Āris Kaksis, 2019. year, Riga Stradin`s University http://aris.gusc.lv/BioThermodynamics/34AtomaUzbuveSAngl.pdf

1 Electron standing wave atomic orbitals — s, p, d, f.

Electrons in atoms standing wave energy level determines frequency times plank constant **f•h=E.** Electrons exist negatively charged (–) as standing waves, what sciences designated as **electron orbitals**, due to central symmetry of electron filled atom space relating to central positive charge (+) on nucleus.

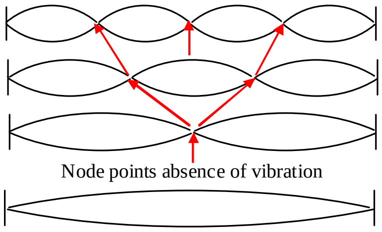
Periodic table of elements has seven **periods** 1,2,3,4,5,6,7 with seven ground tones **orbitals** $\mathbf{s_1,s_2,s_3,s_4}$, $\mathbf{s_5}$, $\mathbf{s_6}$, $\mathbf{s_7}$,. Quantum numbers are seven **n** =1, 2, 3, 4, 5,6, 7 as musical ground tones **do**, **re**, **mi**, **fa**, **sol**, la, **si** in octave. Electron standing wave ground tone **s** orbitals have three overtones **p**, **d**, **f** – sub **orbitals:**

p sub **orbital** – *Geeks* protos – first, one node plane 1,
d sub **orbital** – *Geeks* deitos – second, two node planes 2,
f sub **orbital** – *Latin* finēre, last one finite, three node planes 3.

Wave nature of electrons (micro objects) are quite different in relation with body objects (macro objects). The macro object as body in atom is the nucleus in which is concentrated all atomic mass. Electron mass is 1 unit and relatively 7294 times less as-proton mass. That is mach less like as feather attached to body of bird. Nucleus size is 0.00001 Å = 10^{-15} m, while atomic size is measured in one angstrom (1Å= 10^{-10} m). Atom size represents electron, which as standing wave occupy all atomic space with greatest occurrence probability layering on outer surface which is the edge of atom. Electron have made atomic volume 10^{15} times (Peta times) greater volume of nucleus. Coordinate site of nucleus lies on the center of atom with precision 0.00001 Å. Electron makes the three dimensional **orbitals** with the center located in nucleus. Positive charge (+) of nucleus bind negative charged (–) electron **orbital**. Three dimensional standing waves are formed and based on fundamental 3D vibration of electrons like as linear standing waves based on ground tones of musical instrument strings for guitar, contrabass, piano etc. 1.fig., which are linear shape analog for electron 3D three dimensional standing waves in atoms. Standing wave formation are mathematically described by physical laws using the quantum numbers **k** to vibration frequency $\mathbf{f_1}$ of ground tone for overtone **s, p, d, f** frequencies $\mathbf{k•f_1}$. > 1,2,3,4.

When we click on piano 1.**do** key sounds the ground tone **do**, what we listen. The piano string is fixed between left and right points and string size is fixed with length **L**.

← left **D** is length of string → right



4. third octave do **third** overtone with three nodes for string **1** do.

3. second octave sol **second overtone** with two nodes for string **1** do.

2. second octave do **first overtone** with one node on middle for string **1** do.

1. string first octave do **ground tone** standing wave in linear box with string length **D**

Figure.1. Sound making standing waves for first octave **do** on distance **l** stretched string for first octave **do** ground tone and three overtones **2.**, **3.** and **4.** .

