TABLES OF ATOMS, ATOMIC NUCLEI, AND SUBATOMIC PARTICLES

Ivan P. Selinov

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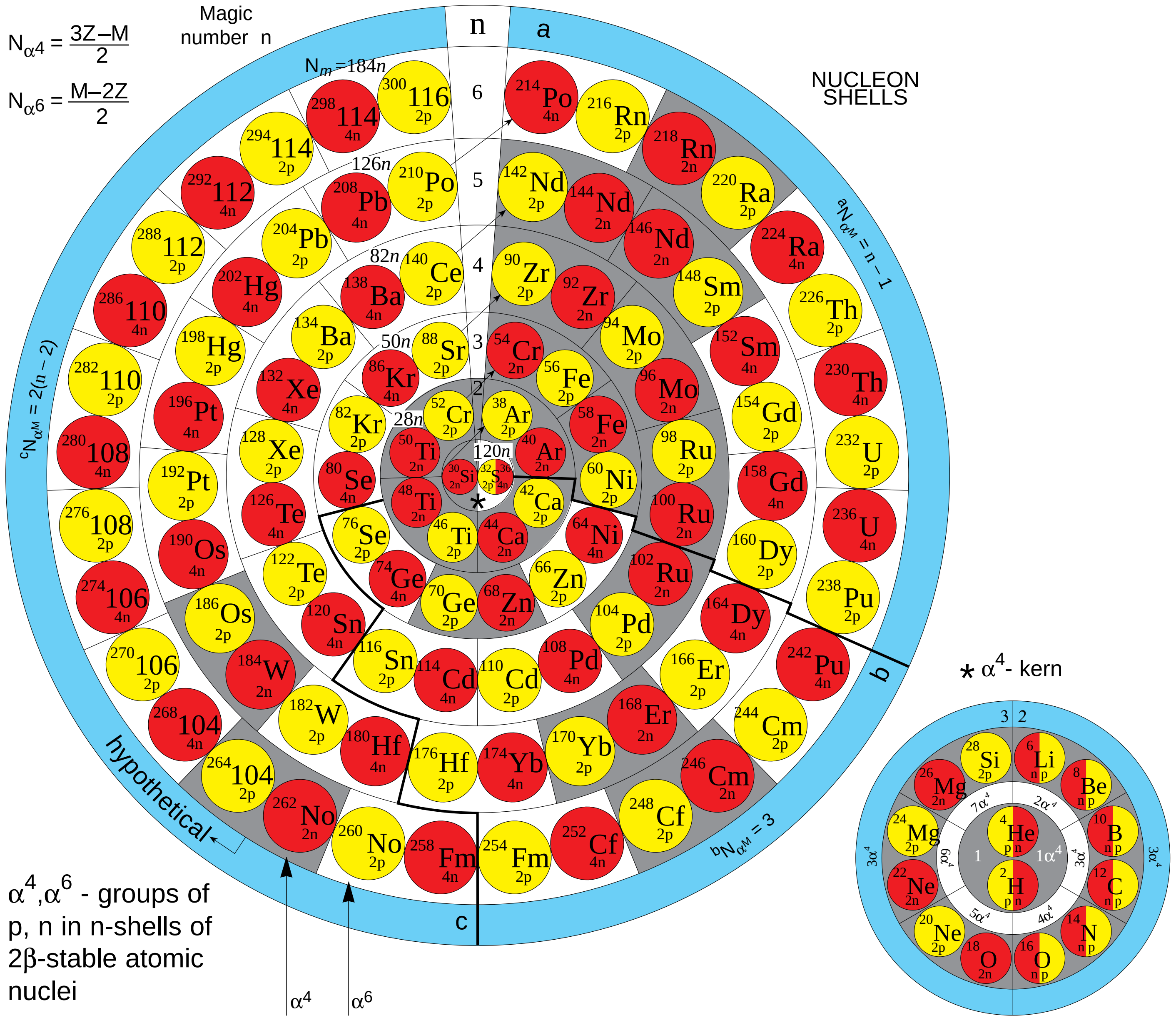
$$N_{\alpha 4} = \frac{3Z-M}{2}$$

$$N_{\alpha 6} = \frac{M-2Z}{2}$$



α4,α6 - groups of p, n in n-shells of 2β-stable atomic nuclei

$$^nN_{\alpha M} = {}^nN_{\alpha 4} + {}^nN_{\alpha 6} = 3n - 2, \quad \Delta^nN_{\alpha M} = 3, \quad \Delta\Delta^{n>2}N_{\alpha 4} = -1$$

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I. PERIODIC TABLE OF THE ATOMS

D.I.Mendeleev, the discoverer of the periodic law («physical and chemical properties of elements and their compounds are in a periodic dependence on atomic weights of elements»), arranged all elements in a periodic system (1869 —1871) in order of increasing atomic weight. In a present-day table of elements, atoms are arranged in order of increasing number of electrons (Z) in them. Therefore the Mendeleev's periodic system of elements may also be called the periodic Table (system) of atoms. The number of electrons in the K-, L-, M-, and N-shells of atomic structure (and, respectively, the number of elements in periods) are expressed by the Pauli-Stoner equation (1925): $^nZ_{sh} = \sum_{n=1}^{n} 2(2l+1)_{l=n-1} = 2n^2$. The scheme inserted in the subgroup VIIIb illustrates the completion of filling K-, L-, M-, and N-shells by s^2-,p^6-,d^{10}-, and f^{14}-subshells in first periods of dyads.

