14 | 13/21 | 31/44 | ☀ | -68.56  | 3/2 | 2.1min (β') |
| Ge      | 32 | /1 | 2/2 | 6/6 | 10/14 | 14/12 | 32/34 | ☀ | -61.621 | 0°  | 2.3h (c)   |
|         |    |    | 67 | 2/2 | 6/6 | 10/14 | 14/12 | 32/35 | ☀ | -62.45  | (1/2)° | 19.0min (c) |
| 68      | 2/2 | 5/7 | 10/14 | 15/13 | 32/36 | ☀ | -66.972 | 0°  | 274d (c)  |
| 69      | /1 | 2/2 | 5/7 | 10/14 | 15/13 | 32/37 | ☀ | -67.096 | 5/2 | 39.0h (c)  |
| 70      | 2/2 | 5/7 | 10/14 | 15/15 | 32/38 | ☀ | -70.561 | 0°  | 20.5%      |
| 71      | /1 | 2/2 | 6/6 | 10/14 | 14/16 | 32/39 | ☀ | -69.906 | 1/2 | 11.2d (c)  |
| 72      | 2/2 | 6/6 | 10/14 | 14/18 | 32/40 | ☀ | -72.583 | 0°  | 27.4%      |
| 73      | /1 | 2/2 | 6/6 | 10/14 | 14/18 | 32/41 | ☀ | -71.294 | 9/2 | 7.8%       |
| 74      | 2/2 | 6/6 | 10/14 | 14/20 | 32/42 | ☀ | -73.422 | 0°  | 36.5%      |
| 75      | /1 | 2/2 | 5/7 | 12/12 | 13/21 | 32/43 | ☀ | -71.856 | 1/2 | 82.8min (β) |
| 76      | 2/2 | 6/6 | 10/14 | 14/22 | 32/44 | ☀ | -73.214 | 0°  | 7.8%       |
| 77      | /1 | 2/2 | 5/7 | 10/14 | 15/21 | 32/45 | ☀ | -71.214 | 7/2 | 11.3h (β') |
| 78      | 2/2 | 5/7 | 10/14 | 15/23 | 32/46 | ☀ | -71.76  | 0°  | 1.45h (β') |
| 79      | /1 | 2/2 | 5/7 | 10/14 | 15/23 | 32/47 | ☀ | -69.56  | (1/2)° | 19s (β')   |
| As      | 33 | /1 | 2/2 | 5/7 | 10/14 | 16/14 | 33/37 | ☀ | -64.339 | 4°  | 53min (c)  |
|         |    |    | 71 | 2/2 | 5/7 | 10/14 | 16/14 | 33/38 | ☀ | -67.893 | 5/2 | 61h (c)   |
| 72      | 2/2 | 6/6 | 10/14 | 15/17 | 33/39 | ☀ | -68.232 | 2°  | 26.0h (c) |
| 73      | /1 | 2/2 | 6/6 | 10/14 | 15/17 | 33/40 | ☀ | -70.949 | 3/2 | 80.3d (c) |
| 74      | 2/2 | 6/6 | 10/14 | 15/19 | 33/41 | ☀ | -70.860 | 2°  | 17.8d (c) |
| 75      | /1 | 2/2 | 5/7 | 12/12 | 14/20 | 33/42 | ☀ | -73.034 | 3/2 | 100%       |
| 76      | 2/2 | 6/6 | 10/14 | 15/21 | 33/43 | ☀ | -72.291 | 2°  | 26.3h (β') |
| 77      | /1 | 2/2 | 6/6 | 10/14 | 15/21 | 33/44 | ☀ | -73.916 | 3/2 | 38.8h (β') |
| 78      | 2/2 | 6/6 | 10/14 | 15/23 | 33/45 | ☀ | -72.74  | (2)° | 91min (β)  |
| 79      | /1 | 2/2 | 6/6 | 10/14 | 15/23 | 33/46 | ☀ | -73.71  | 3/2 | 9.0min (β') |

* The p/n's on all shells except the first shell of $^{70}_{31}$Ca_{sp} and $^{71}_{31}$Ca_{sp} are the same, but differ in stability. This shows different characteristics of "○"-nuclides and "⊙"-ones.
### Shell Structure of Nuclides

| Nuclide | Z | A  | Shell structure of nucleon (p/n) | King of structure | Binding energy (MeV) | 1\( ^* \) | T_{1/2} |
|---------|---|----|---------------------------------|------------------|---------------------|----------|---------|
| Se      | 34 | 71 | 2/2 6/6 10/14 16/14            | 34/37            | -63.46              | 5/2      | 4.7min (e) |
|         |    | 72 | 2/2 5/7 12/12 15/17            | 34/38            | -67.894             | 0"       | 8.4d (e)  |
|         |    | 73 | 2/2 5/7 12/12 15/17            | 34/39            | -68.209             | 9/2"     | 7.1h (e)  |
|         |    | 74 | 2/2 5/7 10/14 17/17            | 34/40            | -72.213             | 0"       | 0.87%    |
|         |    | 75 | 2/2 5/7 12/12 15/19            | 34/41            | -72.213             | 5/2      | 11.8d (e) |
|         |    | 76 | 2/2 6/6 10/14 16/20            | 34/42            | -75.259             | 0"       | 9.0%     |
|         |    | 77 | 2/2 6/6 10/14 16/20            | 34/43            | -74.606             | 1/2      | 7.6%     |
|         |    | 78 | 2/2 6/6 10/14 16/22            | 34/44            | -77.032             | 0"       | 23.5%    |
|         |    | 79 | 2/2 5/7 12/12 15/23            | 34/45            | -75.911             | 7/2"     | <6.5×10^6y (β) |
|         |    | 80 | 2/2 6/6 10/14 16/24            | 34/46            | -77.761             | 0"       | 49.8%    |
|         |    | 81 | 2/2 5/7 12/12 15/25            | 34/47            | -76.391             | (1/2)    | 18.5min (β) |
|         |    | 82 | 2/2 6/6 10/14 16/26            | 34/48            | -77.586             | 0"       | 9.2%     |
|         |    | 83 | 2/2 5/7 10/14 17/25            | 34/49            | -75.333             | 9/2"     | 22.5min (β) |
|         |    | 84 | 2/2 5/7 10/14 17/27            | 34/50            | -75.942             | 0"       | 3.3 min (β) |
| Br      | 35 | 76 | 2/2 6/6 10/14 17/19            | 35/41            | -70.303             | 1"       | 16.1h (e) |
|         |    | 77 | 2/2 6/6 10/14 17/19            | 35/42            | -73.242             | 3/2      | 57.0h (e) |
|         |    | 78 | 2/2 6/6 10/14 17/21            | 35/43            | -73.458             | 1"       | 6.46min (e) |
|         |    | 79 | 2/2 5/7 12/12 16/22            | 35/44            | -76.070             | 3/2      | 50.69%   |
|         |    | 80 | 2/2 6/6 10/14 17/23            | 35/45            | -75.891             | 1"       | 17.6 min (e) |
|         |    | 81 | 2/2 5/7 12/12 16/24            | 35/46            | -77.976             | 3/2      | 49.31%   |
|         |    | 82 | 2/2 6/6 10/14 17/25            | 35/47            | -77.498             | 5"       | 35.3h (β) |
|         |    | 83 | 2/2 6/6 10/14 17/25            | 35/48            | -79.025             | (3/2)    | 2.39h (β) |
|         |    | 84 | 2/2 6/6 10/14 17/27            | 35/49            | -77.759             | 2"       | 31.8min (β) |
|         |    | 85 | 2/2 6/6 10/14 17/27            | 35/50            | -78.67              | (3/2)    | 2.9min (β) |
| Kr      | 36 | 75 | 2/2 6/6 12/12 16/18            | 36/39            | -64.166             | 4.3min (e) |
|         |    | 76 | 2/2 5/7 12/12 17/19            | 36/40            | -69.10              | 0"       | 14.8h (e) |
|         |    | 77 | 2/2 5/7 12/12 17/19            | 36/41            | -70.236             | 5/2      | 75min (e) |
|         |    | 78 | 2/2 5/7 10/14 19/19            | 36/42            | -74.150             | 0"       | 0.356%   |
|         |    | 79 | 2/2 5/7 12/12 17/21            | 36/43            | -74.439             | 1/2      | 35.0h (e) |
|         |    | 80 | 2/2 6/6 10/14 18/22            | 36/44            | -77.897             | 0"       | 2.27%    |
|         |    | 81 | 2/2 5/7 12/12 17/23            | 36/45            | -77.654             | 7/2"     | 2.1×10^6y (e) |
|         |    | 82 | 2/2 6/6 10/14 18/24            | 36/46            | -80.591             | 0"       | 11.6%    |
|         |    | 83 | 2/2 6/6 10/14 18/24            | 36/47            | -79.985             | 9/2"     | 11.5%    |
|         |    | 84 | 2/2 6/6 10/14 18/26            | 36/48            | -82.432             | 0"       | 57.0%    |
|         |    | 85 | 2/2 5/7 12/12 17/27            | 36/49            | -81.472             | 9/2"     | 10.7y (β) |
|         |    | 86 | 2/2 6/6 10/14 18/28            | 36/50            | -83.263             | 0"       | 17.3%    |
|         |    | 87 | 2/2 5/7 12/12 17/29            | 36/51            | -80.707             | 5/2      | 76 min (β) |
Shell Structure of Nuclides.

| Nuclide | Z  | A   | Shell structure of nucleon (p/n) | kink of structure | Binding energy (MeV) | I* | T½ |
|---------|----|-----|----------------------------------|------------------|---------------------|----|-----|
|         |    | 1   | 2    | 3   | 4   | 5   | 6   | 7   | ΣP/n |         |       |
|         |    | 188 | 2/2  | 5/7 | 10/14 | 19/29 | 36/52 | O | -79.689 | 0° | 2.84 (β⁻) |
|         |    | 189 | /1  | 2/2 | 5/7 | 10/14 | 19/29 | 36/53 | O | -76.79 | (5/2) | 3.18min (β⁻) |
| Rb      | 37 | 82  | 2/2  | 6/6 | 10/14 | 19/23 | 37/45 | O | -76.213 | 1° | 1.25min (c) |
|         |    | 83  | /1  | 2/2 | 6/6 | 10/14 | 19/23 | 37/46 | O | -78.914 | 5/2 | 86.2d (c) |
|         |    | 84  | 2/2  | 6/6 | 10/14 | 19/25 | 37/47 | O | -79.752 | 2° | 32.9d (c) |
|         |    | 85  | /1  | 2/2 | 5/7 | 12/12 | 18/26 | 37/48 | O | -82.159 | 5/2 | 72.17% |
|         |    | 86  | 2/2  | 6/6 | 10/14 | 19/27 | 37/49 | O | -82.739 | 2° | 18.8d (β⁻) |
|         |    | 87  | /1  | 2/2 | 5/7 | 12/12 | 18/28 | 37/50 | O | -84.596 | 3/2 | 27.83% |
|         |    | 88  | 2/2  | 6/6 | 10/14 | 19/29 | 37/51 | O | -82.602 | 2° | 17.8 (β⁻) |
|         |    | 89  | /1  | 2/2 | 6/6 | 10/14 | 19/29 | 37/52 | O | -81.717 | (3/2) | 15.2min (β⁻) |
|         |    | 90  | 2/2  | 5/7 | 10/14 | 20/28 | /2  | 37/53 | O | -79.57 | (1°) | 153α (β*) |
| Sr      | 38 | 81  | /1  | 2/2 | 5/7 | 12/12 | 19/21 | 38/43 | O | -71.40 | (1/2) | 22min (c) |
|         |    | 82  | 2/2  | 5/7 | 12/12 | 19/23 | 38/44 | O | -75.999 | 0° | 25.0d (c) |
|         |    | 83  | /1  | 2/2 | 5/7 | 12/12 | 19/23 | 38/45 | O | -76.664 | 7/2° | 32.4d (c) |
|         |    | 84  | 2/2  | 6/6 | 10/14 | 20/24 | 38/46 | O | -81.641 | 0° | 0.56% |
|         |    | 85  | /1  | 2/2 | 5/7 | 12/12 | 19/25 | 38/47 | O | -81.095 | 9/2° | 64.8d (c) |
|         |    | 86  | 2/2  | 6/6 | 10/14 | 20/26 | 38/48 | O | -84.512 | 0° | 9.8% |
|         |    | 87  | /1  | 2/2 | 6/6 | 10/14 | 20/26 | 38/49 | O | -84.869 | 9/2° | 7.0% |
|         |    | 88  | 2/2  | 6/6 | 10/14 | 20/28 | 38/50 | O | -87.911 | 0° | 82.6%** |
|         |    | 89  | /1  | 2/2 | 5/7 | 12/12 | 19/29 | 38/51 | O | -86.203 | 5/2° | 50.5d (β⁻) |
|         |    | 90  | 2/2  | 6/6 | 10/14 | 20/28 | /2  | 38/52 | O | -85.935 | 0° | 28.8y (β⁻) |
|         |    | 91  | /1  | 2/2 | 6/6 | 10/14 | 20/28 | /2  | 38/53 | O | -83.666 | (5/2)° | 9.5β (β⁻) |
|         |    | 92  | 2/2  | 5/7 | 10/14 | 20/28 | 1/3 | 38/54 | O | -82.892 | 0° | 2.7h (β⁻) |
|         |    | 93  | /1  | 2/2 | 5/7 | 10/14 | 20/28 | 1/3 | 38/55 | O | -80.28 | (7/2°) | 7.4min (β⁻) |
| Y       | 39 | 84  | 2/2  | 6/6 | 10/14 | 21/23 | 39/45 | O | -73.692 | 5° | 39min (c)*** |
|         |    | 85  | /1  | 2/2 | 6/6 | 10/14 | 21/23 | 39/46 | O | -77.855 | (1/2)° | 2.7h (c) |
|         |    | 86  | 2/2  | 6/6 | 10/14 | 21/25 | 39/47 | O | -79.239 | 4° | 14.7h (c) |
|         |    | 87  | /1  | 2/2 | 6/6 | 10/14 | 21/25 | 39/48 | O | -83.007 | 1/2° | 80.3h (c) |
|         |    | 88  | 2/2  | 6/6 | 10/14 | 21/27 | 39/49 | O | -84.298 | 4° | 106.6d (c)*** |
|         |    | 89  | /1  | 2/2 | 5/7 | 12/12 | 20/28 | 39/50 | O | -87.695 | 1/2° | 100%**** |