1. ground tone $\lambda_1=\frac{2}{1}\bullet D$ – the wave length and frequency $\mathbf{f_1}$ have the vibration for **first octave do** and make on middle of string one maximum without node points ,

2. first overtone $\lambda_2=\frac{\lambda_1}{2}$ – is one octave higher (**second octave do2**) have wave length and frequency $\mathbf{f_2=2•f_1}$ with one node point on middle of string and make two symmetrical maximum tops to node;

3. second overtone $\lambda_3=\frac{\lambda_1}{3}$ – **sol2** on **second octave** have wave length and frequency $\mathbf{f_3= 3• f_1}$, with two node points sequester three symmetrical maximum tops of standing wave on string;

4. third overtone $\lambda_4=\frac{\lambda_1}{4}$ is two octave higher **third octave do3** have wave length and frequency $\mathbf{f_4=4• f_1}$ with three node points separating string into four identical symmetrical maximum tops of standing wave vibration.

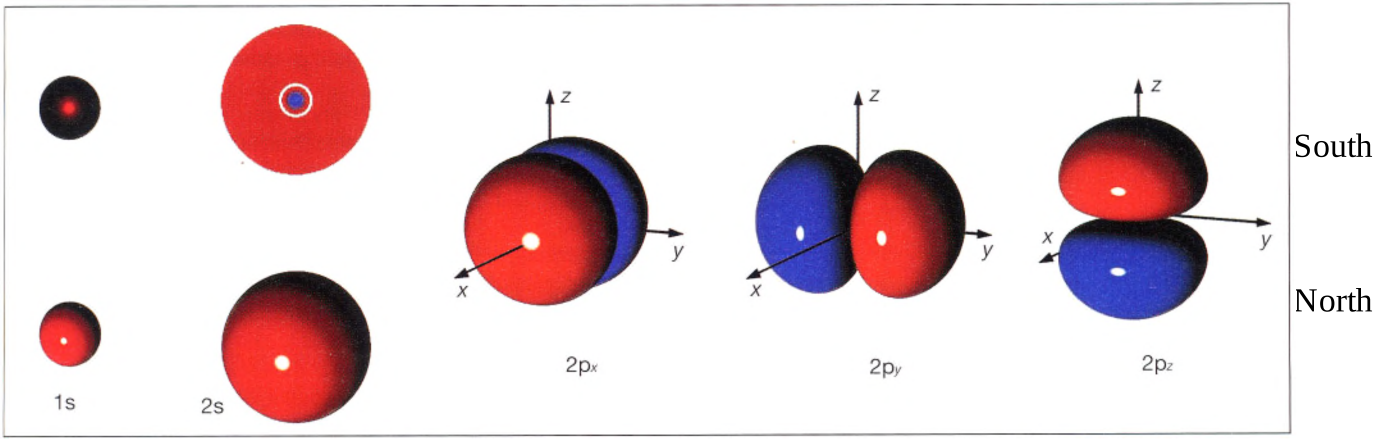
Orbital Quantum number *ℒ*=k-1 are multiply factors which multiple ground tone frequency $\mathbf{f_1}$ times **k=1,2,3** and **4** dividing string with length **D** into equal parts **1,2,3** and **4**. Node points on string are silencing sites with absence of vibration and separates overtone standing wave maximums on string into symmetrical region numbers **1, 2, 3** and **4**. Node point numbers are **orbital quantum number *ℒ*** is **k** minus **one** (**–1**) so:

1 ***ℒ*** **=0** node point **absent** in case **k=1** as ground tones **orbitals** $\mathbf{s_1,s_2,s_3,s_4}$, $\mathbf{s_5}$, $\mathbf{s_6}$, $\mathbf{s_7}$ are spherical, 3D
2 ***ℒ*** **=1** node point **one** in case **k=2** as one node plane **p** sub **orbital** 3D ,
3 ***ℒ*** **=2** node points **two** in case **k=3** as two node planes **d** sub **orbital** 3D ,
4 ***ℒ*** =**3** node points **three** in case **k=4** as three node planes **f** sub **orbital** 3D.