Among hundreds of versions of graphic representations of the Table that are known, tables with 8 and 18 squares are in most common use. In an eight-square table, a-subgroups containing atoms with incomplete peripheral s- and p-subshells are positioned on the left and b-subgroups containing atoms with d- and f-subshells are positioned on the right. In 18-square tables, the relationship between a- and b-subgroups is less evident. In some of them (e.g., in the Japanese chart of nuclides of 1992), atoms with incomplete p-subshells are erroneously positioned in b-subgroups. Moreover, some 18-square tables have an outdated zeroth group instead of the VIIIa-subgroup and vacant squares at the beginning of a table. These erroneous features are often available in eight-square tables, too.

Atomic weights of elements and atomic masses of isotopes are adapted from «Atomic Weights of the Elements 1991», Pure and Applied Chemistry 64, 1519 (1992), and G. Audi and A. H. Wapstra, «The 1993 Mass Evaluation», Nucl. Phys. A565, 1 (1993). New names of elements with Z = 104 - 109 are placed in parenthesis because they are not affirmed by IUPAC. The names of elements with Z > 111 are designated by symbols of their homologues with a prefix (by Mendeleev's suggestion) «eka» (that means «following» in Sanskrit). For elements of the seventh period, which are yet to be discovered, hypothetical (Table III) β-stable isotopes with the largest half-life are given.

II. SYMMETRICAL TABLE OF THE ATOMS AND THE ATOMIC NUCLEI

The symmetrical table of atoms and atomic nuclei shows general regularities in the structure of electron and nucleon shells of atoms and atomic nuclei. The numbers of electrons and nucleons in these shells are expressed by a single formula. The electromagnetic interaction between leptons (electrons) in an atomic shell and the strong interaction between baryons (protons and neutrons) in atomic nuclei as well as the density of particle packing in them are quite different. However, atoms and atomic nuclei manifest some common regularities as a result of their shell structure determined by values of quantum numbers. The periodic systems of atoms and atomic nuclei are adequate to actual shell structures of atoms and atomic nuclei and hence are equally authentic.

III. PERIODIC TABLE OF THE ATOMIC NUCLEI

The Table presents the mass numbers M of all known isotopes of elements (nuclides). Mass numbers of 2β-stable isotopes (2β-decay is the simultaneous emission of two β-particles, β^+ or β^- or the ε-capture of two electrons from an atomic shell by a nuclide) are positioned in middle columns. Side columns contain isotopes that are stable against β-decay but unstable against 2β-decay (M). Moreover, they contain β-radioactive isotopes: neutron-rich isotopes, which are β^- -radioactive (M^{β^-}), and neutron-deficient isotopes, which are either β^+ - or ε-radioactive (M^{ε}). Atomic nuclei with Z ≥ 90 may also fission spontaneously (M) to nuclei of atoms from the middle of the periodic table. The sign ⋮ stands for intermediate mass numbers between the lowest and the highest M values. $\underline{M}$ - isotopes with the highest abundance or the largest half-life (T). $\underset{\sim}{M}$ - radioactive isotopes with $T > 5 \cdot 10^8$ years.

By analogy with Table I, where neutral atoms are arranged in order of increasing electron number (Z), Table III presents 2β-stable isotopes in order of increasing nucleon number (M) of a nuclear core. Periods of Table III end with nuclides having the number n that is called the «magic» number (N_m). Nuclides with N_m have some peculiar features in their nuclear properties. Each subsequent period increases by six protons. To make Table III compact, the fifth and sixth periods are positioned above the preceding periods. The scheme of nuclear shells and formulas for numbers of protons, neutrons, and nucleons in shells are shown under the Table title. The scheme illustrates nucleon shells existing in the 2β-stable nuclear core and combining n- and p- levels. In neutron-rich β^--radioactive and proton rich β^+- and ε-radioactive nuclides, independent n- and p-shells are described by the shell model.

Neutrons (n) and protons (p) alternate regularly in nucleon shells and form 2n2p (α^4) and 4n2p (α^6) groups. The α^4-group is formed in elements $Z^{even} \geq 8$ with three or less 2β-stable isotopes (e.g., $^{28-30}_{14}Si$) and the α^6-group is formed in elements with five (or four) 2β-stable isotopes (e.g., $^{32-34,36}_{16}S$). These groups are identical to the composition of helium isotopes: $^4_2He_2$ (α-particle) and $^6_2He_4$. Therefore they may be called heterohelion groups of p and n. Rigid alternation of protons and neutrons with heterohelion-group formation results from superdense packing of nucleons in a nucleus, which occupy more than half of its volume. By analogy with the molecule of the biological code, where different hydrocarbon molecules alternate regularly, α^4 and α^6 quasimolecules alternate in accordance with the «nuclear code» determining their number ($^{n>2}N_{\alpha 4} = \frac{(9n-n^2-12)}{2}$) and position of α^4 (at the beginning of a-, b-, and c-groups) in nucleon shells, Therefore a nucleus is a peculiar kind of a «nuclear molecule» with a heterohelion 2β-stable core [1].

In the lightest atomic nuclei, groups of protons and neutrons alternate in the following way: npnp (α^4) for Z from 1 to 7 and 2n2p (α^4) for Z from 8 to 14. Nuclides with α^4-composition of p and n, namely, ^4_2He, ^8_4Be, $^{12}_6C$, $^{16}_8O$, $^{20}_{10}Ne$, $^{24}_{12}Mg$, and $^{28}_{14}Si$ have the maximum abundance and the highest binding energy. In nuclides ^1H — ^{28}Si, the α^4-kern is formed. In subsequent nuclides, nucleon shells surrounding the α^4-kern appear. Nucleon shells are formed by filling a unified system of ground neutron (2n) and proton (2p) levels (the scheme on the cover).

