Energies of Atomic Electrons from Krypton to Fermium

Daniele Sasso

Abstract

The electronic configuration of xenon regarding more external sub-levels (2+6),2 gives stability and inertia to xenon atom and it allows to understand the behaviour of subsequent chemical elements represented by transition elements including rare earths and actinides. The same thing happens for radon atom that has in external sub-levels the configuration (8+2),6. The prime difficulty in calculating energies of atomic electrons is no doubt the appraisal of effective shielding of internal electrons with regard to external electrons and it is important because that shielding reduces the size of nuclear charge that has to be considered in calculation.

1. Introduction

In a preceding article[1] we have calculated energies of electrons inside atom starting from hydrogen (Z=1) to krypton (Z=36). In this article we intend to continue this work with regard to atoms of subsequent chemical elements to fermium. Nevertheless while for preceding chemical elements we calculated energies of all electrons inside atom, for subsequent elements we will do the calculation only for electrons that are in more external sub-levels because from a physico-chemical viewpoint these electrons are more revealing.
The preceding calculation[1] has demonstrated energies of electrons inside atoms are very regular and they increase, in negative value, for electrons that are in more external sub-levels. Near nucleus, and hence for more internal electrons, energies are smaller.
Like this for instance, krypton has an energy of about -17000eV for the two more internal electrons (sub-level 1s) and of about -105eV for the eight more external electrons (4s).
Therefore for rubidium atom (Z=37), that is the first chemical element after krypton, we will calculate only energy levels of electrons that are into the energy level n=4.
To that end we make use of the deterministic quantum model of atom[1][2][3][4] :

$$E_{nkjs} = -\frac{2Z^2Rhc}{n^2}\left(1-\frac{k^2}{2n^2}\right)\left(1-\frac{1}{2}\frac{\alpha^2Z^2(j-s)^2}{n^4}\right) \qquad (1)$$

in which

n = 1, 2 , ...	quantum number of level
k = 1, 2 ,....... n	quantum number of sub-level
j = ±1, ±2, ...±k	quantum number of orbital momentum
$s = \frac{\lvert j \rvert}{2}$	quantum number of spin that is always positive because the negative sign of electron spin has been considered in (1).

2. Energy levels of atomic electrons of rubidium atom Rb (Z=37)

Rubidium atom has an atomic number Z=37, therefore it has 37 electrons that are distributed in energy levels according the following configuration:

1s	2 electrons	
2s	4 electrons	
2p	4 electrons	(2)
3s	6 electrons	
3p	6 electrons	
3d	6 electrons	
4s	8 electrons	
4p	1 electron	

We will calculate for rubidium only energies of electrons 4s and 4p, even if in actuality only electron 4p is revealing in order to understand the chemical behaviour of this atom in bonds with other atoms.
Energies of electrons 4s have to be calculated considering that these electrons are shielded by more internal complete levels for which the nuclear effective charge is Z=9.

E_{4s1} = - 133.713233589 eV with n=4, k=1, j=1, s=1/2 Z=9

E_{4s2} = - 133.712388735 eV with n=4, k=1, j=2, s=1 Z=9

E_{4s3} = - 133.710980642 eV with n=4, k=1, j=3, s=3/2 Z=9

E_{4s4} = - 133.709009315 eV with n=4, k=1, j=4, s=2 Z=9

E_{4s5} = - 133.710980642 eV with n=4, k=1, j=-1, s=1/2 Z=9

E_{4s6} = - 133.703376947 eV with n=4, k=1, j=-2, s=1 Z=9

E_{4s7} = - 133.690704119 eV with n=4, k=1, j=-3, s=3/2 Z=9

E_{4s8} = - 133.672962162 eV with n=4, k=1, j=-4, s=2 Z=9

The unique electron of the second sub-level p of the fourth level n=4 is shielded also by 8 electrons of the complete sub-level 4s for which the effective nuclear charge is Z=1 and consequently its energy is

E_{4p1} = - 1.49103079567 eV with n=4, k=2, j=1, s=1/2 Z=1

Like all atoms that have only one electron into the most external level, also rubidium has a smallest value of energy for the most external electron and hence a smallest value of ionization energy.