* 90Rb, 90Sr show the characteristic of 6-shelled structures.
** 88Sr is a 5-shelled nucleus, showing that p/n=20/28 is a stable combination of 5th full-filled shell.
*** the number of protons of a stable nucleus is smaller than or equal to 20 (p≤20). When the 5th shell is most outside, the proton number may be bigger than 20. But they are all non-stable nuclei.
**** 39Y is a 5-shelled of “O” category. It shows that p/n=20/28 is a stable combination of the p/n on the 5th shell. 89Sr releases an electron, 89Zr attracts an electron and decays into 39Y. It shows that p/n=20/28 is a stable combination of p/n on the 5th shell. At the same time it shows that such quasi-full structures as p/n=19/29 and p/n=21/27 can not form stable nuclides.
### Shell Structure of Nuclides

| Nuclide | Z  | A  | Shell structure of nucleon (p/n) | Shell structure of nucleus (p/n) | \( \Sigma P/n \) | \( \delta P/n \) | King of structure | Binding energy \( \Delta (\text{MeV}) \) | \( t_1/2 \) | \( t_{1/2} \) |
|---------|----|----|-------------------------------|---------------------------------|-------------|-------------|-----------------|-----------------|-----------|-----------|
| Nb      | 41 | 89 | 2/2 5/7 12/12 20/28 2/2 | 1/2 5/7 12/12 20/28 2/2 | 39:51      | 39:52      | ○               | -86.481         | 2\(^*\)   | 64.1h (β\(^-\)) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 21/25 | 2/2 5/7 12/12 21/25 | 40:47      | 40:48      | ○               | -79.43          | (9/2\(^+\)) | 1.6h (c)* |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Nb      | 41 | 89 | 2/2 5/7 12/12 20/26 2/2 | 1/2 5/7 12/12 20/26 2/2 | 41:48      | 41:49      | ○               | -80.621         | (1/2\(^+\)) | 2.0h (c)** |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 20/28 1/1 | 2/2 5/7 12/12 20/28 1/1 | 40:50      | 40:51      | ○               | -87.892         | 5/2\(^+\) | 78.4h (c) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Nb      | 41 | 89 | 2/2 5/7 12/12 18/30 2/4 | 1/2 5/7 12/12 18/30 2/4 | 40:55      | 40:56      | ○               | -85.663         | 5/2\(^-\) | 64.0d (β\(^+\)) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 18/30 3/5 | 2/2 5/7 12/12 18/30 3/5 | 40:57      | 40:58      | ○               | -81.292         | 3/5\(^+\) | 16.9h (β\(^+\)) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Nb      | 41 | 89 | 2/2 5/7 12/12 20/28 2/2 | 1/2 5/7 12/12 20/28 2/2 | 41:52      | 41:53      | ○               | -87.209         | 9/2\(^-\) | 100%       |
| Mo      | 42 | 90 | 2/2 5/7 12/12 20/28 2/2 | 1/2 5/7 12/12 20/28 2/2 | 41:54      | 41:55      | ○               | -86.367         | 6/2\(^-\) | 2.0×10\(^4\) (β\(^-\)) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 20/28 2/2 | 1/2 5/7 12/12 20/28 2/2 | 41:56      | 41:57      | ○               | -85.608         | 6/2\(^+\) | 72min (β\(^-\)) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Mo      | 42 | 90 | 2/2 5/7 12/12 20/28 2/2 | 1/2 5/7 12/12 20/28 2/2 | 42:48      | 42:49      | ○               | -82.199         | 9/2\(^-\) | 15.5min (c) |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 20/28 2/2 | 1/2 5/7 12/12 20/28 2/2 | 42:50      | 42:51      | ○               | -83.807         | 6/2\(^+\) | 14.8%      |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 20/28 3/3 | 1/2 5/7 12/12 20/28 3/3 | 42:52      | 42:53      | ○               | -88.412         | 0\(^-\) | 9.3%       |
|         |    |    |                               |                                 |             |             |                 |                 |           |            |
| Zr      | 40 | 87 | 2/2 5/7 12/12 20/28 3/3 | 1/2 5/7 12/12 20/28 3/3 | 42:54      | 42:55      | ○               | -88.795         | 5/2\(^-\) | 15.9%      |

\* \( ^{87}Zr\) and \( ^{Zr}_{40}\) are the same with \( ^{Y}_{40}\). The number of protons on the 5\(^{th}\) shell is greater than 20 (p>20). They are all non-stable nuclides.

\*\* \( ^{90}Zr\), \( ^{92}Mo\), and \( ^{94}Mo\) show that p\(9/2\) is 18/30 and is a stable combination of p/n on 5th full-filled shell.

\*\*\* \( ^{89}Nb\) restricted by the maximal number of protons of all shells, developed into a 6-shelled nuclide, of which \( P_1=2, P_2=6 \). \( P_1≤12 \). \( P_1≤20 \).
**Shell Structure of Nuclides.**

| Nuclide | Z | A | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | I* | T_{1/2} |
|---------|---|---|---------------------------------|------------------|---------------------|----|--------|
|         |   |    | 1 2 3 4 5 6 7  ΣP/n             |                  |                     |    |        |
| 97      | /1| 2/2 | 6/6 10/14 20/28 4/4 42/55         | ◯                | -87.544             | 5/2* | 9.6%   |
| 98      | 2/2 | 5/7| 12/12 18/30 5/5 42/56           | ◯                | -88.115             | 0*  | 24.1%  |
| 99      | /1| 2/2 | 6/6 10/14 20/28 4/6 42/57         | ◯                | -85.970             | 1/2* | 66.6h  (β⁻) |
| 100     | 2/2 | 6/6| 10/14 18/30 5/6 42/58           | ◯                | -86.198             | 0*  | 9.6%   |
| 101     | /1| 2/2 | 5/7 12/12 18/30 5/7 42/59         | ◯                | -83.516             | 1/2* | 14.6min |
| Tc      | 43| 94 | 2/2 5/7 12/12 20/28 4/2 43/51     | ◯                | -84.156             | 7*  | 293min (c) |
| 95      | /1| 2/2 | 6/6 10/14 20/28 5/3 43/54         | ◯                | -86.013             | 9/2* | 20.0h (c) |
| 96      | 2/2 | 6/6| 10/14 20/28 5/5 43/53           | ◯                | -85.821             | 7*  | 4.3d (c) |
| 97      | /1| 2/2 | 6/6 10/14 20/28 4/6 43/55         | ◯                | -86.224             | 9/2* | 2.6×10⁸y (c) |
| 98      | 2/2 | 5/7| 12/12 20/28 4/6 43/56           | ◯                | -87.326             | 9/2* | 2.14×10⁷ (β⁻) |
| 99      | /1| 2/2 | 5/7 12/12 20/28 5/6 44/57         | ◯                | -86.019             | 1*  | 15.8s (β⁻) |
| 100     | 2/2 | 6/6| 10/14 20/28 5/7 43/57           | ◯                | -86.019             | 1*  | 15.8s (β⁻) |
| Ru      | 44| 94 | 2/2 6/6 12/12 20/28 4/2 44/50     | ◯                | -82.571             | 0*  | 52min (c)* |
| 95      | /1| 2/2 | 6/6 10/14 20/28 5/2 44/51         | ◯                | -83.452             | 5/2* | 1.65h (c) |
| 96      | 2/2 | 6/6| 12/12 20/28 4/4 44/52           | ◯                | -86.075             | 0*  | 5.5%   |
| 97      | /1| 2/2 | 5/7 12/12 20/28 5/3 44/53         | ◯                | -86.075             | 5/2* | 2.88d (c) |
| 98      | 2/2 | 5/7| 12/12 20/28 5/5 44/54           | ◯                | -86.226             | 0*  | 1.86%  |
| 99      | /1| 2/2 | 5/7 12/12 20/28 5/5 44/55         | ◯                | -87.620             | 5/2* | 12.7%  |
| 100     | 2/2 | 6/6| 10/14 20/28 6/6 44/56           | ◯                | -89.222             | 0*  | 12.6%  |
| 102     | 2/2 | 5/7| 12/12 18/30 7/7 44/58           | ◯                | -89.100             | 0*  | 31.6%  |
| 103     | /1| 2/2 | 6/6 10/14 20/28 6/8 44/59         | ◯                | -87.261             | 3/2* | 39.4d (β⁻) |
| 104     | 2/2 | 6/6| 10/14 18/30 8/8 44/60           | ◯                | -88.099             | 0*  | 18.7%  |
| 105     | /1| 2/2 | 5/7 12/12 18/30 7/9 44/61         | ◯                | -85.938             | 3/2* | 4.44h (β⁻) |
| 106     | 2/2 | 6/6| 10/14 18/30 8/10 44/62          | ◯                | -86.333             | 0*  | 372d (β⁻) |
| 107     | /1| 2/2 | 6/6 10/14 18/30 8/10 44/63         | ◯                | -83.71              | 5(2) | 3.8min (β⁻) |
| Rh      | 45| 98 | 2/2 5/7 12/12 20/28 6/4 45/53     | ◯                | -83.168             | 2(2) | 8.7min (c) |
| 99      | /1| 2/2 | 5/7 12/12 20/28 6/4 45/54         | ◯                | -85.517             | 1/2* | 16.1d (c) |
| 100     | 2/2 | 6/6| 10/14 20/28 7/5 45/55           | ◯                | -85.592             | 1*   | 20.8h (c) |
| 101     | /1| 2/2 | 6/6 10/14 20/28 7/5 45/56         | ◯                | -87.410             | 1/2* | 3.3y (c) |
| 102     | 2/2 | 5/7| 12/12 18/30 8/6 45/57           | ◯                | -86.807             | 6*   | 2.9h (c) |
| 103     | /1| 2/2 | 6/6 10/14 20/28 7/7 45/58         | ◯                | -88.024             | 1/2* | 100%   |
| 104     | 2/2 | 6/6| 10/14 20/28 7/9 45/59           | ◯                | -86.952             | 1*   | 42.3s (β⁻) |
| 105     | /1| 2/2 | 6/6 10/14 20/28 7/9 45/60         | ◯                | -87.855             | 7/2* | 35.4h (β⁻) |