Hypothetical pleiads of β-stable isotopes of elements with Z ≥ 102 are calculated by the equation:

$M_{Z\geq 102} = 3Z - 2\overset{o}{N}_{\alpha^4} + \beta^{=0 \text{ for } Z^{odd}}_{=0,\pm1,2,4 \text{ for } Z^{even}}$, where β is the pleiad number denoting the excess or deficit of neutrons in comparison with the central isotope ($\overset{o}{M}$) with β = 0. The value of N_{α^4}, the number of α^4-alternations of p and n, is given in the Table near the isotope completing the 2n2p-alternation. $\overset{o}{N}_{\alpha^4} = N_{\alpha^4} - 1$ is the number of α^4-alternations of p and n up to and including the central $\overset{o}{M}$ isotope of a pleiad.

All Z^{even}-elements having three 2β-stable isotopes at α^4-alternation of p and n are positioned at the beginning of a-,b-, and c-groups of nuclides in periods. It seems likely that in the sixth period, at the beginning of the c-group, the last α^4-alternation of p and n in this shell is positioned. Therefore it is suggested that nobelium has three 2β-stable isotopes ($^{260-262}_{102}No$). Each element has its own value of β. For example, in the pleiad of β-stable isotopes of the element with Z = 104, we have:

$M_{104} = 3\cdot104 - 2\cdot\overset{o}{23} + \beta\,(= 0, \pm1, 2, 4) = 262, 264\div26\overset{o}{6}\div268, 270.$

All β-stable isotopes of elements with Z from 92 up to 100 inclusive predicted from the alternation of α^4- and α^6-groups of p and n as early as 1950, have already been discovered.[1]

IV. SYMMETRICAL TABLE OF THE SUBATOMIC PARTICLES

The symmetrical Table of subatomic particles with data taken from the tables [2] is prepared for teaching purposes. It is called symmetrical because different forms of symmetry manifest themselves in particle properties at all levels of the structure of matter. This symmetry is so obvious that «when thinking about the history of elementary particle physics, one is tempted to imagine that symmetry itself, breaking through the asphalt crust of human lack of understanding guides a theorist's pen and thus persuades an experimentalist to discover its existence». (L.B.Okun)[3].

Five groups of the triangle diagram show mesons and baryons (hadrons) consisting of a quark and an antiquark, of three quarks or of three antiquarks. (For brevity, particles and antiparticles are indicated by the same symbol: with the sign of the charge written to the right of a particle and to the left of an antiparticle). Each subsequent group has a new heavier quark (this quark gives the name to the group). The ordinal number of a group is $n = n_q$-1, where n_q is the number of different quarks in a group. The ordinal number n = 6 corresponds to the numbers of leptons (or quarks) in their mysterious quark-lepton symmetry. Four types of interactions (forces) between subatomic particles (with virtual particles acting as their carriers) are given above six groups of particles.

By now a number of predicted particles have been discovered: quarks and gluons, Z^o- and $^-W^+$-bosons, J/ψ- and Y- mesons, and a great number of resonances (short-lived excited states of particles). In the future, after the discovery of new particles (including more primary particles: preons creating quarks and leptons, Higgs particles determining mass), the symmetrical table of subatomic particles will change, but its contours will probably remain the same.

The triangle diagram contains only the so-called stable hadrons. Particles of the same quark composition as in the diagram but with different quark orientation ($^o\Sigma^o(u{\downarrow}d{\downarrow})$) and those which are unstable against electromagnetic decays are positioned near this diagram. All hadrons in the triangle diagram are composed of different quarks and are stable against both electromagnetic and strong interactions. Therefore their lifetimes are much longer than those of the same-quark particles (J/ψ, Y) and particles unstable against electromagnetic decays ($\overset{o}{\pi}$, η, $^o\Sigma^o$).

The Table presents formulas for determination of the number of mesons and baryons in hadron groups and the number of atoms and atomic nuclei in periods of tables of elements and nuclei. A peculiar similarity principle shows itself in similar formulas for the number of particles in shell structures of atoms, atomic nuclei, and for the number of mesons and baryons in quasi-stable hadron groups. From these formulas it follows that the number of electrons in atomic subshells and the number of protons in nucleon shells increase by constant increments $\Delta^n Z_e = 4$ and $\Delta^n Z_p = 6$, respectively. An increase in the numbers of electrons in shells of atoms ($\Delta\Delta^n Z_{ch} = 4$) and numbers of nucleons and neutrons in periods of the system of atomic nuclei and in the numbers of particles and antiparticles in groups of quasi-stable baryons is characterized by constant increments, too: $\Delta\Delta^n M$, $\Delta\Delta^n N$, $\Delta\Delta^n B_{q\tilde{q}} = 2$. In addition to the fundamental systematics of hadrons and their resonances (which was used to predict the Ω-baryon and other particles), in the quark model (see p.1319, 1321 in [2]), the systematics of quasi-stable hadrons exists, which is similar to the systematics of atoms and atomic nuclei in the periodic tables of elements (Table I) and nuclides (Table III).

At the bottom of Table IV, two examples of particle decay modes [4] and the table of the main properties [2] of hadrons stable against strong interactions are presented.

The author is grateful to Prof. D. Saxon, the Chairman of the Advisory Committee of the 27*th* International Conference on High Energy Physics (Glasgow, July 1994), for valuable remarks that were accounted for in the tables.