3. Energy levels of atomic electrons of strontium atom Sr (Z=38)

In concordance with the preceding consideration we will calculate only energy levels of electrons that are into the second sub-level p of the level n=4. Hence

E_{4p1} = - 5.96412318353 eV with n=4, k=2, j=1, s=1/2 Z=2

E_{4p2} = - 5.96412271839 eV with n=4, k=2, j=2, s=1 Z=2

4. Energy levels of atomic electrons of yttrium atom Y (Z=39)

Energies of electrons of yttrium in the external sub-level p of the level n=4 are:

E_{4p1} = - 13.4192743716 eV with n=4, k=2, j=1, s=1/2 Z=3

E_{4p2} = - 13.4192649506 eV with n=4, k=2, j=2, s=1 Z=3

E_{4p3} = - 13.419249249 eV with n=4, k=2, j=3, s=3/2 Z=3

5. Energy levels of atomic electrons of zirconium atom Zr (Z=40)

Energies of electrons of zirconium in the external sub-level p of the level n=4 are:

E_{4p1} = - 23.8564834298 eV with n=4, k=2, j=1, s=1/2 Z=4

E_{4p2} = - 23.856453655 eV with n=4, k=2, j=2, s=1 Z=4

E_{4p3} = - 23.8564040302 eV with n=4, k=2, j=3, s=3/2 Z=4

E_{4p4} = - 23.856334556 eV with n=4, k=2, j=4, s=2 Z=4

6. Energy levels of atomic electrons of niobium atom Nb (Z=41)

Energies of electrons of niobium in the external sub-level p of the level n=4 are:

E_{4p1} = - 37.2757466355 eV with n=4, k=2, j=1, s=1/2 Z=5

E_{4p2} = - 37.2756739435 eV with n=4, k=2, j=2, s=1 Z=5

E_{4p3} = - 37.2755527896 eV with n=4, k=2, j=3, s=3/2 Z=5

E_{4p4} = - 37.2753831741 eV with n=4, k=2, j=4, s=2 Z=5

E_{4p5} = - 37.2755527896 eV with n=4, k=2, j=-1, s=1/2 Z=5

7. Energy levels of atomic electrons of molybdenum atom Mo (Z=42)

Energies of electrons of molybdenium in the external sub-level p of the level n=4 are:

E_{4p1} = - 53.6770598032 eV with n=4, k=2, j=1, s=1/2 Z=6

E_{4p2} = - 53.676909068 eV with n=4, k=2, j=2, s=1 Z=6

E_{4p3} = - 53.6766578436 eV with n=4, k=2, j=3, s=3/2 Z=6

E_{4p4} = - 53.6763061288 eV with n=4, k=2, j=4, s=2 Z=6

E_{4p5} = - 53.6766578436 eV with n=4, k=2, j=-1, s=1/2 Z=6

E_{4p6} = - 53.6753012303 eV with n=4, k=2, j=-2, s=1 Z=6

8. Energy levels of atomic electrons of technetium atom Tc (Z=43)

Energies of electrons of technetium in the external sub-level p of the level n=4 are:

E_{4p1} = - 73.0604178127 eV with n=4, k=2, j=1, s=1/2 Z=7

E_{4p2} = - 73.0601385582 eV with n=4, k=2, j=2, s=1 Z=7

E_{4p3} = - 73.0596731335 eV with n=4, k=2, j=3, s=3/2 Z=7

E_{4p4} = - 73.0590215391 eV with n=4, k=2, j=4, s=2 Z=7

E_{4p5} = - 73.0596731335 eV with n=4, k=2, j=-1, s=1/2 Z=7

E_{4p6} = - 73.0571598402 eV with n=4, k=2, j=-2, s=1 Z=7

E_{4p7} = - 73.0529710176 eV with n=4, k=2, j=-3, s=3/2 Z=7

9. Energy levels of atomic electrons of ruthenium atom Ru (Z=44)

Energies of electrons of ruthenium in the external sub-level p of the level n=4 are:

E_{4p1} = - 95.4258146194 eV with n=4, k=2, j=1, s=1/2 Z=8

E_{4p2} = - 95.4253382232 eV with n=4, k=2, j=2, s=1 Z=8

E_{4p3} = - 95.4245442279 eV with n=4, k=2, j=3, s=3/2 Z=8

E_{4p4} = - 95.4234326372 eV with n=4, k=2, j=4, s=2 Z=8

E_{4p5} = - 95.4245442279 eV with n=4, k=2, j=-1, s=1/2 Z=8

E_{4p6} = - 95.4202566615 eV with n=4, k=2, j=-2, s=1 Z=8

E_{4p7} = - 95.4131107155 eV with n=4, k=2, j=-3, s=3/2 Z=8

E_{4p8} = - 95.4031063903 eV with n=4, k=2, j=-4, s=2 Z=8

10. Energy levels of atomic electrons of rhodium atom Rh (Z=45)

The sub-level 4p is complete in ruthenium and with rhodium the sub-level d (k=3) of the level n=4 begins to become full. The completion of the sub-level 4p doesn’t involve particular consequences for rhodium atom.
Energies of electrons of rhodium in the sub-level p and in the sub-level d of the level n=4 are:

sub-level 4p, k=2

E_{4p1} = - 120.773243242 eV with n=4, k=2, j=1, s=1/2 Z=9

E_{4p2} = - 120.772480147 eV with n=4, k=2, j=2, s=1 Z=9

E_{4p3} = - 120.771208322 eV with n=4, k=2, j=3, s=3/2 Z=9

E_{4p4} = - 120.769427768 eV with n=4, k=2, j=4, s=2 Z=9

E_{4p5} = - 120.771208322 eV with n=4, k=2, j=-1, s=1/2 Z=9

E_{4p6} = - 120.764340468 eV with n=4, k=2, j=-2, s=1 Z=9

E_{4p7} = - 120.752894041 eV with n=4, k=2, j=-3, s=3/2 Z=9

E_{4p8} = - 120.73686905 eV with n=4, k=2, j=-4, s=2 Z=9

sub-level 4d, k=3

E_{4d1} = - 99.2065926626 eV with n=4, k=3, j=1, s=1/2 Z=9

11. Energy levels of atomic electrons of palladium atom Pd (Z=46)

Energies of electrons of palladium in the sub-levels p and d of the level n=4 are:

sub-level 4p, k=2

E_{4p1} = - 149.102695773 eV with n=4, k=2, j=1, s=1/2 Z=10

E_{4p2} = - 149.101532697 eV with n=4, k=2, j=2, s=1 Z=10

E_{4p3} = - 149.099594234 eV with n=4, k=2, j=3, s=3/2 Z=10

E_{4p4} = - 149.096880388 eV with n=4, k=2, j=4, s=2 Z=10

E_{4p5} = - 149.099594234 eV with n=4, k=2, j=-1, s=1/2 Z=10

E_{4p6} = - 149.08912654 eV with n=4, k=2, j=-2, s=1 Z=10

E_{4p7} = - 149.071680382 eV with n=4, k=2, j=-3, s=3/2 Z=10

E_{4p8} = - 149.047255759 eV with n=4, k=2, j=-4, s=2 Z=10

sub-level 4d, k=3

E_{4d1} = - 122.477214385 eV with n=4, k=3, j=1, s=1/2 Z=10

E_{4d2} = - 122.476259001 eV with n=4, k=3, j=2, s=1 Z=10

With the first 2 electrons of the sub-level d (n=4, k=3) of palladium, the period that begins with rubidium Rb (Z=37) is finished and the new period begins with silver.

12. Energy levels of atomic electrons of silver atom Ag (Z=47)

Energies of electrons of silver in the sub-levels p and d of the level n=4 are:

sub-level 4p, k=2

E_{4p1} = - 180.414163374 eV with n=4, k=2, j=1, s=1/2 Z=11

E_{4p2} = - 180.412460512 eV with n=4, k=2, j=2, s=1 Z=11

E_{4p3} = - 180.40962241 eV with n=4, k=2, j=3, s=3/2 Z=11

E_{4p4} = - 180.405649067 eV with n=4, k=2, j=4, s=2 Z=11

E_{4p5} = - 180.40962241 eV with n=4, k=2, j=-1, s=1/2 Z=11

E_{4p6} = - 180.394296657 eV with n=4, k=2, j=-2, s=1 Z=11

E_{4p7} = - 180.368753737 eV with n=4, k=2, j=-3, s=3/2 Z=11

E_{4p8} = - 180.332993649 eV with n=4, k=2, j=-4, s=2 Z=11

sub-level 4d, k=3

E_{4d1} = - 122.477214385 eV with n=4, k=3, j=1, s=1/2 Z=11

E_{4d2} = - 122.476259001 eV with n=4, k=3, j=2, s=1 Z=11

The electron 4d3 of silver is shielded by preceding 46 electrons and it has energy

E_{4d3} = - 1.22477504165 eV with n=4, k=3, j=3, s=3/2 Z=1

12. Energy levels of atomic electrons of cadmium atom Cd (Z=48)

For cadmium we consider only energies of electrons of the sub-level d (k=3):