* The p/n’s on the 3°, 4°, and 5° shells of Ru⁹⁴ all belong to “I” category, i, e, the p/n stickey of full protons Through absorption of two electrons, it decays into Mo⁹⁴ and tend to be stable. It shows that nuclides whose p/n’s of all all shells alternate between full and non-full are more likely to be stable. Most of the stable nuclides bear this characteristic.
### Shell Structure of Nuclides

| nuclide | Z  | A | Shell structure of nucleon (p/n) | King of structure | Binding energy (MeV) | 1° | T½ [y] |
|---------|----|---|---------------------------------|-------------------|---------------------|----|--------|
|         | 1 | 2 | 3    | 4 | 5 | 6 | 7 | ∑P/n | β-    |        |        |
| Pd      | 106 | 2/2 | 5/7 | 12/12 | 18/30 | 8/10 | 46/61 | ○ | -86.372 | 1° | 29.8s (β⁻) |
|         | 100 | 2/2 | 5/7 | 12/12 | 20/28 | 7/5 | 46/54 | ○ | -85.230 | 0° | 3.6d (c) |
|         | 101 | 2/2 | 5/7 | 12/12 | 20/28 | 7/5 | 46/55 | ○ | -85.428 | 5/2 | 8.5h (c) |
|         | 102 | 2/2 | 5/7 | 12/12 | 20/28 | 7/7 | 46/56 | ○ | -87.925 | 0° | 1.0% |
|         | 103 | 2/2 | 6/6 | 10/14 | 20/28 | 8/6 | 46/57 | ○ | -87.478 | 5/2 | 17.0d (c) |
|         | 104 | 2/2 | 6/6 | 10/14 | 20/28 | 8/8 | 46/58 | ○ | -89.400 | 0° | 11.0% |
|         | 105 | 2/2 | 6/6 | 10/14 | 20/28 | 8/8 | 46/59 | ○ | -88.422 | 5/2 | 22.2% |
|         | 106 | 2/2 | 5/7 | 12/12 | 18/30 | 9/9 | 46/60 | ○ | -89.913 | 0° | 27.3% |
|         | 107 | 2/2 | 6/6 | 10/14 | 20/28 | 8/10 | 46/61 | ○ | -88.371 | 5/2 | 6.5×10⁷y (β⁻) |
|         | 108 | 2/2 | 6/6 | 10/14 | 18/30 | 10/10 | 46/62 | ○ | -89.523 | 0° | 26.7% |
|         | 109 | 2/2 | 5/7 | 12/12 | 18/30 | 9/11 | 46/63 | ○ | -87.606 | 5/2 | 13.4h (β⁻) |
|         | 110 | 2/2 | 5/7 | 10/14 | 18/30 | 11/11 | 46/64 | ○ | -88.335 | 0° | 11.8% |
|         | 111 | 2/2 | 6/6 | 10/14 | 18/30 | 10/12 | 46/65 | ○ | -86.03 | 5/2 | 23min (β⁻) |
|         | 112 | 2/2 | 5/7 | 10/14 | 18/30 | 11/13 | 46/66 | ○ | -88.326 | 0° | 21.0h (β⁻) |
| Ag      | 47 | 103 | 2/2 | 5/7 | 12/12 | 20/28 | 8/6 | 47/56 | ○ | -84.80 | 7/2 | 65.7min (c) |
|         | 104 | 2/2 | 6/6 | 10/14 | 20/28 | 9/7 | 47/57 | ○ | -85.150 | 5° | 69.2min (c) |
|         | 105 | 2/2 | 6/6 | 10/14 | 20/28 | 9/7 | 47/58 | ○ | -87.075 | 1/2 | 41.3d (c) |
|         | 106 | 2/2 | 5/7 | 12/12 | 18/30 | 10/8 | 47/59 | ○ | -86.929 | 1° | 24.0min (c) |
|         | 107 | 2/2 | 6/6 | 10/14 | 20/28 | 9/9 | 47/60 | ○ | -88.404 | 1° | 51.83% |
|         | 108 | 2/2 | 6/6 | 10/14 | 20/28 | 9/11 | 47/61 | ○ | -87.602 | 1° | 2.4min (β⁻) |
|         | 109 | 2/2 | 5/7 | 12/12 | 18/30 | 10/10 | 47/62 | ○ | -88.722 | 1/2 | 48.17% |
|         | 110 | 2/2 | 5/7 | 12/12 | 18/30 | 10/12 | 47/63 | ○ | -87.456 | 1° | 24.4s (β⁻) |
|         | 111 | 2/2 | 5/7 | 12/12 | 18/30 | 10/12 | 47/64 | ○ | -88.226 | 1/2 | 7.45d (β⁻) |
|         | 112 | 2/2 | 6/6 | 10/14 | 18/30 | 11/13 | 47/65 | ○ | -86.620 | 2° | 3.14h (β⁻) |
| Cd      | 48 | 104 | 2/2 | 5/7 | 12/12 | 20/28 | 9/7 | 48/56 | ○ | -83.57 | 0° | 58min (c) |
|         | 105 | 2/2 | 5/7 | 12/12 | 20/28 | 9/7 | 48/57 | ○ | -84.336 | 5/2 | 56.6min (c) |
|         | 106 | 2/2 | 5/7 | 12/12 | 20/28 | 9/9 | 48/58 | ○ | -87.131 | 0° | 1.25% |
|         | 107 | 2/2 | 6/6 | 10/14 | 20/28 | 10/8 | 48/59 | ○ | -86.987 | 5/2 | 6.50h (c) |
|         | 108 | 2/2 | 6/6 | 10/14 | 20/28 | 10/10 | 48/60 | ○ | -89.251 | 0° | 0.89% |
|         | 109 | 2/2 | 5/7 | 12/12 | 18/30 | 11/9 | 48/61 | ○ | -88.540 | 5/2 | 463d (c) |
|         | 110 | 2/2 | 5/7 | 12/12 | 18/30 | 11/11 | 48/62 | ○ | -90.349 | 0° | 12.5% |
|         | 111 | 2/2 | 5/7 | 12/12 | 18/30 | 11/11 | 48/63 | ○ | -89.254 | 1/2 | 12.8% |
|         | 112 | 6/6 | 10/14 | 18/30 | 12/12 | 48/64 | ○ | -90.578 | 0° | 24.1% |
|         | 113 | 6/6 | 10/14 | 18/30 | 12/12 | 48/65 | ○ | -89.050 | 1/2 | 12.2% |
|         | 114 | 5/7 | 10/14 | 18/30 | 13/13 | 48/66 | ○ | -90.020 | 0° | 28.7% |
|         | 115 | 6/6 | 10/14 | 18/30 | 12/14 | 48/67 | ○ | -88.093 | 1/2 | 53.4h (β⁻) |
### Shell Structure of Nuclides

| Nuclide | Z  | A   | Shell structure of nucleon (p/n) | King of structure | Binding energy (MeV) | l^* | T_{1/2} |
|---------|----|-----|----------------------------------|-------------------|---------------------|-----|---------|
|         | 1  | 2   | 3      | 4      | 5      | 6      | 7     | ΣP/n    |
| 116     | 116| 2/2 | 6/6    | 10/14  | 18/30  | 12/26  | 48/68 | ○       | -88.718 | 0°     | 7.5%    |
| 117 /1  | 117| 2/2 | 5/7    | 10/14  | 18/30  | 13/15  | 48/69 | ○       | -86.416 | 1/2    | 2.4h (β^-) |
| 118     | 118| 2/2 | 5/7    | 10/14  | 18/30  | 13/17  | 48/70 | ○       | -86.707 | 0°     | 50.3min (β^-) |
| In      | 49 | 110 | 2/2    | 5/7    | 12/12  | 18/30  | 12/10 | 49/61   | ○       | -86.409 | 2°     | 69.1min (e^-) |
|         | 111| 2/2 | 5/7    | 12/12  | 18/30  | 12/10  | 49/62 | ○       | -88.405 | 9/2°   | 2.83d (e^-) |
|         | 112| 2/2 | 6/6    | 10/14  | 18/30  | 13/11  | 49/63 | ○       | -88.000 | 1°     | 14.4min (e^-) |
|         | 113| 2/2 | 5/7    | 12/12  | 18/30  | 12/12  | 49/64 | ○       | -89.372 | 9/2°   | 4.3%    |
|         | 114| 2/2 | 5/7    | 12/12  | 18/30  | 12/14  | 49/65 | ○       | -88.576 | 1°     | 71.9s (β^-) |
|         | 115| 2/2 | 6/6    | 10/14  | 18/30  | 13/13  | 49/66 | ○       | -89.541 | 9/2°   | 95.7%   |
| Sn      | 50 | 109 | 2/2    | 5/7    | 12/12  | 20/28  | 11/9  | 50/59   | ○       | -82.630 | 7/2°   | 18.0min (c) |
|         | 110| 2/2 | 6/6    | 10/14  | 18/30  | 12/10  | 50/60 | ○       | -85.834 | 0°     | 4.1h (c) |
|         | 111| 2/2 | 6/6    | 10/14  | 20/28  | 12/10  | 50/61 | ○       | -85.941 | 1/2°   | 35min (c) |
|         | 112| 2/2 | 6/6    | 10/14  | 20/28  | 12/12  | 50/62 | ○       | -88.658 | 0°     | 1.01%   |
|         | 113| 2/2 | 5/7    | 12/12  | 18/30  | 13/11  | 50/63 | ○       | -88.332 | 1°     | 115.1d (c) |
|         | 114| 2/2 | 5/7    | 12/12  | 18/30  | 13/13  | 50/64 | ○       | -90.560 | 0°     | 0.67%   |
|         | 115| 2/2 | 5/7    | 12/12  | 18/30  | 13/13  | 50/65 | ○       | -90.035 | 1°     | 0.38%   |
|         | 116| 2/2 | 6/6    | 10/14  | 18/30  | 14/14  | 50/66 | ○       | -91.526 | 0°     | 14.6%   |
|         | 117| 2/2 | 6/6    | 10/14  | 18/30  | 14/14  | 50/67 | ○       | -90.399 | 1/2°   | 7.75%   |
|         | 118| 2/2 | 5/7    | 10/14  | 18/30  | 15/15  | 50/68 | ○       | -91.654 | 0°     | 24.3%   |
|         | 119| 2/2 | 5/7    | 10/14  | 18/30  | 15/15  | 50/69 | ○       | -90.067 | 1/2°   | 8.6%    |
|         | 120| 2/2 | 6/6    | 10/14  | 18/30  | 14/18  | 50/70 | ○       | -91.102 | 0°     | 32.4%   |
|         | 121| 2/2 | 5/7    | 10/14  | 18/30  | 15/17  | 50/71 | ○       | -89.202 | 3/2°   | 27.1h (β^-) |
|         | 122| 2/2 | 6/6    | 10/14  | 18/30  | 14/20  | 50/72 | ○       | -89.946 | 0°     | 4.56%   |
|         | 123| 2/2 | 5/7    | 10/14  | 18/30  | 15/19  | 50/73 | ○       | -87.821 | 11/2°  | 129d (β^-) |
|         | 124| 2/2 | 6/6    | 10/14  | 18/30  | 14/22  | 50/74 | ○       | -88.240 | 0°     | 5.46%   |
|         | 125| 2/2 | 5/7    | 10/14  | 18/30  | 15/21  | 50/75 | ○       | -85.903 | 11/2°  | 9.26d (β^-) |
|         | 126| 2/2 | 5/7    | 10/14  | 18/30  | 15/23  | 50/76 | ○       | -86.024 | 0°     | 10^9y (β^-) |
|         | 127| 2/2 | 5/7    | 10/14  | 18/30  | 15/23  | 50/77 | ○       | -83.79  | (11/2°) | 2.1h (β^-) |
| Sb      | 51 | 118 | 2/2    | 5/7    | 10/14  | 18/30  | 16/14 | 51/67   | ○       | -87.976 | 1°     | 3.6min (c) |
|         | 119| 2/2 | 5/7    | 10/14  | 18/30  | 16/14  | 51/68 | ○       | -89.483 | 5/2°   | 30.8h (c) |
|         | 120| 2/2 | 6/6    | 10/14  | 18/30  | 15/17  | 51/69 | ○       | -88.421 | 1°     | 15.8min (c) |
|         | 121| 2/2 | 5/7    | 10/14  | 18/30  | 15/17  | 51/70 | ○       | -89.588 | 5/2°   | 57.3%   |
|         | 122| 2/2 | 5/7    | 10/14  | 18/30  | 16/18  | 51/71 | ○       | -83.323 | 2°     | 2.70d (β^-) |
|         | 123| 2/2 | 5/7    | 12/12  | 18/30  | 14/20  | 51/72 | ○       | -89.218 | 7/2°   | 42.7%   |
|         | 124| 2/2 | 6/6    | 10/14  | 18/30  | 15/21  | 51/73 | ○       | -87.613 | 3°     | 60.2d (β^-) |
### Shell Structure of Nuclides