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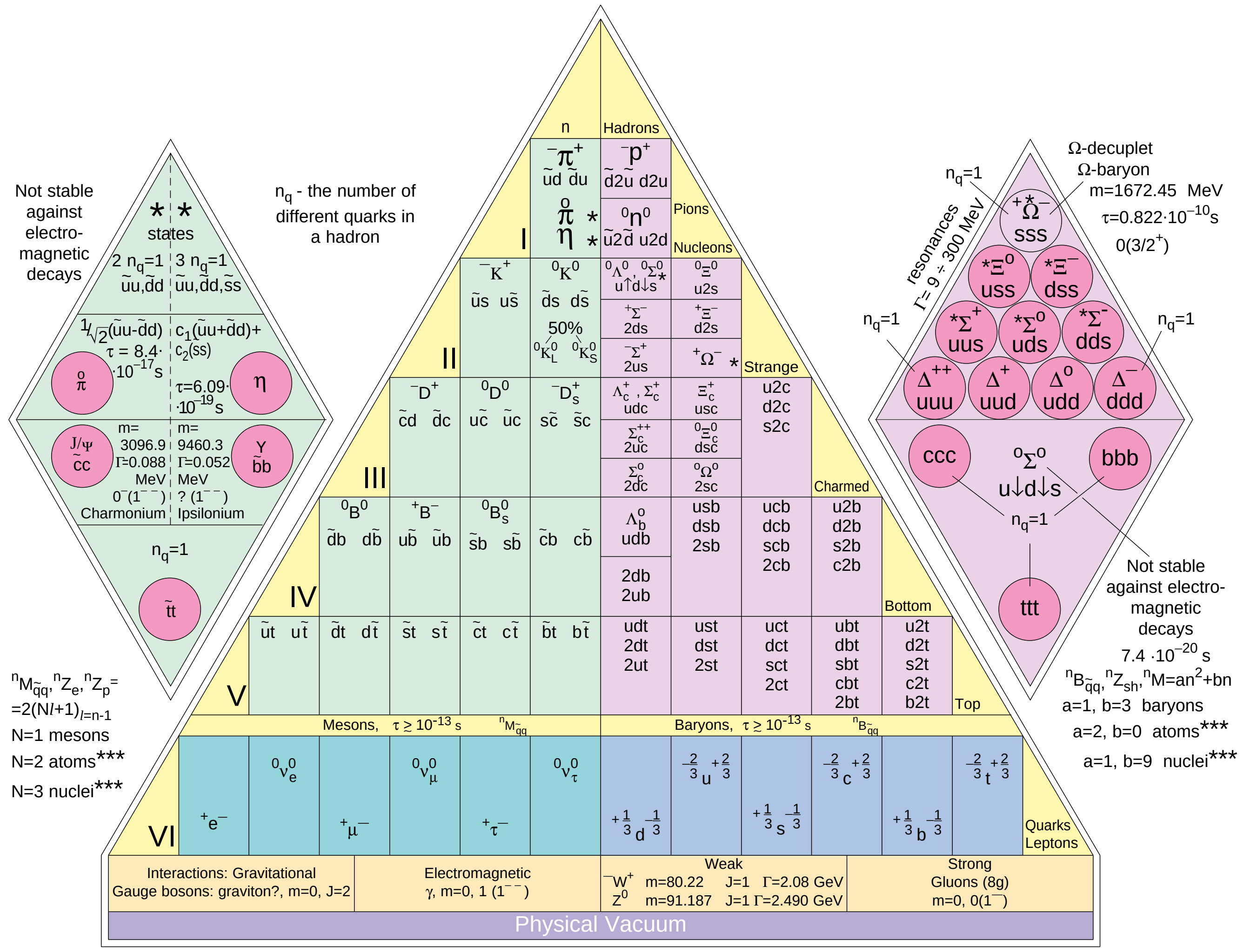
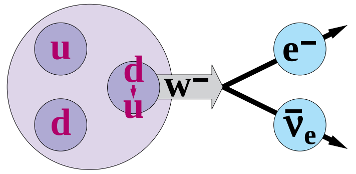
[1] I.P.Selinov. The Structure and Systematics of Atomic Nuclei, Nauka, Moscow, 1990; I.P.Selinov, Nuclidography, Moscow, 1995.
[2] Summary Tables of the Review of Particle Properties, Particle Data Group, Phys. Rev. D50, 1173 (1994).
[3] L.B.Okun. Particle Physics. The Quest for the Substance of Substance. Contemporary Concepts in Physics. Volume 2, page 79. Harwood Academie Publishers, Chor-London-Paris-NewYork, 1985.
[4] Standard Model of Fundamental Particles and Interactions. Fundamental Particles and Interactions. Chart Committee, 1988

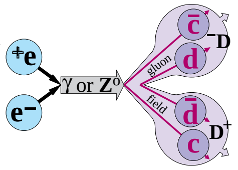
SYMMETRICAL TABLE OF THE SUBATOMIC PARTICLES





A neutron β^--decays to a proton, an electron, and an antineutrino via a virtual (mediating) W^- boson.[4]

An electron and positron (antielectron) colliding at high energy can annihilate to produce D^+ and ^-D mesons via a virtual Z^o boson or a virtual photon.[4]