E_{4d1} = - 122.477214385 eV with n=4, k=3, j=1, s=1/2 Z=12

E_{4d2} = - 122.476259001 eV with n=4, k=3, j=2, s=1 Z=12

Like for silver, also the two subsequent electrons of cadmium are shielded by preceding 46 electrons. Hence energies of these two electrons are:

E_{4d3} = - 4.899096728 eV with n=4, k=3, j=3, s=3/2 Z=2

E_{4d4} = - 4.89909316125 eV with n=4, k=3, j=4, s=2 Z=2

13. Energy levels of atomic electrons of indium atom In (Z=49)

Also for indium we consider only energies of electrons of the sub-level d:

E_{4d1} = - 206.986120953eV with n=4, k=3, j=1, s=1/2 Z=13

E_{4d2} = - 206.98339228 eV with n=4, k=3, j=2, s=1 Z=13

Three subsequent electrons of indium are shielded by preceding 46 electrons, for which energies of these electrons are:

E_{4d3} = - 11.0229547402 eV with n=4, k=3, j=3, s=3/2 Z=3

E_{4d4} = - 11.0229366834 eV with n=4, k=3, j=4, s=2 Z=3

E_{4d5} = - 11.0229547402 eV with n=4, k=3, j=-1, s=1/2 Z=3

14. Energy levels of atomic electrons of tin atom Sn (Z=50)

Also for tin we consider only energies of electrons of the sub-level d:

E_{4d1} = - 240.054740978 eV with n=4, k=3, j=1, s=1/2 Z=14

E_{4d2} = - 240.051070771 eV with n=4, k=3, j=2, s=1 Z=14

The subsequent electrons of tin are shilded by preceding 46 electrons, for which:

E_{4d3} = - 19.5963318821eV with n=4, k=3, j=3, s=3/2 Z=4

E_{4d4} = - 19.5962748137 eV with n=4, k=3, j=4, s=2 Z=4

E_{4d5} = - 19.5963318821 eV with n=4, k=3, j=-1, s=1/2 Z=4

E_{4d6} = - 19.5963869122 eV with n=4, k=3, j=-2, s=1 Z=4

15. Energy levels of atomic electrons of antimony atom Sb (Z=51)

Energies of electrons of the sub-level d (k=3):

E_{4d1} = - 275.572836696eV with n=4, k=3, j=1, s=1/2 Z=15

E_{4d2} = - 275.568000057 eV with n=4, k=3, j=2, s=1 Z=15

The subsequent 5 electrons of antimony are shielded by preceding 46 electrons, for wich energies of these electrons are:

E_{4d3} = - 30.6192040771 eV with n=4, k=3, j=3, s=3/2 Z=5

E_{4d4} = - 30.6190647492 eV with n=4, k=3, j=4, s=2 Z=5

E_{4d5} = - 30.6192040771 eV with n=4, k=3, j=-1, s=1/2 Z=5

E_{4d6} = - 30.6186666729 eV with n=4, k=3, j=-2, s=1 Z=5

E_{4d7} = - 30.6177709996 eV with n=4, k=3, j=-3, s=3/2 Z=5

16. Energy levels of atomic electrons of tellurium atom Te (Z=52)

Energies of electrons of the sub-level d:

E_{4d1} = - 313.54039702 eV with n=4, k=3, j=1, s=1/2 Z=16

E_{4d2} = - 313.534135808 eV with n=4, k=3, j=2, s=1 Z=16

The subsequent 6 electrons of tellurium are shielded by preceding 46 electrons, for which energies of these electrons are:

E_{4d3} = - 44.0915403716 eV with n=4, k=3, j=3, s=3/2 Z=6

E_{4d4} = - 44.0912514629 eV with n=4, k=3, j=4, s=2 Z=6

E_{4d5} = - 44.0915403716 eV with n=4, k=3, j=-1, s=1/2 Z=6

E_{4d6} = - 44.0904260108 eV with n=4, k=3, j=-2, s=1 Z=6

E_{4d7} = - 44.0885687427 eV with n=4, k=3, j=-3, s=3/2 Z=6

E_{4d8} = - 44.085968567 eV with n=4, k=3, j=-4, s=2 Z=6

17. Energy levels of atomic electrons of iodine atom I (Z=53)

Energies of electrons of the sub-level d:

E_{4d1} = - 353.957410105 eV with n=4, k=3, j=1, s=1/2 Z=17

E_{4d2} = - 353.949430634 eV with n=4, k=3, j=2, s=1 Z=17

Subsequent 7 electrons of iodine are shielded by 46 electrons. 6 of these 7 electrons complete the sub-level d (k=3) of the level n=4 and the seventh electron occupies the first quantum state of the sub-level k=4 of the level n=4. Energies of these electrons are:

E_{4d3} = - 60.0133029311 eV with n=4, k=3, j=3, s=3/2 Z=7

E_{4d4} = - 60.0127676926 eV with n=4, k=3, j=4, s=2 Z=7

E_{4d5} = - 60.0133029311 eV with n=4, k=3, j=-1, s=1/2 Z=7

E_{4d6} = - 60.0112384404 eV with n=4, k=3, j=-2, s=1 Z=7

E_{4d7} = - 60.0077976213 eV with n=4, k=3, j=-3, s=3/2 Z=7

E_{4d8} = - 60.0029804751 eV with n=4, k=3, j=-4, s=2 Z=7

sub-level 4f

E_{4f1} = - 41.7488101791 eV with n=4, k=4, j=1, s=1/2 Z=7

18. Energy levels of atomic electrons of xenon atom Xe (Z=54)

Energies of electrons of the sub-level d (k=3) of xenon:

E_{4d1} = - 396.823863343 eV with n=4, k=3, j=1, s=1/2 Z=18

E_{4d2} = - 396.813834095 eV with n=4, k=3, j=2, s=1 Z=18

The remaining 8 electrons of xenon are shielded by 46 electrons like preceding elements. 6 of these electrons complete the sub-level 4d and the remaining 2 electrons occupy the first two quantum states of the sub-level 4f. Energies of these electrons are:

E_{4d3} = - 78.3844470446 eV with n=4, k=3, j=3, s=3/2 Z=8

E_{4d4} = - 78.383533952 eV with n=4, k=3, j=4, s=2 Z=8

E_{4d5} = - 78.3844470446 eV with n=4, k=3, j=-1, s=1/2 Z=8

E_{4d6} = - 78.3809251149 eV with n=4, k=3, j=-2, s=1 Z=8

E_{4d7} = - 78.3750552299 eV with n=4, k=3, j=-3, s=3/2 Z=8

E_{4d8} = - 78.3668373913 eV with n=4, k=3, j=-4, s=2 Z=8

sub-level 4f

E_{4f1} = - 41.7488101791 eV with n=4, k=4, j=1, s=1/2 Z=8

E_{4f2} = - 41.7488101791 eV with n=4, k=4, j=2, s=1 Z=8

The same situation repeats for xenon like for argon. In fact the configuration (6+2) of external electrons of argon in the level n=3 gives stability and inertia to atom that belongs to the group of inert elements. Similarly for xenon, the analogus configuration (6+2) of external electrons, 6 electrons in the sublevel 4d and 2 electrons in the sublevel 4f, gives stability to xenon atom that similarly belongs to the group of inert elements.

19. Energy levels of atomic electrons of caesium atom Cs (Z=55)

Inert properties of xenon atom involve the subsequent chemical element, represented by caesium (Z=55), has the same behaviour for the last external electron as for potassium. That is electron with quantum state 4f3 is shielded by (Z-1) electrons.
For the last time we calculate energies of electrons of the sub-level 4d, afterwards we will calculate only energies of electrons of the sub-level 4f.
Energies of electrons of the sub-level d (k=3):

E_{4d1} = - 442.139743354 eV with n=4, k=3, j=1, s=1/2 Z=19

E_{4d2} = - 442.127292683 eV with n=4, k=3, j=2, s=1 Z=19

The subsequent electrons of caesium are shielded by preceding 46 electrons. Energies of these electrons are:

E_{4d3} = - 99.2049211218 eV with n=4, k=3, j=3, s=3/2 Z=9

E_{4d4} = - 99.2034585236 eV with n=4, k=3, j=4, s=2 Z=9

E_{4d5} = - 99.2049211218 eV with n=4, k=3, j=-1, s=1/2 Z=9

E_{4d6} = - 99.1992796711 eV with n=4, k=3, j=-2, s=1 Z=9

E_{4d7} = - 99.1898772501 eV with n=4, k=3, j=-3, s=3/2 Z=9

E_{4d8} = - 99.1767138617 eV with n=4, k=3, j=-4, s=2 Z=9

sub-level 4f

E_{4f1} = - 69.013281853 eV with n=4, k=4, j=1, s=1/2 Z=9

E_{4f2} = - 69.0128457994 eV with n=4, k=4, j=2, s=1 Z=9

The last electron of caesium is shielded by preceding 54 electrons and it has energy