| Nuclide | Z | A | Shell structure of nucleon (p/n) | $\Sigma P/n$ | king of structure | Binding energy $\Delta$(MeV) | $T_{1/2}$ | $T_{1/2}$ |
|---------|---|---|---------------------------------|------------|------------------|-----------------------------|---------|---------|
| Te      | 52 | 117 | 2/2 5/7 12/12 18/30 15/13 52/65 | 52/66 | -87.164 | 1/2’ 62min (c) | 118 | 2/2 6/6 10/14 18/30 16/14 52/70 | -87.671 | 0’ 6.00d (c) |
|         | 119 | 2/2 6/6 10/14 18/30 16/14 52/67 | -87.189 | 1/2’ 16.0h (c) | 120 | 2/2 6/6 10/14 18/30 16/16 52/68 | -89.404 | 0’ 0.91% |
|         | 121 | 2/2 5/7 10/14 18/30 17/15 52/69 | -88.486 | 1/2’ 16.8d (c) | 122 | 2/2 5/7 10/14 18/30 17/17 52/70 | -90.304 | 0’ 2.5% |
|         | 123 | 2/2 5/7 10/14 18/30 17/17 52/71 | -89.166 | 1/2’ 0.89% | 124 | 2/2 6/6 10/14 18/30 16/20 52/72 | -90.518 | 0’ 4.6% |
|         | 125 | 2/2 6/6 10/14 18/30 16/20 52/73 | -89.019 | 1/2’ 7.0% | 126 | 2/2 6/6 10/14 18/30 16/22 52/74 | -90.066 | 0’ 18.7% |
|         | 127 | 2/2 5/7 12/12 18/30 15/23 52/75 | -88.285 | 3/2’ 9.4h (β⁻) | 128 | 2/2 6/6 10/14 18/30 16/24 52/76 | -88.992 | 0’ 31.7% |
|         | 129 | 2/2 5/7 10/14 18/30 17/23 52/77 | -87.007 | 3/2’ 69min (β⁻) | 130 | 2/2 6/6 10/14 18/30 16/26 52/78 | -87.348 | 0’ 34.5% |
|         | 131 | 2/2 5/7 10/14 18/30 17/25 52/79 | -85.201 | 3/2’ 25.0min (β⁻) | 132 | 2/2 5/7 10/14 18/30 17/27 52/80 | -85.213 | 0’ 78.2h (β⁻) |
|         | 133 | 2/2 5/7 10/14 18/30 17/27 52/81 | -82.93 | (3/2)’ 12.5min (β⁻) | 134 | 2/2 6/6 10/14 18/30 17/27 52/82 | -82.97 | 5/2' 13.2h (c) |
| I       | 53 | 123 | 2/2 5/7 10/14 18/30 18/16 53/70 | -87.97 | 5/2’ 4.18d (c) | 124 | 2/2 6/6 10/14 18/30 17/19 53/71 | -87.361 | 2’ 100%
|         | 125 | 2/2 5/7 10/14 18/30 17/19 53/72 | -88.841 | 5/2’ 60.2d (c) | 126 | 2/2 6/6 10/14 18/30 17/21 53/73 | -87.911 | 2’ 13.0d (c) |
|         | 127 | 2/2 5/7 12/12 18/30 16/22 53/74 | -88.980 | 5/2’ 100% | 128 | 2/2 6/6 10/14 18/30 17/23 53/75 | -87.734 | 1’ 25.0min (β⁻) |
|         | 129 | 2/2 6/6 10/14 18/30 17/23 53/76 | -88.505 | 7/2’ 1.6×10⁶y (β⁻) | 130 | 2/2 6/6 10/14 18/30 17/25 53/77 | -86.897 | 5’ 12.4h (β⁻) |
|         | 131 | 2/2 6/6 10/14 18/30 17/25 53/78 | -87.451 | 7/2’ 8.04d (β⁻) | 132 | 2/2 6/6 10/14 18/30 17/27 53/79 | -85.706 | 4’ 2.30h (β⁻) |
| Xe      | 54 | 121 | 2/2 5/7 12/12 18/30 17/15 54/67 | -82.33 | (5/2)’ 40.1min (c) | 122 | 2/2 6/6 10/14 18/30 18/16 54/68 | -85.16s | 0’ 20.1h (c) |
|         | 123 | 2/2 6/6 10/14 18/30 18/16 54/69 | -85.29 | (1/2)’ 2.08h (c) | 124 | 2/2 6/6 10/14 18/30 18/18 54/70 | -87.45 | 0’ 0.996% |
|         | 125 | 2/2 5/7 12/12 18/30 17/19 54/71 | -87.11 | (1/2)’ 17h (c) | 126 | 2/2 5/7 10/14 18/30 19/19 54/72 | -89.162 | 0’ 0.990% |
|         | 127 | 2/2 5/7 12/12 18/30 17/21 54/73 | -88.316 | (1/2)’ 36.4d (c) | 128 | 2/2 6/6 10/14 18/30 18/20 54/74 | -88.605 | 0’ 0.996% |
Shell Structure of Nuclides.

| Nuclide | Z  | A     | Shell structure of nucleon (p/n) | 1  | 2   | 3   | 4   | 5   | 6   | 7   | ΣP/n | King of structure | Binding energy (MeV) | 1τ  | T1/2 |
|---------|----|-------|----------------------------------|----|-----|-----|-----|-----|-----|-----|------|------------------|---------------------|-----|------|
| Ca 55   | 22 | 128   | 2/2                             | 6/6| 10/14| 20/28| 16/24| 54/74|      |      | -89.861         | 0°                  | 1.92%|       |
| Ca 55   | 22 | 129 /1| 2/2                             | 6/6| 10/14| 20/28| 16/24| 54/75|      |      | -88.698         | 1/2°                | 26.4%|       |
| Ca 55   | 22 | 130   | 2/2                             | 6/6| 10/14| 18/30| 18/24| 54/76|      |      | -89.881         | 0°                  | 4.1% |       |
| Ca 55   | 22 | 131 /1| 2/2                             | 6/6| 10/14| 18/30| 18/24| 54/77|      |      | -88.521         | 3/2°                | 21.2%|       |
| Ca 55   | 22 | 132   | 2/2                             | 6/6| 10/14| 18/30| 18/26| 54/78|      |      | -89.296         | 0°                  | 26.9%|       |
| Ca 55   | 22 | 133 /1| 2/2                             | 5/7| 12/12| 18/30| 17/27| 54/79|      |      | -87.662         | 3/2°                | 5.25d (β⁻)       |       |
| Ca 55   | 22 | 134   | 2/2                             | 6/6| 10/14| 18/30| 18/28| 54/80|      |      | -88.125         | 0°                  | 10.4%|       |
| Ca 55   | 22 | 135 /1| 2/2                             | 5/7| 10/14| 18/30| 19/27| 54/81|      |      | -86.506         | 3/2°                | 9.1h (β⁻)        |       |
| Ca 55   | 22 | 136   | 2/2                             | 6/6| 10/14| 18/30| 18/30| 54/82|      |      | -86.425         | 0°                  | 8.9%*          |       |
| Ca 55   | 22 | 137 /1| 2/2                             | 5/7| 10/14| 18/30| 19/29| 54/83|      |      | -82.215         | 7/2°                | 3.82min (β⁻)     |       |
| Ba 56   | 36 | 127   | 2/2                             | 6/6| 10/14| 18/30| 19/23| 55/75|      |      | -86.863         | 1°                  | 29.2min (ε)      |       |
| Ba 56   | 36 | 131 /1| 2/2                             | 6/6| 10/14| 18/30| 19/23| 55/76|      |      | -88.066         | 5/2°                | 9.69d (ε)        |       |
| Ba 56   | 36 | 132   | 2/2                             | 6/6| 10/14| 18/30| 19/25| 55/77|      |      | -87.175         | 2°                  | 6.47d (ε)        |       |
| Ba 56   | 36 | 133 /1| 2/2                             | 5/7| 12/12| 18/30| 18/26| 55/78|      |      | -88.089         | 7/2°                | 100%           |       |
| Ba 56   | 36 | 134   | 2/2                             | 6/6| 10/14| 18/30| 19/27| 55/79|      |      | -86.909         | 4°                  | 2.06y (β⁻)       |       |
| Ba 56   | 36 | 135 /1| 2/2                             | 6/6| 10/14| 18/30| 19/27| 55/80|      |      | -87.665         | 7/2°                | 3×10⁶y (β⁻)      |       |
| Ba 56   | 36 | 136   | 2/2                             | 6/6| 10/14| 18/30| 19/29| 55/81|      |      | -86.358         | 5°                  | 13.1d (β⁻)       |       |
| Ba 56   | 36 | 137 /1| 2/2                             | 6/6| 10/14| 18/30| 19/29| 55/82|      |      | -86.560         | 7/2°                | 30.2y (β⁻)       |       |
| Ba 56   | 36 | 138   | 2/2                             | 6/6| 10/14| 18/30| 19/31| 55/83|      |      | -82.98          | 3°                  | 32.2min (β⁻)     |       |

*136⁵⁴Xe: show that p/n=18/30 is a stable combination of the 5ᵗʰ full shell. The 5ᵗʰ and 6ᵗʰ shells are the same. At the same time it shows the characteristics of magnetic nucleonic pairing between neighboring shells.

**13⁶⁵Ba and 13⁷⁶Ba: show that p/n=18/30 and p/n=20/28 are stable combinations of the 5ᵗʰ full shell.
## Shell Structure of Nuclides

| Nuclide | Z | A | Shell structure of nucleon (p/n) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ΣP/n | binding energy (MeV) | λ | T½ |
|---------|---|---|----------------------------------|---|---|---|---|---|---|---|-----|---------------------|---|----|
| La      | 57| 135/1 | 2/2 | 6/6 | 10/14 | 18/30 | 21/25 | 57/78 | ⊗ | -86.670 | 5/2⁺ | 19.5h (e) |
|         |   | 136  | 2/2 | 6/6 | 10/14 | 18/30 | 21/27 | 57/79 | ⊗ | -86.04  | 1⁺ | 9.87min (e) |
|         |   | 137  | 2/2 | 6/6 | 10/14 | 18/30 | 21/27 | 57/80 | ⊗ | -87.13s | 7/2⁺ | 6×10⁷y (e) |
|         |   | 138  | 2/2 | 5/7 | 12/12 | 18/30 | 20/30 | 57/81 | ⊗ | -86.524 | 5⁻ | 0.089% |
|         |   | 139  | 2/2 | 5/7 | 12/12 | 18/30 | 20/30 | 57/82 | ⊗ | -87.231 | 7/2⁺ | 99.911% |
|         |   | 140  | 2/2 | 6/6 | 10/14 | 20/28 | 19/33 | 57/83 | ⊗ | -84.320 | 3⁻ | 40.3h (β⁻) |
|         |   | 141  | 2/2 | 6/6 | 10/14 | 20/28 | 19/33 | 57/84 | ⊗ | -83.008 | 7/2⁺ | 3.90h (β⁻) |
|         |   | 142  | 2/2 | 6/6 | 10/14 | 18/30 | 21/33 | 57/85 | ⊗ | -80.018 | 2⁻ | 91.1min (β⁻) |
| Ce      | 58| 133/1 | 2/2 | 5/7 | 12/12 | 18/30 | 21/33 | 58/75 | ⊗ | -82.17s | 1/2⁺ | 5.4h (e) |
|         |   | 134  | 2/2 | 5/7 | 12/12 | 18/30 | 21/25 | 58/76 | ⊗ | -84.77s | 0⁻ | 76h (e) |
|         |   | 135  | 2/2 | 5/7 | 12/12 | 18/30 | 21/25 | 58/77 | ⊗ | -84.551 | 1/2⁺ | 17.6h (e) |
|         |   | 136  | 2/2 | 6/6 | 10/14 | 20/28 | 20/28 | 58/78 | ⊗ | -86.50  | 0⁻ | 0.190% |
|         |   | 137  | 2/2 | 5/7 | 12/12 | 18/30 | 21/27 | 58/79 | ⊗ | -85.91s | 3/2⁻ | 9.0h (e) |
|         |   | 138  | 2/2 | 6/6 | 10/14 | 20/28 | 20/30 | 58/80 | ⊗ | -87.565 | 0⁻ | 0.254% |
|         |   | 139  | 2/2 | 5/7 | 12/12 | 18/30 | 21/29 | 58/81 | ⊗ | -86.966 | 3/2⁻ | 137.2d (e) |
|         |   | 140  | 2/2 | 6/6 | 10/14 | 20/28 | 20/32 | 58/82 | ⊗ | -88.08i | 0⁻ | 88.5% |
|         |   | 141  | 2/2 | 5/7 | 12/12 | 18/30 | 21/31 | 58/83 | ⊗ | -85.438 | 7/2⁻ | 32.5d (β⁻) |
|         |   | 142  | 2/2 | 6/6 | 12/14 | 18/30 | 22/32 | 58/84 | ⊗ | -84.535 | 0⁻ | 11.1% |
|         |   | 143  | 2/2 | 5/7 | 10/14 | 20/28 | 21/33 | 58/85 | ⊗ | -81.610 | 3/2⁻ | 33.0h (β⁻) |
|         |   | 144  | 2/2 | 5/7 | 10/14 | 18/30 | 23/33 | 58/86 | ⊗ | -80.431 | 0⁻ | 284d (β⁻) |
|         |   | 145  | 2/2 | 5/7 | 10/14 | 18/30 | 23/33 | 58/87 | ⊗ | -77.12  | 5/2⁻ | 2.98min (β⁻) |
| Pr      | 59| 138  | 2/2 | 6/6 | 10/14 | 20/28 | 21/29 | 59/79 | ⊗ | -83.128 | 1⁻ | 1.45min (e) |
|         |   | 139  | 2/2 | 6/6 | 10/14 | 20/28 | 21/29 | 59/80 | ⊗ | -84.854 | 5/2⁺ | 4.4h (e)* |
|         |   | 140  | 2/2 | 6/6 | 10/14 | 20/28 | 21/31 | 59/81 | ⊗ | -84.693 | 0⁻ | 3.39min (e) |
|         |   | 141  | 2/2 | 5/7 | 12/12 | 18/30 | 22/30 | 59/82 | ⊗ | -86.018 | 5/2⁻ | 100% |
|         |   | 142  | 2/2 | 6/6 | 10/14 | 20/28 | 21/33 | 59/83 | ⊗ | -83.790 | 2⁻ | 19.2h (β⁻) |
|         |   | 143  | 2/2 | 6/6 | 10/14 | 20/28 | 21/33 | 59/84 | ⊗ | -83.065 | 7/2⁻ | 13.6d (β⁻) |
|         |   | 144  | 2/2 | 6/6 | 10/14 | 20/28 | 21/35 | 59/85 | ⊗ | -80.750 | 0⁻ | 17.3min (β⁻) |
| Nd      | 60| 139/1 | 2/2 | 5/7 | 12/12 | 20/28 | 21/29 | 60/79 | ⊗ | -82.05  | 3/2⁻ | 29.7min (e) |
|         |   | 140  | 2/2 | 5/7 | 12/12 | 18/30 | 23/29 | 60/80 | ⊗ | -84.22  | 0⁻ | 3.37d (e) |
|         |   | 141  | 2/2 | 5/7 | 12/12 | 18/30 | 23/29 | 60/81 | ⊗ | -84.203 | 3/2⁻ | 2.5h (e) |
|         |   | 142  | 2/2 | 6/6 | 10/14 | 20/28 | 22/32 | 60/82 | ⊗ | -85.949 | 0⁻ | 27.2%** |