Hadrons Stable against Strong Interactions, $\tau \geq 10^{-20}$ s **

$I^G(J^{PC})$ $^+e^-$ antiparticle particle Positron	$^+\pi^-$ $1^-(0^-)$ m = 139.56995 MeV $\tau = 2.6030\cdot10^{-8}$ s	$^-K^+$ $1/2\,(0^-)$ m = 493.677 MeV $\tau = 1.2371\cdot10^{-8}$ s	$^-D^+$ $1/2\,(0^-)$ m = 1869.4 MeV $\tau = 1.057\cdot10^{-12}$ s	$^-D_s^+$ $0\,(0^-)$ m = 1968.5 MeV $\tau = 0.467\cdot10^{-12}$ s	$^-B^+$ $1/2\,(0^-)$ m = 5278.7 MeV $\tau = 1.54\cdot10^{-12}$ s
$\overset{0}{\pi}$ Mesons $1^-\;(0^{-+})$ m = 134.9764 MeV $\tau = 8.4\cdot10^{-17}$ s	η $0^+(0^{-+})$ m = 547.45 MeV Γ = 1.20 keV	$K_L^0\,\tau = 5.17\cdot10^{-8}$ s 50% $K_S^0\,\tau = 0.8926\cdot10^{-10}$ s $1/2\,(0^-)$ 50% m = 947.672 MeV	$^0D^0$ $1/2\,(0^-)$ m = 1864.6 MeV $\tau = 0.415\cdot10^{-12}$ s	$^0B_S^0$ $1/2\,(0^-)$ m = 5375 $\tau = 1.34\cdot10^{-12}$ s	$^0B^0$ m = 5279 MeV $\tau = 1.50\cdot10^{-12}$ s
$^-p^+$ Baryons $1/2\,(1/2^+)$ m = 938.27231 MeV Stable	$^0\Lambda^0$ $0(1/2^+)$ m = 1115.684 MeV $\tau = 2.632\cdot10^{-10}$ s	$^-\Sigma^+$ $1\,(1/2^+)$ m = 1179.37 MeV $\tau = 0.799\cdot10^{-10}$ s	$^+\Xi^-$ $1/2\,(1/2^+)$ m = 1321.32 MeV $\tau = 1.639\cdot10^{-10}$ s	Λ_c^+ $0\,(1/2^+)$ m = 2285.1 MeV $\tau = 2.00\cdot10^{-13}$ s	$1/2\,(1/2^+)$ Ξ_c^+ m = 2465.1 MeV $\tau = 3.5\cdot10^{-13}$ s Ξ_c^0 m = 2470.3 MeV $\tau = 0.98\cdot10^{-13}$ s
$^on^o$ $1/2\,(1/2^+)$ m = 939.56563 MeV $\tau = 887.0$ s	$^0\Sigma^0$ $1(1/2^+)$ m = 1192.55 MeV $\tau = 7.4\cdot10^{-20}$ s	$^+\Sigma^-$ $(1/2^+)$ m = 1179.436 MeV $\tau = 1.497\cdot10^{-10}$ s	$^0\Xi^0$ $1/2\,(1/2^+)$ m = 1314.9 MeV $\tau = 2.9\cdot10^{-10}$ s	Σ_c^{++} m=2453.1 MeV $1(1/2^+)$ Σ_c^+ m = 2453.8 MeV Σ_c^o m = 2452.4 MeV	Λ_b^o m = 5641 MeV $\tau = 1.07\cdot10^{-12}$ s $0\,(1/2^+)$
$^+e^-$ Stable m = 0.51099906 MeV J=1/2	$^0\nu_e^0$ m < 7 eV J =1/2	$^+\mu^-$, $\tau = 2.19703\cdot10^{-6}$ s m = 105.658389 MeV J=1/2	$^o\nu_\mu^o$ m < 0.27 MeV	$^+\tau^-$, $\tau = 295.6\cdot10^{-15}$ s m = 1777.1 Mev	$^o\nu_\tau^o$ Leptons m < 0.31 MeV
$\tilde{d}d$ m = 5 - 15 Mev	$\tilde{u}u$ m = 2 - 8 MeV	$\tilde{s}s$ Strange m = 100 - 300 Mev	$\tilde{c}c$ Charmed m = 1.0 ÷ 1.6 GeV	$\tilde{b}b$ Bottom m = 4.1 - 4.5 GeV	$\tilde{t}t$ Top Quarks m ≈ 174 GeV ?

** Particle Properties, Particle Data Group, Phys. Rev. D50, 1173 (1994) [1]
*** Periodic Tables of atoms and nuclei.

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PERIODIC TABLE OF THE ATOMIC NUCLEI

The numbers of nucleons $^{n}M=(n^2+9n)_{n\geq 2}$ and protons $^{n}Z=2(3n-2)_{n\geq 1}$ in nucleon shells and nuclides and elements in n-periods

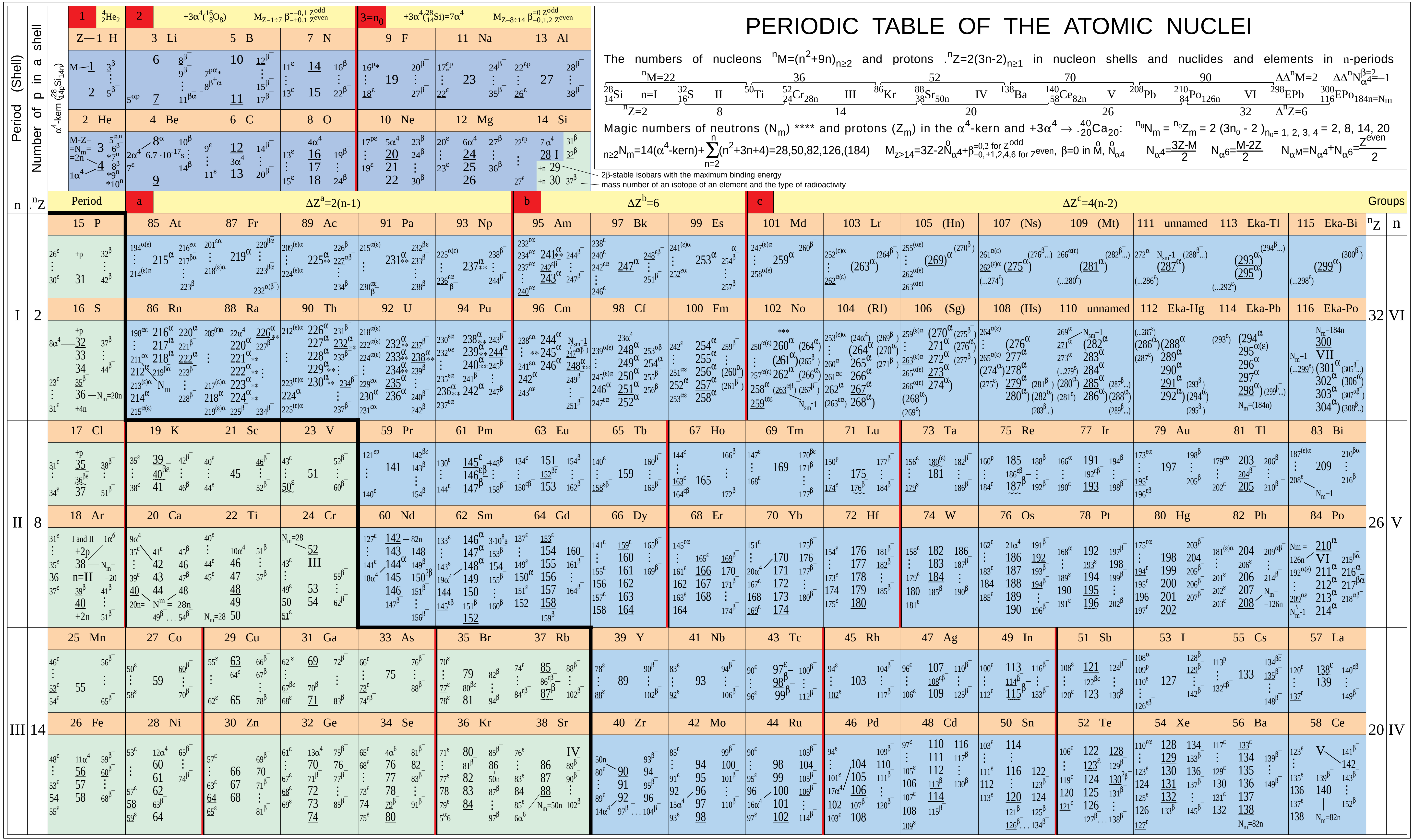
$^{n}M=22$ 36 52 70 90 $\Delta\Delta^{n}M=2$ $\Delta\Delta^{n}N^{\beta=2}_{\alpha 4}=-1$