E_{4f3} = - 0.85201742023 eV with n=4, k=4, j=3, s=3/2 Z=1

20. Energy levels of atomic electrons of barium atom Ba (Z=56)

Considering the first two electrons of the sub-level 4f are shielded by preceding 46 electrons, their energies are:

E_{4f1} = - 85.2015404427 eV with n=4, k=4, j=1, s=1/2 Z=10

E_{4f2} = - 85.1982173651 eV with n=4, k=4, j=2, s=1 Z=10

The last two external electrons of barium, in the sub-level 4f, are shielded by preceding 54 electrons, their energies are:

E_{4f3} = - 3.40806728901 eV with n=4, k=4, j=3, s=3/2 Z=2

E_{4f4} = - 3.40806480766 eV with n=4, k=4, j=4, s=2 Z=2

21. Energy levels of atomic electrons of lanthanum atom La (Z=57)

Sub-level 4f

E_{4f1} = - 103.093807642 eV with n=4, k=4, j=1, s=1/2 Z=11

E_{4f2} = - 103.092834578 eV with n=4, k=4, j=2, s=1 Z=11

E_{4f3} = - 7.66814242811 eV with n=4, k=4, j=3, s=3/2 Z=3

E_{4f4} = - 7.66812986679 eV with n=4, k=4, j=4, s=2 Z=3

E_{4f5} = - 7.66814242811 eV with n=4, k=4, j=-1, s=1/2 Z=3

22. Energy levels of atomic electrons of cerium atom Ce (Z=58)

Sub-level 4f

E_{4f1} = - 122.69007787 eV with n=4, k=4, j=1, s=1/2 Z=12

E_{4f2} = - 122.688699723 eV with n=4, k=4, j=2, s=1 Z=12

E_{4f3} = - 13.6322308744 eV with n=4, k=4, j=3, s=3/2 Z=4

E_{4f4} = - 13.6321911747 eV with n=4, k=4, j=4, s=2 Z=4

E_{4f5} = - 13.6322308744 eV with n=4, k=4, j=-1, s=1/2 Z=4

E_{4f6} = - 13.6320777468 eV with n=4, k=4, j=-2, s=1 Z=4

23. Energy levels of atomic electrons of praseodymium atom Pr (Z=59)

Sub-level 4f

E_{4f1} = - 143.9903455012 eV with n=4, k=4, j=1, s=1/2 Z=13

E_{4f2} = - 143.9884466803 eV with n=4, k=4, j=2, s=1 Z=13

E_{4f3} = - 21.3003158798 eV with n=4, k=4, j=3, s=3/2 Z=5

E_{4f4} = - 21.3002189567 eV with n=4, k=4, j=4, s=2 Z=5

E_{4f5} = - 21.3003158798 eV with n=4, k=4, j=-1, s=1/2 Z=5

E_{4f6} = - 21.2999420335 eV with n=4, k=4, j=-2, s=1 Z=5

E_{4f7} = - 21.2993189564 eV with n=4, k=4, j=-3, s=3/2 Z=5

24. Energy levels of atomic electrons of neodymium atom Nd (Z=60)

Sub-level 4f

E_{4f1} = - 166.99460242 eV with n=4, k=4, j=1, s=1/2 Z=14

E_{4f2} = - 166.992049233 eV with n=4, k=4, j=2, s=1 Z=14

E_{4f3} = - 30.6723759107 eV with n=4, k=4, j=3, s=3/2 Z=6

E_{4f4} = - 30.6721749308 eV with n=4, k=4, j=4, s=2 Z=6

E_{4f5} = - 30.6723759107 eV with n=4, k=4, j=-1, s=1/2 Z=6

E_{4f6} = - 30.6716007031 eV with n=4, k=4, j=-2, s=1 Z=6

E_{4f7} = - 30.6703086905 eV with n=4, k=4, j=-3, s=3/2 Z=6

E_{4f8} = - 30.6684998726 eV with n=4, k=4, j=-4, s=2 Z=6

Neodymium atom isn't an atom with particular properties of inertia and in fact in the scientific literature it isn't considered an inert element, nevertheless we can observe in neodymium atom the level n=4 is full of electrons in all its sub-levels 4s, 4p, 4d, 4f and therefore for subsequent atoms with Z>60, the shielding of external electrons in the level n=5 is performed by preceding 60 electrons.