*139⁵⁹Pr is through two (γ)'decays and exchange of a nucleon with inside shell, generates 139⁵⁵La and becomes stable. The nucleon exchange between shell is a way of nuclear motion, which however does not affect the stable p/n between shells.

**142⁶⁰Nd and 142⁵⁸Ce are similar in nuclide shell structure, both belonging to category with A=142. But they differ in character because of the p/n difference between shells.
Shell Structure of Nuclide.

| Nuclide | Z | A | Shell structure of nucleon (p/n) | ΣP/n | king of structure | Binding energy Δ(MeV) | I$^*$ | T$_{1/2}$ |
|---------|---|---|----------------------------------|-------|------------------|-----------------------|------|----------|
|         | 1 | 2 | 3 | 4 | 5 | 6 | 7 | $\sum\rho/n$ |
| Nd      | 62 | 144 | 2/2 | 6/6 | 10/14 | 20/28 | 22/34 | 60/84 | ○ | -83.746 | 0° | 23.8% |
|        | /1 | 145 | 2/2 | 6/6 | 10/14 | 20/28 | 22/34 | 60/85 | ○ | 81.430 | 7/2 | 8.3% |
|        | 2/2 | 6/6 | 10/14 | 20/28 | 22/36 | 60/86 | ○ | -80.923 | 0° | 17.2% |
|        | /1 | 147 | 2/2 | 5/7 | 10/14 | 18/30 | 23/35 | 60/87 | ○ | -78.144 | 5/2 | 11.0d (β$^-$) |
|        | 2/2 | 6/6 | 12/12 | 18/30 | 24/36 | 60/88 | ○ | -77.407 | 0° | 5.7% |
|        | /1 | 149 | 2/2 | 5/7 | 10/14 | 20/28 | 23/37 | 60/89 | ○ | -74.374 | 5/2 | 1.73h (β$^-$) |
|        | 2/2 | 6/6 | 10/14 | 18/30 | 24/38 | 60/90 | ○ | -73.682 | 0° | 5.6% |
|        | /1 | 151 | 2/2 | 5/7 | 10/14 | 18/30 | 25/37 | 60/91 | ○ | -70.945 | (3/2$^+$) | 12.4min (β$^-$) |
|        | 2/2 | 5/7 | 10/14 | 18/30 | 25/39 | 60/92 | ○ | -70.146 | 0° | 11.4min (β$^-$) |
| Pm      | 61 | 142 | 2/2 | 6/6 | 10/14 | 20/28 | 23/31 | 61/81 | ○ | -81.06 | 1° | 40.5s (α)* |
|        | /1 | 143 | 2/2 | 6/6 | 10/14 | 20/28 | 23/31 | 61/82 | ○ | -82.959 | 5/2 | 265d (e) |
|        | 2/2 | 6/6 | 10/14 | 20/28 | 23/33 | 61/83 | ○ | -81.416 | 5° | 349d (e) |
|        | /1 | 145 | 2/2 | 6/6 | 10/14 | 20/28 | 23/33 | 61/84 | ○ | -81.270 | 5/2 | 17.7y (e) |
|        | 2/2 | 6/6 | 12/12 | 20/28 | 23/35 | 61/85 | ○ | -79.442 | 3° | 5.5y (e)** |
|        | /1 | 147 | 2/2 | 6/6 | 10/14 | 20/28 | 23/35 | 61/86 | ○ | -79.040 | 7/2 | 2.62y (β$^-$) |
|        | 2/2 | 6/6 | 10/14 | 20/28 | 23/37 | 61/87 | ○ | -76.870 | 1° | 5.37d (β$^-$) |
|        | /1 | 149 | 2/2 | 6/6 | 10/14 | 20/28 | 23/37 | 61/88 | ○ | -76.063 | 7/2 | 53.1h (β$^-$) |
|        | 2/2 | 6/6 | 10/14 | 18/30 | 25/37 | 61/89 | ○ | -73.55 | (1') | 2.68h (β$^-$) |
| Sm      | 62 | 142 | 2/2 | 5/7 | 12/12 | 20/28 | 23/31 | 62/80 | ○ | -78.978 | 0° | 72.5min (e) |
|        | /1 | 143 | 2/2 | 5/7 | 12/12 | 20/28 | 23/31 | 62/81 | ○ | -79.511 | 3/2 | 8.83min (e) |
|        | 2/2 | 6/6 | 10/14 | 20/28 | 24/32 | 62/82 | ○ | -81.964 | 0° | 3.1% |
|        | /1 | 145 | 2/2 | 5/7 | 12/12 | 20/28 | 23/33 | 62/83 | ○ | -80.656 | 7/2 | 340d (e) |
|        | 2/2 | 6/6 | 10/14 | 20/28 | 24/34 | 62/84 | ○ | -80.984 | 0° | 10.3×10$^{12}$y (α)*** |
|        | /1 | 147 | 2/2 | 6/6 | 10/14 | 20/28 | 24/34 | 62/85 | ○ | -79.265 | 7/2 | 15.1%*** |
|        | 2/2 | 6/6 | 10/14 | 20/28 | 24/36 | 62/86 | ○ | -79.335 | 0° | 11.3% |
|        | /1 | 149 | 2/2 | 6/6 | 10/14 | 20/28 | 24/36 | 62/87 | ○ | -77.135 | 7/2 | 13.9% |
|        | 2/2 | 6/6 | 10/14 | 18/30 | 26/36 | 62/88 | ○ | -77.049 | 0° | 7.4% |
|        | /1 | 151 | 2/2 | 5/7 | 12/18 | 20/30 | 25/37 | 62/89 | ○ | -74.574 | 5/2 | 90y (β$^-$) |
|        | 2/2 | 6/6 | 10/14 | 18/30 | 26/38 | 62/90 | ○ | -74.761 | 0° | 26.6% |

*Nd and Sm, which neighbor Pm, each have 7 stable isotopes. But Pm does not have a single stable isotope, which can be explained with its $p/n$ on on outside shells. It seems that the $p/n$ of outside shell becomes an even-even combination by the exchange of a nucleon between the 6$^{th}$ and 3$^{rd}$ shells. Even so, this nuclide is not stable. The stable shell structures of Nd and Sm tell us that the $p/n$'s of such nuclides are all even-even combinations except for the first shell. The Pm, after the nuclonic exchange, fails to meet the requirement, so it can not become a stable nuclide even after the nuclonic exchange between the 6$^{th}$ and 3$^{rd}$ shells.

**$^{146}_{61}$ Pm$^{65}$ should have two ways of decay. It turns into $^{146}_{60}$ Nd$^{65}$ after (α) decay and becomes $^{146}_{62}$ Sm$^{65}$ after (β$^-$) decay.

***$^{146}_{62}$ Sm decay in the (α) style and its decay procedure is: $^{146}_{62}$ Sm$^{65}$ + $^{2}He$→ $^{144}_{60}$ Nd$^{65}$. Now it become stable. There are many such examples. $^{147}_{62}$ Sm$^{65}$ is the same as $^{146}_{62}$ Sm$^{65}$ in the $p/n$'s between shells the first shell But they differ in stability. This example shows that not all even–even nuclides tend to be stable. The $^{146}_{62}$ Sm$^{65}$ is the high filling level of outside shells and it is an even–even combination.
### Shell Structure of Nuclides.

| nuclide | Z  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | ΣP/n | binding energy (MeV) | T
|---------|----|-----|-----|-----|-----|-----|-----|-----|------|----------------------|---|
| Tb      | 153 | 1/1 | 2/2 | 5/7 | 12/12| 18/30| 25/39| 62/91| -72.557 | 3/2^+ | 46.8h (β^-) |
| Gd      | 154 | 2/2 | 6/6 | 10/14| 18/30| 26/40| 62/92| -72.454 | 0^- | 22.6%  |
| Gd      | 155 | 2/2 | 5/7 | 10/14| 18/30| 27/39| 62/93| -70.196 | 3/2^- | 22.4min (β^-) |
| Eu      | 148 | 2/2 | 6/6 | 10/14| 18/30| 25/35| 93/85| -76.235 | 5^- | 54.5d (c) |
| Gd      | 149 | 2/2 | 6/6 | 10/14| 20/28| 25/35| 63/86| -76.439 | 5^- | 93.1d (c) |
| Gd      | 150 | 2/2 | 6/6 | 10/14| 20/28| 27/35| 63/87| -74.756 | 0^- | 36y (c)  |
| Gd      | 151 | 2/2 | 5/7 | 12/12| 18/30| 26/36| 63/88| -74.650 | 5^- | 47.9%  |
| Gd      | 152 | 2/2 | 6/6 | 10/14| 18/30| 27/37| 63/89| -72.884 | 3^- | 13y (c)  |
| Gd      | 153 | 2/2 | 5/7 | 12/12| 18/30| 26/38| 63/90| -73.363 | 5^- | 52.1%  |
| Gd      | 154 | 2/2 | 6/6 | 10/14| 18/30| 27/39| 63/91| -71.762 | 0^- | 8.5y (β^-) |
| Gd      | 155 | 2/2 | 6/6 | 10/14| 18/30| 27/39| 63/92| -71.825 | 5^- | 4.9y (β^-) |
| Gd      | 156 | 2/2 | 6/6 | 10/14| 18/30| 27/41| 63/93| -70.083 | 7/2 | 15d (β^-) |
| Gd      | 157 | 2/2 | 6/6 | 10/14| 18/30| 27/41| 63/94| -69.465 | 0^- | 15h (β^-) |
| Gd      | 149 | 2/2 | 5/7 | 12/12| 18/30| 27/33| 64/85| -75.131 | 3/2^- | 9.4d (c) |
| Gd      | 150 | 2/2 | 6/6 | 10/14| 18/30| 28/34| 64/86| -75.765 | 0^- | 1.8x10^2y (α) |
| Gd      | 151 | 2/2 | 5/7 | 12/12| 18/30| 27/35| 64/87| -74.168 | 3/2^- | 120d (c) |
| Gd      | 152 | 2/2 | 6/6 | 10/14| 18/30| 28/36| 64/88| -74.703 | 0^- | 0.20%  |
| Gd      | 153 | 2/2 | 6/6 | 12/12| 18/30| 27/37| 64/89| -73.119 | 3/2^- | 242d (c) |
| Gd      | 154 | 2/2 | 6/6 | 10/14| 18/30| 28/38| 64/90| -73.704 | 0^- | 2.1%   |
| Gd      | 155 | 2/2 | 6/6 | 10/14| 18/30| 28/38| 64/91| -72.071 | 3/2^- | 14.8%  |
| Gd      | 156 | 2/2 | 6/6 | 10/14| 18/30| 28/40| 64/92| -72.536 | 0^- | 20.6%  |
| Gd      | 157 | 2/2 | 5/7 | 10/14| 18/30| 28/40| 64/93| -70.825 | 3/2^- | 15.7%  |
| Gd      | 158 | 2/2 | 6/6 | 10/14| 18/30| 28/42| 64/94| -70.691 | 0^- | 24.8%  |
| Gd      | 159 | 2/2 | 5/7 | 12/12| 18/30| 27/43| 64/95| -68.562 | 3/2^- | 18.6h (β^-) |
| Gd      | 160 | 2/2 | 6/6 | 10/14| 20/28| 26/46| 64/96| -67.943 | 0^- | 21.8%* |
| Gd      | 161 | 2/2 | 6/6 | 12/12| 18/30| 27/45| 64/97| -65.507 | 5/2^- | 3.7min (β^-) |
| Tb      | 156 | 2/2 | 6/6 | 10/14| 18/30| 29/39| 65/91| -70.098 | 3^- | 5.34d (c) |
| Tb      | 157 | 2/2 | 6/6 | 10/14| 18/30| 29/39| 65/92| -70.767 | 3/2^- | 150y (c) |
| Tb      | 158 | 2/2 | 6/6 | 10/14| 18/30| 29/41| 65/93| -69.475 | 3^- | 150y (c) |
| Tb      | 159 | 2/2 | 5/7 | 12/12| 18/30| 28/42| 65/94| -69.536 | 3/2^- | 100%  |
| Tb      | 160 | 2/2 | 6/6 | 10/14| 20/28| 27/45| 65/95| -67.840 | 3^- | 72.1d (β^-) |
| Tb      | 161 | 2/2 | 6/6 | 12/12| 18/30| 27/45| 65/96| -67.466 | 3/2^- | 6.90y (β^-) |
| Tb      | 162 | 2/2 | 5/7 | 12/12| 18/30| 28/44| 65/97| -65.766 | 1^- | 7.7min (β^-) |
| Dy      | 153 | 2/2 | 5/7 | 12/12| 18/30| 29/35| 66/87| -69.155 | 7/2^- | 6.4h (c) |
| Dy      | 154 | 2/2 | 6/6 | 10/14| 18/30| 30/36| 66/88| -70.392 | 0^- | 3x10^2y (α) |