$^{28}_{14}Si$ n=I $^{32}_{16}S$ II ^{50}Ti $^{52}_{24}Cr_{28n}$ III ^{86}Kr $^{88}_{38}Sr_{50n}$ IV ^{138}Ba $^{140}_{58}Ce_{82n}$ V ^{208}Pb $^{210}_{84}Po_{126n}$ VI ^{298}EPb $^{300}_{116}EPo_{184n=Nm}$

$^{n}Z=2$ 8 14 20 26 32 $\Delta^{n}Z=6$

Magic numbers of neutrons (N_m) **** and protons (Z_m) in the α^4-kern and $+3\alpha^4 \rightarrow {}^{40}_{20}Ca_{20}$: $^{n_0}N_m = {}^{n_0}Z_m = 2\,(3n_0 - 2)_{n_0=1,2,3,4} = 2, 8, 14, 20$

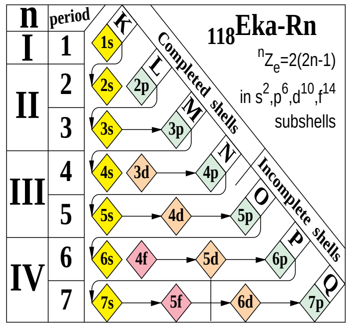
$${}_{n\geq 2}N_m=14(\alpha^4\text{-kern})+\sum_{n=2}^{n}(n^2+3n+4)=28,50,82,126,(184) \quad M_{Z>14}=3Z-2\overset{0}{N}_{\alpha 4}+\beta^{=0,2 \text{ for } Z^{odd}}_{=0,\pm1,2,4,6 \text{ for } Z^{even}},\ \beta=0 \text{ in } \overset{0}{M},\ \overset{0}{N}_{\alpha 4} \quad N_{\alpha 4}=\frac{3Z-M}{2} \quad N_{\alpha 6}=\frac{M-2Z}{2} \quad N_{\alpha M}=N_{\alpha 4}+N_{\alpha 6}=\frac{Z^{even}}{2}$$



*Other exotic nuclides with a half-life of $10^{-19} \div 10^{-22}$ s are not given in the table. **Nuclides, along with α-decay, possess «nuclide radioactivity», i.e., they emit the nuclides ^{14}C, ^{24}Ne, ^{28}Mg, $^{34}Si_{20n}$ and get transmuted to the nuclides with N_m = 126 and/or Z_m = 82 owing to the fact that these fragments at the beginning of the sixth nucleon shell are more weakly bound with the nuclear core than the preceding shell.

***Bimodular (symmetrical) spontaneous fission ($^{262}_{102}No \rightarrow {}^{131}_{51}Sb \xrightarrow{3\beta^-} {}^{131}_{54}Xe$) predicted for No by I.P.Selinov in 1964 from an anomalously high abundance $^{128,130}_{52}Te$, $^{129,131}_{54}Xe$ [1] and discovered by E.K.Hulet and co-authors in ≥1986 for $^{258}_{100}Fm$, $^{259,260}_{101}Md$, $^{258,262}_{102}No$, ^{260}Rf. ****The discover in 1934: I.P.Selinov N_m=20,50,82, J.J.Guggenheimer N_m=50,82, W.J.Elsasser N_m=126 and Z_m.