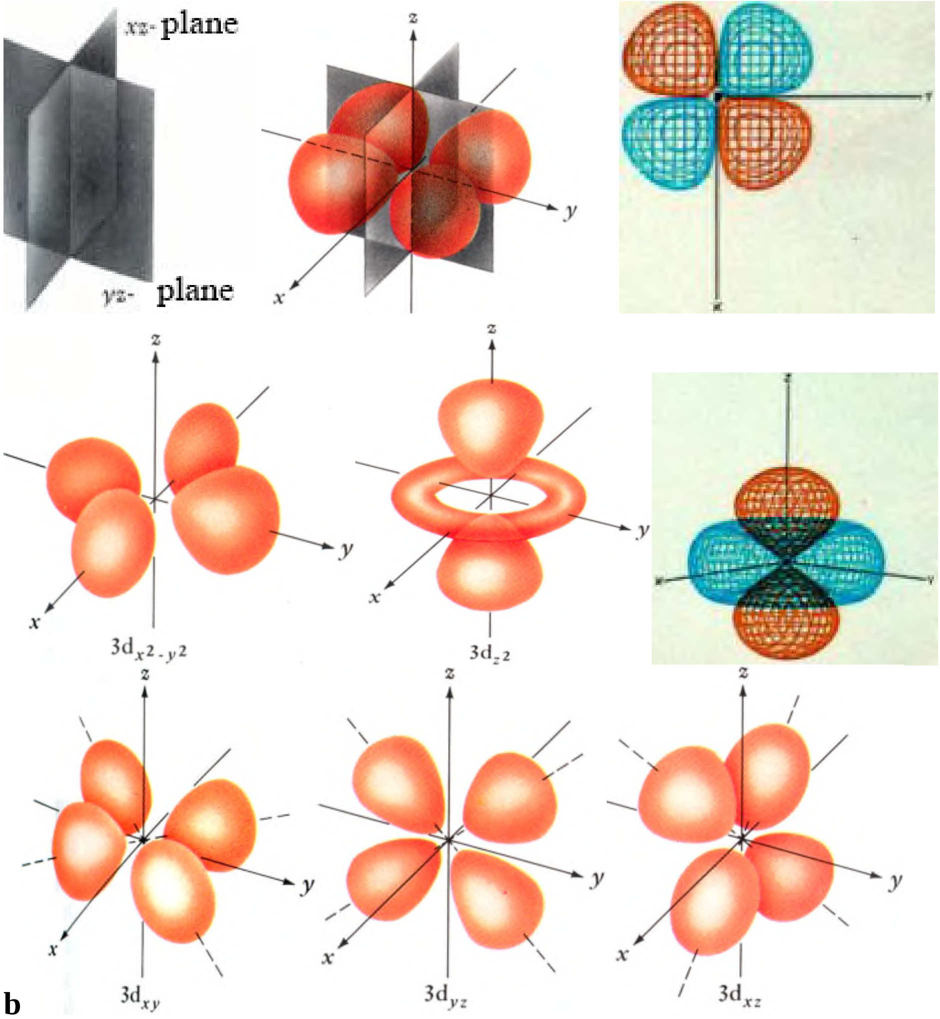
Electron three dimensional waves in atoms for electron standing 3D (three dimension) waves sites of silencing vibrations are on **node planes** for orbitals **p, d** and **f**. **Node planes,** which count is principal quantum number **n** minus **one** (**–1**), separating symmetrical around nucleus into equal regions of vibration overtone standing wave electron 3D orbitals for cases **p, d** and **f**. Atom positively charged (+) nucleus always stay on all present node planes and attaches to the **node plane surfaces** via central symmetry negative (–) electron orbitals.

1s orbital in atom do not have overtone ℒ is **0** second period **2s** orbital has first overtone for **p** orbital ℒ is **1**:

ℒ is **1 one** node plane for **p** orbital separates space in two symmetric vibration regions,
ℒ is **2 two** perpendicular node planes for **d** orbital separates space in four symmetric vibration regions,
ℒ is **3 three** node planes for **f** orbital separates space in eight symmetric vibration regions.



2.figure. **1s, 2s** and **2p** electron orbitals in atom. Exist three independent **2p** orbitals with node planes yz, xz and xy, which separates two standing wave regions red and blue like as for magnets north and south direction.