25. Energy levels of atomic electrons of promethium atom Pm (Z=61)

For promethium atom we calculate still energies of the sub-level 4f. For subsequent atoms we will calculate only energies of electrons in the sub-level n=5.

Sub-level 4f

E_{4f1} = - 191.702842919 eV with n=4, k=4, j=1, s=1/2 Z=15

E_{4f2} = - 191.699478302 eV with n=4, k=4, j=2, s=1 Z=15

E_{4f3} = - 41.7483846479 eV with n=4, k=4, j=3, s=3/2 Z=7

E_{4f4} = - 41.7480123081 eV with n=4, k=4, j=4, s=2 Z=7

E_{4f5} = - 41.7483846479 eV with n=4, k=4, j=-1, s=1/2 Z=7

E_{4f6} = - 41.7469484802 eV with n=4, k=4, j=-2, s=1 Z=7

E_{4f7} = - 41.7445548672 eV with n=4, k=4, j=-3, s=3/2 Z=7

E_{4f8} = - 41.7412038091 eV with n=4, k=4, j=-4, s=2 Z=7

Sub-level 5s , k=1

E_{5s1} = - 1.06877089083 eV with n=5, k=1, j=1, s=1/2 Z=1

26. Energy levels of atomic electrons of samarium atom Sm (Z=62)

Sub-level 5s , k=1

E_{5s1} = - 4.27508342702 eV with n=5, k=1, j=1, s=1/2 Z=2

E_{5s2} = - 4.27508288064 eV with n=5, k=1, j=2, s=1 Z=2

27. Energy levels of atomic electrons of europium atom Eu (Z=63)

Sub-level 5s , k=1

E_{5s1} = - 9.61893719851 eV with n=5, k=1, j=1, s=1/2 Z=3

E_{5s2} = - 9.61893443252 eV with n=5, k=1, j=2, s=1 Z=3

E_{5s3} = - 9.61892982235 eV with n=5, k=1, j=3, s=3/2 Z=3

28. Energy levels of atomic electrons of gadolinium atom Gd (Z=64)

Sub-level 5s , k=1

E_{5s1} = - 17.1003315225 eV with n=5, k=1, j=1, s=1/2 Z=4

E_{5s2} = - 17.1003227807 eV with n=5, k=1, j=2, s=1 Z=4

E_{5s3} = - 17.1003082108 eV with n=5, k=1, j=3, s=3/2 Z=4

E_{5s4} = - 17.1002878131 eV with n=5, k=1, j=4, s=2 Z=4

29. Energy levels of atomic electrons of terbium atom Tb (Z=65)

Sub-level 5s , k=1

E_{5s1} = - 26.719265443 eV with n=5, k=1, j=1, s=1/2 Z=5

E_{5s2} = - 26.7192441006 eV with n=5, k=1, j=2, s=1 Z=5

E_{5s3} = - 26.7192085293 eV with n=5, k=1, j=3, s=3/2 Z=5

E_{5s4} = - 26.7191587303 eV with n=5, k=1, j=4, s=2 Z=5

E_{5s5} = - 26.7190947025 eV with n=5, k=1, j=5, s=5/2 Z=5

30. Energy levels of atomic electrons of dysprosium atom Dy (Z=66)

Sub-level 5s , k=1

E_{5s1} = - 38.4757377306 eV with n=5, k=1, j=1, s=1/2 Z=6

E_{5s2} = - 38.4756934745 eV with n=5, k=1, j=2, s=1 Z=6

E_{5s3} = - 38.4756197146 eV with n=5, k=1, j=3, s=3/2 Z=6

E_{5s4} = - 38.4755164508 eV with n=5, k=1, j=4, s=2 Z=6

E_{5s5} = - 38.4753836828 eV with n=5, k=1, j=5, s=5/2 Z=6

E_{5s6} = - 38.4756197146 eV with n=5, k=1, j=-1, s=1/2 Z=6

31. Energy levels of atomic electrons of holmium atom Ho (Z=67)

Sub-level 5s , k=1

E_{5s1} = - 52.3697468821 eV with n=5, k=1, j=1, s=1/2 Z=7

E_{5s2} = - 52.3696648927 eV with n=5, k=1, j=2, s=1 Z=7

E_{5s3} = - 52.3695282435 eV with n=5, k=1, j=3, s=3/2 Z=7

E_{5s4} = - 52.3693369343 eV with n=5, k=1, j=4, s=2 Z=7

E_{5s5} = - 52.3690909654 eV with n=5, k=1, j=5, s=5/2 Z=7

E_{5s6} = - 52.3695282435 eV with n=5, k=1, j=-1, s=1/2 Z=7

E_{5s7} = - 52.3687903373 eV with n=5, k=1, j=-2, s=1 Z=7