PERIODIC TABLE OF THE ATOMS

n^* $2n^2$	GROUPS PERIODS	I a b							VIII a b	VIII b	
dyads** I 2	K 1	Hydrogen 1 **H** $1s^1$ I / VII 1.00794	II a b	III a b	IV a b	V a b	VI a b	VII a b	Helium 2 **He** $1s^2$ VIII / II 4.002602		
II 8	L 2	Lithium 3 **Li** $2s^1$ 6.941	Beryllium 4 **Be** $2s^2$ 9.012182	Boron 5 **B** $2p^1$ 10.811	Carbon 6 **C** $2p^2$ 12.011	Nitrogen 7 **N** $2p^3$ 14.00674	Oxygen 8 **O** $2p^4$ 15.9994	Fluorine 9 **F** $2p^5$ 18.9984032	Neon 10 **Ne** $2p^6$ 20.1797		
8	3	Sodium 11 **Na** $3s^1$ 22.989768	Magnezium 12 **Mg** $3s^2$ 24.3050	Aluminium 13 **Al** $3p^1$ 26.981539	Silicon 14 **Si** $3p^2$ 28.0855	Phosporous 15 **P** $3p^3$ 30.973762	Sulfur 16 **S** $3p^4$ 32.066	Chlorine 17 **Cl** $3p^5$ 35.4527	Argon 18 **Ar** $3p^6$ 39.948		
III 18	M 4	Potassium 19 **K** $4s^1$ 39.0983	Calcium 20 **Ca** $4s^2$ 40.078	21 Scandium $3d^14s^2$ **Sc** 44.955910	22 Titanium $3d^24s^2$ **Ti** 47.88	23 Vanadium $3d^34s^2$ **V** 50.9415	24 Chromium $3d^54s^1$ **Cr** 51.9961	25 Manganese $3d^54s^2$ **Mn** 54.93805	26 Iron $3d^64s^2$ **Fe** 55.847	27 Cobalt $3d^74s^2$ **Co** 58.93320	28 Nickel $3d^84s^2$ **Ni** 58.6934
		29 Copper $3d^{10}4s^1$ **Cu** 63.546	30 Zinc $3d^{10}4s^2$ **Zn** 65.39	Gallium 31 **Ga** $4p^1$ 69.723	Germanium 32 **Ge** $4p^2$ 72.61	Arsenic 33 **As** $4p^3$ 74.92159	Selenium 34 **Se** $4p^4$ 78.96	Bromine 35 **Br** $4p^5$ 79.904	Krypton 36 **Kr** $4p^6$ 83.80	n - principal quantum number in the n*th* shell atomic weight	
18	5	Rubidium 37 **Rb** $5s^1$ 85.4678	Strontium 38 **Sr** $5s^2$ 87.62	39 Yttrium $4d^15s^2$ **Y** 88.90585	40 Zirconium $4d^25s^2$ **Zr** 91.224	41 Niobium $4d^45s^1$ **Nb** 92.90638	42 Molybdenum $4d^55s^1$ **Mo** 95.94	43 Technetium $4d^55s^2$ **Tc** 97.9072^{β^-}	44 Ruthenium $4d^75s^1$ **Ru** 101.07	45 Rhodium $4d^85s^1$ **Rh** 102.9055	46 Palladium $4d^{10}$ **Pd** 106.42
		47 Silver $4d^{10}5s^1$ **Ag** 107.8682	48 Cadmium $4d^{10}5s^2$ **Cd** 112.411	Indium 49 **In** $5p^1$ 114.818	Tin 50 **Sn** $5p^2$ 118.710	Antimony 51 **Sb** $5p^3$ 121.757	Tellurium 52 **Te** $5p^4$ 127.60	Iodine 53 **I** $5p^5$ 126.90447	Xenon 54 **Xe** $5p^6$ 131.29	Z - atomic number equal to the number of electrons in an atom and protons in an atomic nucleus	
IV 32	N 6	Cesium 55 **Cs** $6s^1$ 132.90543	Barium 56 **Ba** $6s^2$ 137.327	57 Lanthanium $5d^16s^2$ **La** 58-71 138.9055	72 Hafnium $5d^26s^2$ **Hf** 178.49	73 Tantalum $5d^36s^2$ **Ta** 180.9479	74 Tungsten $5d^46s^2$ **W** 183.84	75 Rhenium $5d^56s^2$ **Re** 186.207	76 Osmium $5d^66s^2$ **Os** 190.23	77 Iridium $5d^76s^2$ **Ir** 192.22	78 Platinum $5d^96s^1$ **Pt** 195.08
		79 Gold $5d^{10}6s^1$ **Au** 196.96654	80 Mercury $5d^{10}6s^2$ **Hg** 200.59	Thallium 81 **Tl** $6p^1$ 204.3833	Lead 82 **Pb** $6p^2$ 207.2	Bismuth 83 **Bi** $6p^3$ 208.98037	Polonium 84 **Po** $6p^4$ $208.9824^{\alpha\varepsilon}$	Astatine 85 **At** $6p^5$ $209.9871^{\alpha\varepsilon}$	Radon 86 **Rn** $6p^6$ 222.0176^{α}	atomic mass of the isotope (known) with the largest half-life and the type of radioactivity	
32	7	Francium 87 **Fr** $7s^1$ $223.0197^{\alpha\beta^-}$	Radium 88 **Ra** $7s^2$ 226.0254^{α}	89 Actinium $6d^17s^2$ **Ac** 90-103 227.0278^{β^-}	104 Rutherfordium $(6d^2)$ **(Rf)** $261.1089^{\alpha\Phi}$	105 Hahnium $(6d^3)$ **(Hn)** $262.1144^{\alpha\Phi}$	106 Seaborgium $(6d^4)$ **(Sg)** $263.1186^{\alpha\Phi}$	107 Nielsbohrium $(6d^5)$ **(Ns)** $262.1231^{\alpha\Phi}$	108 Hassium $(6d^6)$ **(Hs)** $265.1306^{\varepsilon\Phi}$	109 Meitnerium $(6d^7)$ **(Mt)** $266.1378^{\varepsilon\Phi}$	110 unnamed $(6d^8)$ $271^{\alpha},(285^{\alpha\Phi})$
		111 unnamed $(6d^9)$ $272^{\alpha},(287^{\alpha\Phi})$	112 $(6d^{10})$ **E-Hg** $(291^{\alpha\Phi})$	113 **E-Tl** $(7p^1)$ $(295^{\alpha\Phi})$	114 **E-Pb** $(7p^2)$ $(298^{\alpha\Phi})$	115 **E-Bi** $(7p^3)$ $(299^{\alpha\Phi})$	116 **E-Po** $(7p^4)$ $(299^{\alpha\varepsilon},300^{\alpha\Phi})$	117 **E-At** $(7p^5)$ $(305^{\alpha\Phi})$	118 **E-Rn** $(7p^6)$ $(307^{\alpha\Phi})(312^{\alpha\Phi})$	mass number of the hypothetical β-stable isotope with the largest half-life	