*The stability of $^{160}_{64}$Gd tells us that the p/n=26/46 is a stable combination of the 6th full shell.*
### Shell Structure of Nuclides.

| nuclide | Z | A | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | 1* | T_{1/2} |
|---------|---|---|----------------------------------|-------------------|---------------------|----|---------|
|        |   |    | 1   | 2   | 3   | 4   | 5   | 6   | 7   | Σp/n |           |           |       |
| 155 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 29/37 | 66/89 | ○   | -69.157 | 3/2   | 10.0h (c) |
| 156    | 2/2 | 6/6 | 10/14 | 20/28 | 28/40 | 66/90 | ○   | -70.527 | 0'    | 0.857%   |
| 157 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 29/39 | 66/91 | ○   | -69.425 | 3/2   | 8.1h (c)  |
| 158    | 2/2 | 6/6 | 10/14 | 20/28 | 28/42 | 66/92 | ○   | -70.410 | 0'    | 0.100%   |
| 159 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 29/41 | 66/93 | ○   | -69.171 | 3/2   | 144.4d (c) |
| 160    | 2/2 | 6/6 | 10/14 | 20/28 | 28/44 | 66/94 | ○   | -69.674 | 0'    | 2.3%     |
| 161 /1 | 2/2 | 6/6 | 10/14 | 20/28 | 28/44 | 66/95 | ○   | -68.056 | 5/2   | 19.90%*  |
| 162    | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 1/1  | 66/96 | ○   | -68.181 | 0'    | 25.5%**  |
| 163 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 1/1  | 66/97 | ○   | -66.382 | 5/2   | 24.9%    |
| 164    | 2/2 | 6/6 | 10/14 | 18/30 | 28/44 | 2/2  | 66/98 | ○   | -65.967 | 0'    | 28.1%    |
| 165 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 1/3  | 66/99 | ○   | -63.611 | 7/2   | 2.33 (f') |
| 166    | 2/2 | 5/7 | 10/14 | 18/30 | 28/44 | 2/4  | 66/100| ○   | -62.583 | 0'    | 81.6h (f') |
| Ho     | 67 | 162 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 2'   | 67/95 | ○   | -66.047 | 1'    | 15min (c) |
| 163 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 2'   | 67/96 | ○   | -66.379 | (7/2) | 33y (c) |
| 164    | 2/2 | 6/6 | 10/14 | 18/30 | 28/44 | 3/1  | 67/97 | ○   | -64.937 | 1'    | 29.0 min (f') |
| 165 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 2/2  | 67/98 | ○   | -64.896 | 7/2   | 100%     |
| 166    | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 2/4  | 67/99 | ○   | -63.007 | 0'    | 26.8h (f') |
| 167 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 2/4  | 67/100| ○   | -62.316 | (7/2) | 3.1h (f') |
| Er     | 68 | 160 | 2/2 | 6/6 | 12/12 | 20/28 | 28/44 | 68/92 | ○   | -66.052 | 0'    | 28.6h (c)*** |
| 161 /1 | 2/2 | 6/6 | 12/12 | 20/28 | 28/44 | 68/93 | ○   | -65.197 | 3/2   | 3.2h     |
| 162    | 2/2 | 5/7 | 12/12 | 20/28 | 28/44 | 1/1  | 68/94 | ○   | -66.335 | 0'    | 0.14%    |
| 163 /1 | 2/2 | 6/6 | 10/14 | 20/28 | 28/44 | 2'   | 68/95 | ○   | -65.168 | 5/2   | 75.1min (c) |
| 164    | 2/2 | 6/6 | 10/14 | 20/28 | 28/44 | 2/2  | 68/96 | ○   | -65.940 | 0'    | 1.56%    |
| 165 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 3/1  | 68/97 | ○   | -65.518 | 5/2   | 10.4h (c) |
| 166    | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 3/3  | 68/98 | ○   | -64.921 | 0'    | 33.4%    |
| 167 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 3/3  | 68/99 | ○   | -63.286 | 7/2   | 22.9%    |
| 168    | 2/2 | 6/6 | 10/14 | 20/28 | 26/46 | 4/4  | 68/100| ○   | -62.985 | 0'    | 27.1%**** |
| 169 /1 | 2/2 | 5/7 | 12/12 | 18/30 | 28/44 | 3/5  | 68/101| ○   | -60.917 | 1/2   | 9.40d (f') |
| 170    | 2/2 | 5/7 | 12/12 | 18/30 | 26/46 | 5/5  | 68/102| ○   | -60.104 | 0'    | 14.9%    |
| 171 /1 | 2/2 | 6/6 | 10/14 | 20/28 | 26/46 | 4/6  | 68/103| ○   | -57.714 | 5/2   | 7.52h (f') |
| 172    | 2/2 | 5/7 | 12/12 | 18/30 | 26/46 | 5/7  | 68/104| ○   | -56.491 | 0'    | 49.3h (f') |

* 160\(^{66}\)Dy\(^{92}\) and 161\(^{66}\)Dy\(^{95}\) are respectively even-\(A\) 6-shell nuclides, showing that \(p/n=28/44\) is a stable combination of the 6\(^{th}\) full shell.

** 162\(^{66}\)Dy\(^{95}\) and 162\(^{67}\)Ho clearly bear the characteristics of a 7-shell structure.

*** 160\(^{68}\)Er\(^{95}\) is a 6-shell nuclide of the "o"category. All the \(p/n\)'s are in agreement with the stable \(p/n\) combination, but they are all "I"combination. This shows that the nuclide composed of nothing but full protons is not stable. After two (\(E^0\)) decays it generates 166\(^{66}\)Dy\(^{94}\) and becomes stable.

**** 168\(^{68}\)Er\(^{110}\) shows that the \(p/n=26/46\) is a stable combination of the 6\(^{th}\) full shell. Similar nuclide 170\(^{68}\)Er\(^{110}\), 172\(^{70}\)Yb\(^{110}\), 173\(^{70}\)Yb\(^{110}\), etc.
Shell Structure of Nuclides.

| nuclide | Z | A | Shell structure of nucleon (p/n) |  |  |  |  |  |  | ΣP/n | Binding energy (MeV) | τ | T_{1/2} |
|---------|---|---|--------------------------------|---|---|---|---|---|---|---|-------------------|---|-------------|
| Tm      | 69 | 166 | 2/2 5/7 12/12 18/30 28/44 4/2 | 69/97 | ○ | -61.874 | 2⁻ | 7.0h (e) |
|         | 167 | /1 | 2/2 5/7 12/12 18/30 28/44 4/2 | 69/98 | ○ | -65.537 | 1/2⁻ | 9.25d (e) |
|         | 168 | 2/2 6/6 10/14 18/30 28/44 5/3 | 69/99 | ○ | -61.306 | 3⁻ | 93.1d (e) |
|         | 169 | /1 | 2/2 5/7 12/12 18/30 28/44 4/4 | 69/100 | ○ | -61.2669 | 1/2⁻ | 100% |
|         | 170 | 2/2 5/7 12/12 18/30 28/44 4/6 | 69/101 | ○ | -59.791 | 1⁻ | 128.6d (β⁻) |
|         | 171 | /1 | 2/2 5/7 12/12 18/30 28/44 4/6 | 69/102 | ○ | -59.205 | 1/2⁻ | 1.92y (β⁻) |
|         | 172 | 2/2 6/6 10/14 18/30 28/44 5/7 | 69/103 | ○ | -57.380 | 2⁻ | 63.6h (β⁻) |
| Yb      | 70 | 166 | 2/2 6/6 10/14 20/28 28/44 4/2 | 70/96 | ○ | -61.582 | 0⁻ | 56.7h (e) |
|         | 167 | /1 | 2/2 6/6 10/14 20/28 28/44 4/2 | 70/97 | ○ | 60.583 | 5/2⁺ | 17.5min (e) |
|         | 168 | 2/2 6/6 10/14 20/28 28/44 4/4 | 70/98 | ○ | -61.565 | 0⁻ | 0.135% |
|         | 169 | /1 | 2/2 5/7 12/12 18/30 28/44 5/3 | 70/99 | ○ | -60.361 | 7/2⁻ | 32.0d (e) |
|         | 170 | 2/2 5/7 12/12 18/30 28/44 5/5 | 70/100 | ○ | -60.759 | 0⁻ | 3.1% |
|         | 171 | /1 | 2/2 5/7 12/12 18/30 28/44 5/5 | 70/101 | ○ | -59.302 | 1/2⁻ | 14.4% |
|         | 172 | 2/2 6/6 10/14 20/28 26/46 6/6 | 70/102 | ○ | -59.250 | 0⁻ | 21.9% |
|         | 173 | /1 | 2/2 6/6 10/14 20/28 26/46 6/6 | 70/103 | ○ | -57.546 | 5/2⁺ | 16.2% |
|         | 174 | 2/2 5/7 12/12 18/30 26/46 7/7 | 70/104 | ○ | -59.940 | 0⁻ | 31.6% |
|         | 175 | /1 | 2/2 6/6 10/14 20/28 26/46 6/8 | 70/105 | ○ | -54.691 | 7/2⁻ | 4.19d (β⁻) |
|         | 176 | 2/2 6/6 10/14 18/30 26/46 8/8 | 70/106 | ○ | -53.490 | 0⁻ | 12.6% |
|         | 177 | /1 | 2/2 5/7 12/12 18/30 26/46 7/9 | 70/107 | ○ | -50.986 | 9/2⁻ | 1.9h (β⁻) |
|         | 178 | 2/2 6/6 10/14 18/30 26/46 8/10 | 70/108 | ○ | -49.66 | 0⁻ | 74min |
| Lu      | 71 | 172 | 2/2 6/6 10/14 18/30 28/44 7/5 | 71/101 | ○ | -56.726 | 4⁻ | 6.70d (e) |
|         | 173 | /1 | 2/2 6/6 10/14 18/30 28/44 7/5 | 71/102 | ○ | -56.871 | 7/2⁻ | 1.37y (e) |
|         | 174 | 2/2 5/7 12/12 18/30 26/46 8/6 | 71/103 | ○ | -55.562 | 1⁻ | 3.3y (e) |
|         | 175 | /1 | 2/2 5/7 12/12 18/30 26/46 7/7 | 71/104 | ○ | -55.459 | 7/2⁻ | 97.39% |
|         | 176 | 2/2 5/7 12/12 18/30 26/46 8/8 | 71/105 | ○ | -53.381 | 7⁻ | 2.61% |
|         | 177 | /1 | 2/2 6/6 10/14 18/30 28/44 7/9 | 71/106 | ○ | 52.382 | 7⁻ | 6.71d (β⁻) |
|         | 178 | 2/2 5/7 12/12 18/30 26/46 8/10 | 71/107 | ○ | -50.30 | 1⁻ | 28.4min (β⁻) |
| Hf      | 72 | 171 | /1 2/2 6/6 10/14 20/28 28/44 6/4 | 72/99 | ○ | -55.30₄ | (7/2⁻) | 12.1h (e) |
|         | 172 | 2/2 5/7 12/12 18/30 28/44 7/5 | 72/100 | ○ | -56.33₄ | 0⁻ | 1.87y (e) |
|         | 173 | /1 | 2/2 5/7 12/12 18/30 28/44 7/5 | 72/101 | ○ | -55.27₄ | 1/2⁻ | 24.0h (e) |
|         | 174 | 2/2 5/7 12/12 18/30 28/44 7/7 | 72/102 | ○ | 55.830 | 0⁻ | 0.16% |
|         | 175 | /1 | 2/2 6/6 10/14 20/28 26/46 8/6 | 72/103 | ○ | -54.548 | 5/2⁻ | 70d (c) |
|         | 176 | 2/2 6/6 10/14 20/28 26/46 8/8 | 72/104 | ○ | -54.567 | 0⁻ | 5.2% |
|         | 177 | /1 | 2/2 6/6 10/14 20/28 26/46 8/8 | 72/105 | ○ | -52.879 | 7/2⁻ | 18.6% |
|         | 178 | 2/2 5/7 12/12 18/30 26/46 9/9 | 72/106 | ○ | -52.434 | 0⁻ | 27.1% |
|         | 179 | /1 | 2/2 5/7 12/12 18/30 26/46 9/9 | 72/107 | ○ | -50.462 | 9/2⁻ | 13.7% |
|         | 180 | 2/2 6/6 10/14 18/30 26/46 10/10 | 72/108 | ○ | -49.779 | 0⁻ | 35.2% |
### Shell Structure of Nuclides