3.figure. Five **d** electron orbitals:

(**a**) xz and yz node planes for $\mathbf{d_{xy}}$ orbital. Designated xy orbitals in **d** index means that four electron orbital regions separated by node planes xz and yz lay on xy plane.

(**b**) azimutal quantum number **L** for all fife orbitals is **L**=2, so each orbital has two perpendicular node planes. Electron orbital d_{z^2} has conical silencing node surfaces with angle degree 90° on what no electron wave.

Plank constant times frequency is Energy E= h×f of green λ= 555 nm photon f= 540×10^{12} Hz; E= 3.58×10^{-19} J/photon Avogadro $N_A=6.022\times10^{23}$ mol^{-1} number for one mol energy is E_{555nm}=216 kJ/mol. or one green light photon E_{555nm}=2.23 eV.

Mass ratio $\mathbf{m_{proton}/m_e} = 6{,}64476\cdot10^{-24}/9{,}109534\cdot10^{-28}=7294{,}3$ times
Plank constanth=$6.626070040(81)\times10^{-34}$ J•s or h= $4.135667662(25)\times10^{-15}$ eV•s

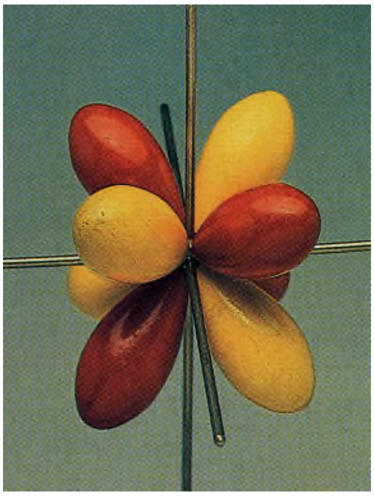


Figure.4. One of seven possible **f** orbitals. Remarkable are three mutual perpendicular node plane presence (xy, yz and xz planes) as determines azimutal quantum number **l** = 3. In three dimensional space of electron orbitals that is last possible overtone and Latin word *finere* (last possible) first letter is used for designation of overtone limits **f** as last possible in three dimensional coordinates. Total **f** orbital account according magnetic number $\mathbf{m_l}$ variation **-l** , …, 0 , …, +**l** are seven **f** orbitals by magnetic numbers:
$\mathbf{m_l} = -3$, $\mathbf{m_l} = -2$, $\mathbf{m_l} = -1$, $\mathbf{m_l} = 0$, $\mathbf{m_l} = 1$, $\mathbf{m_l} = 2$, $\mathbf{m_l} = 3$.

Electrons in atoms have seven ground tones with principle quantum numbers **n = 1, 2, 3, 4, 5, 6, 7**. Periodic table of chemical elements has seven periods in seven rows. Each period start with metal having in outer shell one electron on $\boxed{\uparrow}$ orbital **1s, 2s, 3s, 4s, 5s, 6s, 7s** respectively **H, Li, Na, K, Rb, Cs, Fr**. Remark: Fit one to octave tonality Do major gamma consist of seven ground tones **do, re, mi, fa, sol, la, si**, like as all atoms in nature are made up in seven periods with seven principle quantum **numbers n = 1, 2, 3, 4, 5, 6, 7**.

Magnetic quantum number $\mathbf{m}_\ell$ shows the possible spatial orientation of orbitals having the azimutal quantum number ℓ magnetic $\mathbf{m}_\ell$ can take values from the interval **–** $\boldsymbol{\ell}$**, …, 0 , …, +** $\boldsymbol{\ell}$.