LANTHANIDES	58 Cerium $4f^15d^1$ **Ce** 140.115	59 Praseodymium $4f^3$ **Pr** 140.90765	60 Neodimium $4f^4$ **Nd** 144.24	61 Promethium $4f^5$ **Pm** 144.9127^{ε}	62 Samarium $4f^6$ **Sm** 150.36	63 Europium $4f^7$ **Eu** 151.965	64 Gadolinium $4f^75d^1$ **Gd** 157.25	65 Terbium $4f^9$ **Tb** 158.92534	66 Dysprosium $4f^{10}$ **Dy** 162.50	67 Holmium $4f^{11}$ **Ho** 164.93032	68 Erbium $4f^{12}$ **Er** 167.26	69 Thulium $4f^{13}$ **Tm** 168.93421	70 Ytterbium $4f^{14}$ **Yb** 173.04	71 Lutetium $4f^{14}5d^1$ **Lu** 174.967
ACTINIDES	90 Thorium $7s^26d^2$ **Th** III / IV 232.0381	91 Protactinium $5f^26d^1$ **Pa** 231.03588	92 Uranium $5f^36d^1$ **U** 238.0289	93 Neptunium $5f^46d^1$ **Np** 237.0482^{α}	94 Plutonium $5f^6$ **Pu** 244.0642^{α}	95 Americium $5f^7$ **Am** 243.0614^{α}	96 Curium $5f^76d^1$ **Cm** $247.0703^{\alpha(\beta-)}$	97 Berkelium $5f^9$ **Bk** 247.0703^{α}	98 Californium $5f^{10}$ **Cf** 251.0796^{α}	99 Einsteinium $5f^{11}$ **Es** 252.083^{α}	100 Fermium $5f^{11}$ **Fm** 257.0951^{α}	101 Mendelevium $5f^{13}$ **Md** $258.0984^{\alpha\varepsilon}$	102 Nobelium $5f^{14}$ **No** 259.1011	103 Lawrencium $(5f^{14}6d^1)$ **Lr** $262.1098^{\alpha\varepsilon}$

*n - ordinal number of dyads consisting of two periods with $2n^2$ atoms in each of them and the number of K-, L-, M-, and N-shells completed in the first periods of dyads.

**the first dyad can be supplemented with the second period (z=0), containing the neutron and the antineutron.

***see Table III.

SYMMETRICAL TABLE OF THE ATOMS AND THE ATOMIC NUCLEI

Electron shells	6	5	4	3	2	1	*n*
	P	O	N	M	L	K	Shells
	72	50	32	18	8	2	$^nZ_{sh}$ $2n^2$
Atomic subshells in the n*th* shell	s^2	s^2	s^2	s^2	s^2	s^2	$^nN_{\alpha M} = {}^nN_{\alpha 4} + {}^nN_{\alpha 6}$, groups: 2n2p ($\alpha^4$), 4n2p ($\alpha^6$) - nuclear «subshells» in the *n*th shell
	p^6	p^6	p^6	p^6	p^6	$1\alpha^6$	
	d^{10}	d^{10}	d^{10}	d^{10}	$1\alpha^4$	$1\alpha^4$ $2\alpha^6$	
	f^{14}	f^{14}	f^{14}	$1\alpha^4$	$1\alpha^4$ $2\alpha^6$	$1\alpha^4$ $2\alpha^6$	
	(g^{18})	(g^{18})	$1\alpha^4$	$3\alpha^4$	$1\alpha^4$ $2\alpha^6$	$1\alpha^4$ $2\alpha^6$	
	(h^{22})		$2\alpha^4$ $1\alpha^6$	$3\alpha^6$	$1\alpha^4$ $2\alpha^6$	$3\alpha^6$	
α^4-kern($7\alpha^4$)	$1\alpha^4$	$3\alpha^6$	$3\alpha^6$	$3\alpha^6$	$3\alpha^6$	$3\alpha^6$	
		$4\alpha^M$	$7\alpha^M$	$10\alpha^M$	$13\alpha^M$	$16\alpha^M$	$^nN_{\alpha M}$ $3n$-2
28		+22	+36	+52	+70	+90	^nM n^2+9n
$^{28}_{14}Si$	$^{32}_{16}S$	$^{50}_{22}Ti$	$^{86}_{36}Kr$	$^{138}_{56}Ba$	$^{208}_{82}Pb$	$(^{298}_{114}EPb_{184})$	N_m
Nucleon shells	$^{36}_{16}S_{20}$	$^{52}_{24}Cr_{28}$	$^{88}_{38}Sr_{50}$	$^{140}_{58}Ce_{82}$	$^{210}_{84}Po_{126}$	$(^{300}_{116}EPo_{184})$	
	2	8	14	20	26	(32)	^nZ_p $2(3n-2)$
	1	2	3	4	5	6	*n*

$^nZ_e, {}^nZ_p=2(Nl+1)_{l=n-1}$; N=2 for atoms, N=3 for nuclei *

$^nZ_{sh}, {}^nM=an^2+bn$; a=2, b=0 for atoms; a=1, b=9 for nuclei **

*N=1 for mesons ; ** b=3 for baryons

Symmetrical Table of Subatomic Particles (Table IV).