| nuclide | Z  | A  | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | 1σ | T1/2 |
|---------|----|----|---------------------------------|------------------|---------------------|-----|------|
| Ta      | 73 | 178| 2/2                            | 5/2              | -50.52              | 1+  | 9.31min (c) |
| W       | 74 | 178| 2/2                            | 6/6              | -50.43              | 0+  | 21.5d (β⁺) |
| He      | 75 | 182| 2/2                            | 5/2              | -45.43              | 2+  | 12.7h (α)  |
| Os      | 76 | 182| 2/2                            | 6/6              | -44.58              | 0+  | 21.5h (α)  |

*Note: T1/2 values are given in days (d) and half-lives (h) for specific nuclear transitions.*
Shell Structure of Nuclides.

| nuclide | Z | A | Shell structure of nucleon (p/n) | king of structure | Binding energy \( \Delta \text{(MeV)} \) | \( I^* \) | \( T_{\nu2} \) |
|---------|---|---|---------------------------------|------------------|-----------------------------|-------|--------|
| 191     |   | 6/6 | 10/14 18/30 26/46 14/16 76/115 ⊙ | -36.388          | 9/2 15.4d (β⁻)             |
| 192     |   | 6/6 | 10/14 18/30 26/46 14/18 76/116 ⊙ | -35.875          | 0' 41.0%                   |
| 193     |   | 5/7 | 10/14 18/30 26/46 15/17 76/117 ⊙ | -33.387          | 3/2 30.6h (β⁻)             |
| 194     |   | 5/7 | 10/14 18/30 26/46 15/19 76/118 ⊙ | -32.417          | 0' 6.0y (β⁻)               |
| Ir      | 77 | 6/6 | 10/14 18/30 26/46 15/13 77/111 ⊙ | -38.323          | (2') 41.5h (α)             |
| 189     |   | 6/6 | 10/14 18/30 26/46 15/13 77/112 ⊙ | -38.488          | 3/2 13.1d (α)              |
| 190     |   | 5/7 | 10/14 18/30 26/46 16/14 77/113 ⊙ | -36.70           | (4') 11.8d (α)             |
| 191     |   | 6/6 | 10/14 18/30 26/46 15/15 77/114 ⊙ | -36.698          | 3/2 37.3%                  |
| 192     |   | 6/6 | 10/14 18/30 26/46 15/17 77/115 ⊙ | -34.826          | 4' 74.2d (β⁻)              |
| 193     |   | 5/7 | 10/14 18/30 26/46 16/16 77/116 ⊙ | -34.519          | 3/2 62.7%                  |
| 194     |   | 5/7 | 10/14 18/30 26/46 16/18 77/117 ⊙ | -32.514          | 1' 19.2h (β⁻)              |
| 195     |   | 5/7 | 10/14 18/30 26/46 16/18 77/118 ⊙ | -31.692          | (3/2') 2.8h (β⁻)           |
| Pt      | 78 | 6/6 | 10/14 20/28 26/46 14/12 78/109 ⊙ | -36.81s          | 3/2 2.35h (α)              |
| 188     |   | 5/7 | 12/12 18/30 26/46 15/13 78/110 ⊙ | 37.788           | 0' 10.2d (α)               |
| 189     |   | 5/7 | 12/12 18/30 26/46 15/13 78/111 ⊙ | -36.57s          | 3/2 10.9h (α)              |
| 190     |   | 5/7 | 12/12 18/30 26/46 15/15 78/112 ⊙ | -37.318          | 0‘ 0.013%                  |
| 191     |   | 6/6 | 10/14 18/30 26/46 16/14 78/113 ⊙ | -35.698          | 3/2 2.9d (α)               |
| 192     |   | 6/6 | 10/14 18/30 26/46 16/16 78/114 ⊙ | -36.283          | 0' 0.78%                   |
| 193     |   | 5/7 | 10/14 18/30 26/46 17/15 78/115 ⊙ | -34.458          | (1/2') 50y (α)             |
| 194     |   | 5/7 | 10/14 18/30 26/46 17/17 78/116 ⊙ | -34.756          | 0’ 32.9%                   |
| 195     |   | 5/7 | 10/14 18/30 26/46 17/17 78/117 ⊙ | -32.802          | 1/2 33.8%                  |
| 196     |   | 6/6 | 10/14 18/30 26/46 16/20 78/118 ⊙ | -32.652          | 0' 25.3%                   |
| 197     |   | 5/7 | 10/14 18/30 26/46 17/19 78/119 ⊙ | -30.431          | 1/2' 18.3h (β⁻)            |
| 198     |   | 6/6 | 10/14 18/30 26/46 16/22 78/120 ⊙ | -29.921          | 0’ 7.2%                    |
| 199     |   | 5/7 | 10/14 18/30 26/46 17/21 78/121 ⊙ | -27.420          | (5/2') 30.8min (β⁻)        |
| 200     |   | 5/7 | 10/14 20/28 26/46 15/25 78/122 ⊙ | -26.66s          | 0' 12.5h (β⁻)              |
| Au      | 79 | 5/7 | 10/14 18/30 26/46 18/16 79/115 ⊙ | -32.256          | 1’ 39.5h (α)               |
| 194     |   | 5/7 | 10/14 18/30 26/46 18/16 79/116 ⊙ | -32.57z          | 3/2 186d (α)               |
| 196     |   | 6/6 | 10/14 18/30 26/46 17/17 79/117 ⊙ | -31.16z          | 2' 61.8d (α)               |
| 197     |   | 5/7 | 10/14 18/30 26/46 18/18 79/118 ⊙ | -31.150          | 3/2’ 100%                  |
| 198     |   | 5/7 | 10/14 18/30 26/46 18/20 79/119 ⊙ | -29.591          | 2' 2.696d (β⁻)             |
| 199     |   | 5/7 | 10/14 18/30 26/46 15/20 79/120 ⊙ | -29.104          | 3/2 3.14d (β⁻)             |
| 200     |   | 6/6 | 10/14 20/28 26/46 15/25 79/121 ⊙ | -27.30           | 1’ 48.4min (β⁻)            |
| Hg      | 80 | 5/7 | 12/12 18/30 26/46 17/15 80/113 ⊙ | -31.02s          | 3/2 3.8h (α)               |
| 193     |   | 5/7 | 10/14 18/30 26/46 18/16 80/114 ⊙ | -32.206          | 0’ 520y (α)                |
| 194     |   | 6/6 | 10/14 18/30 26/46 18/16 80/115 ⊙ | -31.05           | 1/2 9.5h (α)               |
| 196     |   | 6/6 | 10/14 18/30 26/46 18/18 80/116 ⊙ | -31.846          | 0’ 0.15%                   |
### Shell Structure of Nuclides.

| nuclide | Z | A | Shell structure of nucleon (p/n) | King of structures | Binding energy (MeV) | T1/2 (d) |
|---------|---|---|---------------------------------|-----------------|---------------------|----------|
| 197     | /1| 2/2| 5/7 | 10/14 | 18/30 | 26/46 | 19/17 | 80/117 | 5/2 | -30.725 | 1/2 | 64.1h (E) |
| 198     | 2/2| 5/7 | 10/14 | 18/30 | 26/46 | 19/19 | 80/118 | 0 | -30.964 | 0' | 10.0% |
| 199     | /1| 2/2| 5/7 | 10/14 | 18/30 | 26/46 | 19/19 | 80/119 | 0 | -29.557 | 1/2 | 16.8% |
| 200     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 16/24 | 80/120 | 0 | -29.514 | 0' | 23.1% |
| 201     | /1| 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 16/24 | 80/121 | 0 | -27.672 | 3/2 | 13.2% |
| 202     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 16/26 | 80/122 | 0 | -27.356 | 0' | 29.8% |
| 203     | /1| 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 17/25 | 80/123 | 0 | -25.277 | 5/2 | 46.6d (β) |
| 204     | 2/2| 6/6 | 10/14 | 18/30 | 26/46 | 18/26 | 80/124 | 0 | -24.703 | 0' | 6.9% |
| 205     | /1| 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 17/27 | 80/125 | 0 | -22.299 | 1/2 | 5.2min (β) |
| Pb 82   | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 17/23 | 81/119 | 0 | -27.060 | 2' | 26.1h (e) |
| 201     | /1| 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 17/23 | 81/120 | 0 | -27.185 | 1/2' | 73h (e) |
| 202     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 17/25 | 81/121 | 0 | -25.988 | 2' | 12.2d (e) |
| 203     | /1| 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 18/24 | 81/122 | 0 | -25.769 | 1/2' | 29.5% |
| 204     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 18/27 | 81/123 | 0 | -24.353 | 2' | 3.77y (β) |
| 205     | /1| 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 18/26 | 81/124 | 0 | -23.837 | 1/2' | 70.5% |
| Bi 83   | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 17/29 | 81/125 | 0 | -22.269 | 0' | 4.20min (β) |
| Pb 82   | 2/2| 5/7 | 12/12 | 18/30 | 28/44 | 17/23 | 82/119 | 0 | -25.327 | 5/2 | 9.3h (e) |
| 202     | 2/2| 5/7 | 12/12 | 18/30 | 28/44 | 17/25 | 82/120 | 0 | -25.942 | 0' | 5.0×10^2y (e) |
| 203     | /1| 2/2| 5/7 | 12/12 | 18/30 | 28/44 | 17/25 | 82/121 | 0 | -24.794 | 5/2 | 51.9h (e)* |
| 204     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 18/26 | 82/122 | 0 | -25.117 | 0' | 1.42% |
| 205     | /1| 2/2| 5/7 | 12/12 | 18/30 | 28/44 | 17/27 | 82/123 | 0 | -23.777 | 5/2 | 5.0×10^2y (e) |
| 206     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 18/28 | 82/124 | 0 | -23.795 | 0' | 24.1% |
| 207     | /1| 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 18/28 | 82/125 | 0 | -22.463 | 1/2 | 22.1% |
| 208     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 18/30 | 82/126 | 0 | -21.759 | 0' | 52.3% |
| 209     | /1| 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 19/29 | 82/127 | 0 | -17.624 | 9/2' | 3.25h (β) |
| 210     | 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 19/31 | 82/128 | 0 | -14.738 | 0' | 22.3y (β) |
| 211     | /1| 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 19/31 | 82/129 | 0 | -10.492 | (9/2') | 36.1min (β) |
| 212     | 2/2| 5/7 | 12/12 | 18/30 | 26/46 | 19/33 | 82/130 | 0 | -7.562 | 0' | 10.6h (β) |
| Bi 83   | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 19/27 | 83/123 | 0 | -20.033 | 6' | 6.24d (e) |
| 207     | /1| 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 19/27 | 83/124 | 0 | -20.058 | 9/2 | 32y (e) |
| 208     | 2/2| 6/6 | 10/14 | 20/28 | 26/46 | 19/29 | 83/125 | 0 | -18.879 | 5' | 3.68×10^2y (e) |
| 209     | /1| 5/7 | 12/12 | 18/30 | 26/46 | 20/28 | 83/126 | 0 | -18.268 | 9/2 | 100%** |
| 210     | 6/6 | 10/14 | 20/28 | 26/46 | 19/31 | 83/127 | 0 | -14.801 | 1' | 5.01d (β) |

* For **203\(^{82}\)Pb\(_{122}\) and **205\(^{83}\)Pb\(_{122}\), the P/n's are respectively 17/25 and 17/27. After absorbing an electron and exchanging nucleons with 6\(^6\) shell, they turn into **203\(^{82}\)Tl\(_{122}\) and **205\(^{83}\)Tl\(_{122}\), tending to be stable.