For orbitals **s, p, d** and **f** are known spatial orientations with magnetic quantum numbers $\mathbf{m}_\ell$:
s, $\boldsymbol{\ell}$ **= 0**: $\mathbf{m}_\ell = 0$ spherical orbital and first letter s of Greeks word *sphaira – ball* in English;
p, $\boldsymbol{\ell}$ **= 1**: $\mathbf{m}_\ell = -1$, $\mathbf{m}_\ell = 0$, $\mathbf{m}_\ell = 1$ of Greeks word *prõtos – first* in English one node separate in two parts;
d, $\boldsymbol{\ell}$ **= 2**: $\mathbf{m}_\ell = -2$, $\mathbf{m}_\ell = -1$, $\mathbf{m}_\ell = 0$, $\mathbf{m}_\ell = 1$, $\mathbf{m}_\ell = 2$ of Greeks word *deuteros–second,two* in English figure.3.;
f, $\boldsymbol{\ell}$ **= 3**: $\mathbf{m}_\ell = -3$, $\mathbf{m}_\ell = -2$, $\mathbf{m}_\ell = -1$, $\mathbf{m}_\ell = 0$, $\mathbf{m}_\ell = 1$, $\mathbf{m}_\ell = 2$, $\mathbf{m}_\ell = 3$ of Latin word *finēre – end* in English.
d electron orbitals have five possible spatial orientations with azimutal number $\boldsymbol{\ell}$ **=** 2 fig.3. .
f electron orbitals have seven possible spatial orientations with azimutal number $\boldsymbol{\ell}$ **=** 3 fig.4. .

Principal quantum number **n** characterize the electron energy amount in atom and size of atom. If greater is principal quantum number, then higher is electron energy in atom and then higher is size of electron orbital. For example the radius of IA group metal atoms becomes greater if principal quantum number is greater ascending:
n = 1 **rH = 0,37** Å for first period metal hydrogen atom,
n = 2 **rLi = 1,52** Å for second period metal lithium atom,
n = 3 **rNa = 1,86** Å for third period metal sodium atom,
n = 4 **rK = 2,31** Å for fourth period metal potassium atom,
n = 5 **rRb = 2,44** Å for fifth period metal rubidium atom,
n = 6 **rCs = 2,62** Å for six period metal cesium atom,
n = 7 **rFr = 2,7** Å for seven period metal francium atom,

Pauli law: two electrons can not occupy the same orbital for any chemical element atom if they have the equal all four quantum numbers: principal quantum number **n**, azimutal quantum number $\boldsymbol{\ell}$, magnetic quantum number $\mathbf{m}_\ell$ and quantum number **spin**. Two quantum numbers **spins** are $+^1/_2$ and $-^1/_2$ magnetic moments ↑and↓.

One electron orbital can occupy two electrons with opposite **spins**. **Spin** is the magnetic moment $\overset{N}{\underset{S}{\uparrow}}$ what have made the standing wave electron. Electron having opposite **spin** $\overset{\mathbf{S}}{\underset{\mathbf{N}}{\downarrow}}$ attracts with anti parallel **spin** in one orbital $\boxed{\overset{N}{\underset{S}{\uparrow}}\overset{S}{\underset{N}{\downarrow}}}$ together.

Two electrons can occupying the same orbital with equal three quantum numbers: principal quantum number **n**, azimutal quantum number $\boldsymbol{\ell}$, magnetic quantum number $\mathbf{m}_\ell$ but vary fourth quantum number **spins** which are anti parallel each to other $+^1/_2$ and $-^1/_2$ or ↑and↓, that is maximum possible number two electrons into one orbital $\boxed{\uparrow\downarrow}$.

Hund’s law 5.fig. (energy minimum principle of electron) state electron orbitals occupying sequence from lowest energy level orbitals **1s** ↑ to ascending electron orbital energy increase. Chemical element atoms in periodic table have the color last occupied orbital. That is outer shell energy level valence electron orbital color.

For **s** orbitals blue colors 🟦, **p** orbitals yellow color 🟨, **d** orbitals red color 🟥, and **f** orbitals green colors 🟩.