** *209\(^{83}\)Bi\(_{122}\) is a stable nuclide with P/n=20/28. It shows that p/n=5/7, p/n=10/14 and p/n=20/28 is a stable combination of interaction of interaction between protons and neutrons.
**Shell Structure of Nuclides.**

| nuclide | Z  | A    | Shell structure of nucleon (p/n) | king of structure | Binding energy (MeV) | T_{1/2} |
|---------|----|------|----------------------------------|-------------------|----------------------|---------|
|         | 2n| 6   | 1/2                              | 2/2               | 5/7                  | 8/4     |
| He      | 206| 1/2  | 10/14                            | 18/30             | 24/46                | 20/30   | -11.865 | 9/2  2.15min (α) |
| Po      | 84 | 2/2  | 5/7                              | 10/14             | 18/30                | 22/44   | 19/27  84/122 | ○    -18.190 | 0°  8.8d (ε) |
|         | 209| 1/2  | 2/2                              | 10/14             | 20/28               | 24/46   | 19/27  84/122 | ○    -17.150 | 5/2  5.8h (ε) |
| At      | 85 | 2/2  | 6/6                              | 10/14             | 20/28               | 24/46   | 20/28  84/124 | ○    -17.475 | 0°  2.90y (α)* |
|         | 209| 1/2  | 2/2                              | 6/6               | 10/14               | 20/28   | 20/28  84/125 | ○    -16.373 | 1/2  10.2y (α)** |
| Rn      | 86 | 2/2  | 5/7                              | 12/12             | 18/30               | 26/46   | 22/30  85/128 | ○    -6.589  | 9/2  0.11μs (α) |
| Fr      | 87 | 2/2  | 5/7                              | 10/14             | 18/30               | 28/44   | 21/25  86/121 | ○    -8.69   | 5/2  9.3min (ε) |
| Ra      | 88 | 2/2  | 5/7                              | 10/14             | 18/30               | 20/28   | 26/46  22/30  | 86/126 | ○    -8.666  | 0°  24min (α) |
|         | 209| 1/2  | 2/2                              | 5/7               | 12/12               | 18/30   | 28/44  21/29  | 86/124 | ○    -9.608   | 0°  2.4h (α)** |
|         | 212| 1/2  | 2/2                              | 5/7               | 10/14               | 18/30   | 28/44  21/29  | 86/125 | ○    -8.761   | 1/2  14.6h (ε) |
|         | 218| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 22/36  86/132  | ○    5.212   | 0°  35ms (α) |
|         | 222| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 22/40  86/136  | ○    16.370  | 0°  3.82d (α) |
|         | 224| 2/2  | 5/7                              | 10/14             | 18/30               | 26/46   | 23/41  86/138  | ○    22.26s   | 0°  107min (β) |
|         | 212| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 23/29  87/125  | ○    -3.69s   | 5°  20min (ε) |
|         | 215| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 23/31  87/128  | ○    0.309  | 9/2  0.12μs (α) |
|         | 220| 2/2  | 5/7                              | 10/14             | 18/30               | 26/46   | 24/36  87/133  | ○    11.470  | 1°  27.4s (α) |
|         | 223| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 23/39  87/136  | ○    18.382  | (3/2) 21.8min (β) |
|         | 222| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 24/38  88/134  | ○    14.312  | 0°  38s (α) |
|         | 223| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 24/38  88/135  | ○    17.235  | 1/2° 11.4d (α) |
|         | 224| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 24/40  88/136  | ○    18.813  | 0°  3.66d (α) |
|         | 225| 2/2  | 5/7                              | 10/14             | 18/30               | 26/46   | 25/39  88/137  | ○    21.987  | (3/2)° 14.8d (β) |
|         | 226| 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 24/42  88/138  | ○    23.666  | 0°  160y (α) |
|         | 227| 2/2  | 5/7                              | 10/14             | 18/30               | 26/46   | 25/41  88/139  | ○    27.185  | (3/2)° 42min (β) |
| Ac      | 89 | 2/2  | 6/6                              | 10/14             | 20/28               | 26/46   | 25/39  89/135  | ○    20.219  | (0)° 2.9h (ε) |
|         | 225| 2/2  | 5/7                              | 12/12             | 18/30               | 26/46   | 26/38  89/136  | ○    21.626  | (3/2)° 10.0d (α) |

* 208\(^84\)Po\(_{122}\) becomes stable after (n) decay. Its decay procedure is: 208\(^84\)Po\(_{124}\) + 4\(^2\)He → 204\(^82\)Po\(_{122}\).

** The decay procedure of 209\(^84\)Po\(_{123}\) is: 209\(^84\)Po\(_{123}\) + 4\(^2\)He → 205\(^82\)Po\(_{121}\) + e⁻ → 205\(^81\)Tl\(_{121}\), tending to be stable.

*** 210\(^86\)Rn\(_{124}\) becomes stable after (α) decay and (ε) decay. Its decay procedure is: 210\(^86\)Rn\(_{124}\) → 4\(^2\)He → 206\(^84\)Po\(_{122}\) + e⁻ → 206\(^83\)Bi\(_{123}\) + e⁻ → 206\(^82\)Pb\(_{122}\) → 206\(^82\)Pb\(_{124}\).
### Shell Structure of Nuclides

| Nuclide | Z  | A  | Shell structure of nucleon (p/n) | Binding energy (MeV) | $I^+$ | $T_{1/2}$ |
|---------|----|----|----------------------------------|----------------------|------|----------|
|         | 226| 2/6| 6/6 10/14 20/28 26/46 25/41 89/137 | 24.301               | (1)  | 29h ($)  |
|         | 227| /1 | 6/6 10/14 20/28 26/46 25/41 89/138 | 25.850               | 3/2  | 21.77y ($)|
|         | 228| 2/6| 6/6 10/14 20/28 26/46 25/43 89/139 | 28.895               | (3)  | 6.1h ($)  |
| Th      | 90 | 2/6| 6/6 10/14 20/28 26/46 26/42 90/138 | 26.758               | 0    | 1.91y (a) |
|         | 229| /1 | 6/6 10/14 20/28 26/46 26/44 90/139 | 29.581               | 5/2  | 7300y (a) |
|         | 230| 2/6| 6/6 10/14 20/28 26/46 27/43 90/140 | 30.861               | 0    | 7.5×10^6y (a) |
|         | 231| /1 | 5/7 12/18 30/24 26/46 26/46 90/141 | 33.812               | 5/2  | 25.52h ($) |
|         | 232| 2/6| 6/6 10/14 20/28 26/46 27/45 90/142 | 35.447               | 0    | 100%*     |
|         | 233| /1 | 5/7 12/18 30/24 26/46 27/41 90/143 | 38.732               | (1/2+) | 22.3min ($) |
| Pa      | 91 | 2/6| 6/6 10/14 20/28 26/46 27/43 91/138 | 29.887               | (5/2) | 1.4d (c)  |
|         | 230| 2/6| 6/6 10/14 20/28 26/46 28/42 91/139 | 32.166               | (2)  | 17.7d (c) |
|         | 231| /1 | 5/7 12/18 30/24 26/46 27/45 91/140 | 33.423               | (3/2) | 3.28×10^6y (a) |
|         | 232| 2/6| 6/6 10/14 20/28 26/46 27/45 91/141 | 35.934               | (2)  | 1.31d ($)  |
|         | 233| /1 | 5/7 12/18 30/24 26/46 28/24 91/142 | 37.487               | (3/2) | 27.6d ($)  |
| U       | 92 | 2/6| 6/6 10/14 20/28 26/46 28/46 92/141 | 36.915               | 5/2* | 1.592×10^3y (a) |
|         | 234| 2/6| 6/6 10/14 20/28 26/46 28/46 92/142 | 38.143               | 0    | 2.45×10^3y (a) |
|         | 235| /1 | 6/6 10/14 20/28 26/46 28/44 92/143 | 40.916               | 7/2  | 0.720%**  |
|         | 236| 2/6| 6/6 10/14 20/28 26/46 28/48 92/144 | 42.442               | 0    | 2.34×10^3y (a) |
|         | 237| /1 | 5/7 12/18 30/24 26/46 29/47 92/145 | 45.389               | 1/2  | 6.75d ($)  |
|         | 238| 2/6| 6/6 10/14 20/28 26/46 28/50 92/146 | 47.307               | 0    | 9.9275%** |
|         | 239| /1 | 5/7 12/18 30/24 26/46 29/49 92/147 | 50.572               | 5/2* | 23.5min ($) |
| Np      | 93 | 2/6| 6/6 10/14 20/28 26/46 29/47 93/143 | 43.361               | (6)  | 1.1×10^5y (c) |
|         | 237| /1 | 5/7 12/18 30/24 26/46 30/46 93/144 | 44.869               | 5/2* | 2.14×10^5y (a) |
|         | 238| 2/6| 6/6 10/14 20/28 26/46 29/49 93/145 | 47.453               | 2    | 2.117d ($) |
|         | 239| /1 | 6/6 10/14 20/28 26/46 29/49 93/146 | 49.306               | 5/2* | 2.36d ($)  |
| Pu      | 94 | 2/6| 6/6 10/14 20/28 26/46 31/45 94/143 | 45.087               | 7/2  | 45.3d (c) |
|         | 238| 2/6| 6/6 10/14 20/28 26/46 30/48 94/144 | 46.161               | 0    | 87.74y (a) |
|         | 239| /1 | 6/6 10/14 20/28 26/46 30/48 94/145 | 48.585               | 1/2* | 2.41×10^5y (a)** |
|         | 240| 2/6| 6/6 10/14 20/28 26/46 30/50 94/146 | 50.123               | 0    | 6570y (a) |
|         | 241| /1 | 5/7 12/18 30/24 26/46 31/49 94/147 | 52.953               | 5/2* | 14.4y ($)  |
|         | 242| 2/6| 6/6 10/14 20/28 26/46 30/52 94/148 | 54.715               | 0    | 3.76×10^5y (a)*** |

* $^{232}_{90}$Th is a stable nuclide with p/n=26/46 on outside shells. It is the same as the p/n combination of the 6th full shell. Its shows that p/n=26/46 is a stable combination. $^{235}_{92}$U, after (α) decay, generates $^{229}_{90}$Th, tending to be stable.

** The protons and neutrons on outside shells of $^{235}_{92}$U and $^{233}_{92}$U are all even-even combinations and are close to the p/n of the 6th full shell. Its numbers of protons and neutrons on outside shells are 28 and 50, being the characteristic of "magic number"

*** $^{238}_{94}$Pu, after (α) decay, generates $^{234}_{92}$U, tending to be stable.

**** $^{242}_{94}$Pu, after (α) decay, generates $^{238}_{92}$Np, tending to be stable.
### Shell Structure of Nuclides.

| Nuclide | Z  | A    | Shell structure of nucleon (p/n) | Binding energy (MeV) | \(T_{1/2}\) |
|---------|----|------|----------------------------------|---------------------|------------|
|         | 234| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 235| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 236| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 237| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 238| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 239| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 240| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 241| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 242| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 243| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |
|         | 244| 6/6  | 1 10/28 26/46 28/64 30/80 32/96 34/112 | 57.752             | 0.0752     |

Notes: 1) The percentage in the table indicates the filling level of the isotopes. \(\beta^-\) stands for the \(\beta^-\) decay; \(\alpha\) for the atom decay; \(\gamma\) for the rail electronic capture and \(\beta^+\) decay; \(\delta\) for (α) decay; \(\delta\) for (α) decay; \(\delta\) for spontaneous fission.
2) The basic data of the table are taken from: V. S. Snirley et al, Nuclear Wallet Cards, 1979.
K. S. Krane Introductory Nuclear Physics, 1987
3) The basic data of the table are taken from: Nuclear Physics (P390–P405), Xu Sida, QingHua University Press, 1992.
4) The stable lists the shell structures of 935 nuclides of the original table. Lost if new nuclides have been discovered by experiments since the table was made. For all the newly-discovered nuclides, their shell structures can be worked out according to the criteria given in this thesis. For an example, \(^{213}\text{Rn}_{86}\): From its structure we know that it decays in \((\alpha)\) style and the decay product is \(^{209}\text{Po}_{84}\).
5) Although we have managed to work out the table of shell structures of all known nuclides, the correctness of the table has yet to be verified by lost of experiments. We are sure there are bound to be exceptions. For an example, \(^{9}\text{B}_{2}\) may be a special proton-core nuclide and its structure: \(^{9}\text{B}_{2}\). This may explain why \(^{9}\text{B}_{2}\) is entirely different in stability form its mirror-image nuclide \(^{9}\text{Be}_{4}\).

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