Energy amount (energy levels **n** from **1** to **7** and orbitals **s**🟦, **p**🟨, **d**🟥 and **f**🟩) diagram

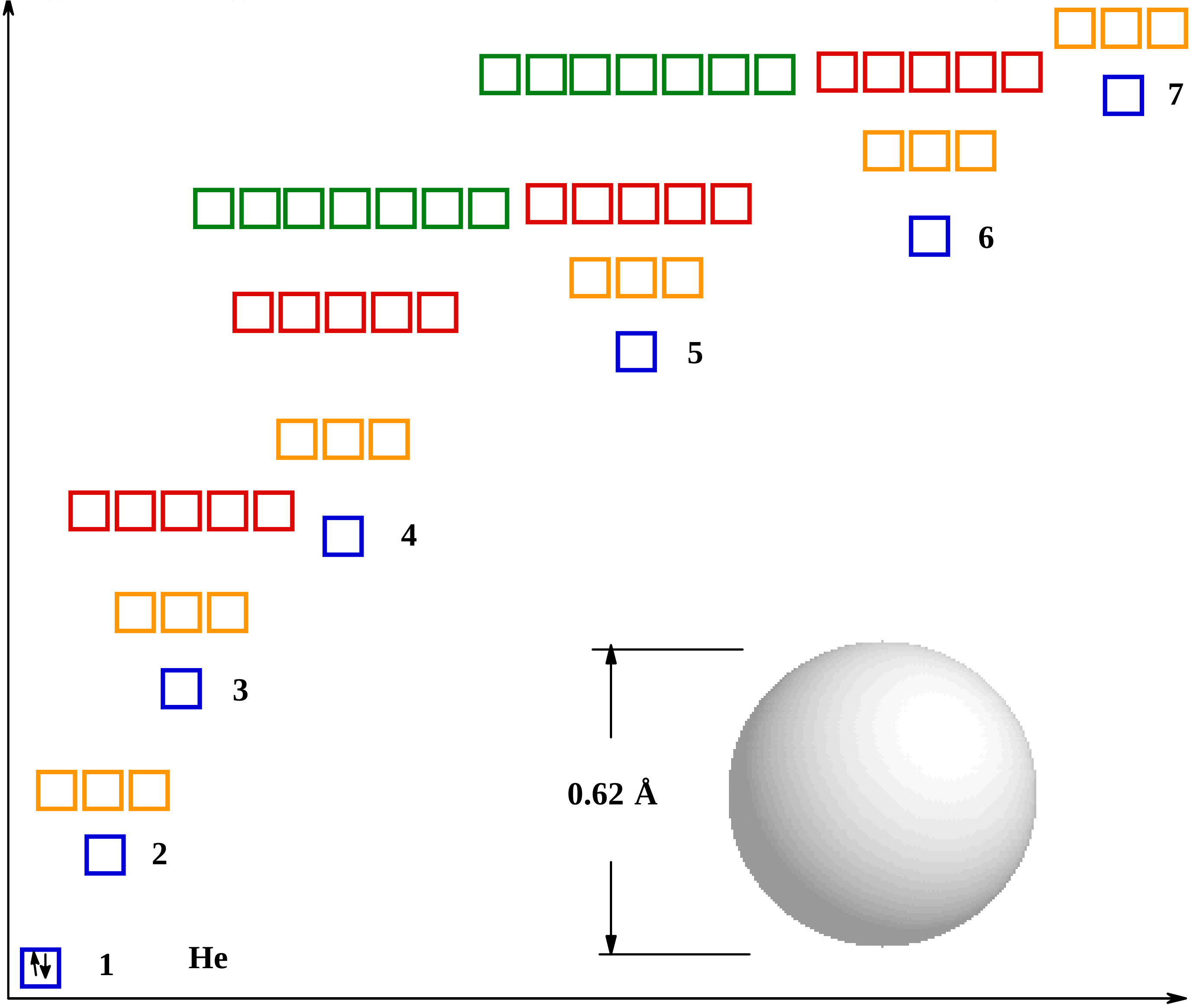


Figure.5. Relative energy amount of electron on atomic orbitals in acceding order starting from first period with quantum number **n=1** for **1s** orbital for He helium ⇅ and H hydrogen $+^{1}/_{2}$ ↑ elements according energy minimum principle.