32. Energy levels of atomic electrons of erbium atom Er (Z=68)

Sub-level 5s , k=1

E_{5s1} = - 68.4012911229 eV with n=5, k=1, j=1, s=1/2 Z=8

E_{5s2} = - 68.4011512525 eV with n=5, k=1, j=2, s=1 Z=8

E_{5s3} = - 68.4009181344 eV with n=5, k=1, j=3, s=3/2 Z=8

E_{5s4} = - 68.40059177 eV with n=5, k=1, j=4, s=2 Z=8

E_{5s5} = - 68.4001721563 eV with n=5, k=1, j=5, s=5/2 Z=8

E_{5s6} = - 68.4009181344 eV with n=5, k=1, j=-1, s=1/2 Z=8

E_{5s7} = - 68.399659299 eV with n=5, k=1, j=-2, s=1 Z=8

E_{5s8} = - 68.3975612401 eV with n=5, k=1, j=-3, s=3/2 Z=8

The sub-level 5s with 8 electrons, even if non completely full, presents a configuration that gives particular properties to erbium atom, even if it isn't present among inert elements. It involves consequences for the consideration of shielding of subsequent elements.

33. Energy levels of atomic electrons of thulium atom Tm (Z=69)

Sub-level 5s , k=1

E_{5s1} = - 86.5703684033 eV with n=5, k=1, j=1, s=1/2 Z=9

E_{5s2} = - 86.5701443584 eV with n=5, k=1, j=2, s=1 Z=9

E_{5s3} = - 86.5697709484 eV with n=5, k=1, j=3, s=3/2 Z=9

E_{5s4} = - 86.5692481755 eV with n=5, k=1, j=4, s=2 Z=9

E_{5s5} = - 86.5685760386 eV with n=5, k=1, j=5, s=5/2 Z=9

E_{5s6} = - 86.5697709484 eV with n=5, k=1, j=-1, s=1/2 Z=9

E_{5s7} = - 86.5677545376 eV with n=5, k=1, j=-2, s=1 Z=9

E_{5s8} = - 86.5643938524 eV with n=5, k=1, j=-3, s=3/2 Z=9

The first 8 electrons of the sub-level 5s produce a characteristic configuration that allows to consider the ninth electron of the sub-level 5s is shielded by preceding 68 electrons. Hence energy of the electron 5s9 is

E_{5s9} = - 1.06876926314 eV with n=5, k=1, j=-4, s=2 Z=1

34. Energy levels of atomic electrons of ytterbium atom Yb (Z=70)

Sub-level 5s , k=1

E_{5s1} = - 106.876976402 eV with n=5, k=1, j=1, s=1/2 Z=10

E_{5s2} = - 106.876634921 eV with n=5, k=1, j=2, s=1 Z=10

E_{5s3} = - 106.876065785 eV with n=5, k=1, j=3, s=3/2 Z=10

E_{5s4} = - 106.875268996 eV with n=5, k=1, j=4, s=2 Z=10

E_{5s5} = - 106.874244554 eV with n=5, k=1, j=5, s=5/2 Z=10

E_{5s6} = - 106.876065785 eV with n=5, k=1, j=-1, s=1/2 Z=10

E_{5s7} = - 106.872992457 eV with n=5, k=1, j=-2, s=1 Z=10

E_{5s8} = - 106.867870243 eV with n=5, k=1, j=-3, s=3/2 Z=10

E_{5s9} = - 4.27505738337 eV with n=5, k=1, j=-4, s=2 Z=2

E_{5s10} = -4.27504263133 eV with n=5, k=1, j=-5, s=5/2 Z=2

35. Energy levels of atomic electrons of lutetium atom Lu (Z=71)

With ytterbium atom the sub-level 5s is full and the filling of the sub-level 5p begins with lutetium atom. For lutetium we calculate still energies of the sub-level 5s and of the electron of the sub-level 5p:

Sub-level 5s , k=1

E_{5s1} = - 129.321112522 eV with n=5, k=1, j=1, s=1/2 Z=11

E_{5s2} = - 129.32061256 eV with n=5, k=1, j=2, s=1 Z=11

E_{5s3} = - 129.31977929 eV with n=5, k=1, j=3, s=3/2 Z=11

E_{5s4} = - 129.31861271 eV with n=5, k=1, j=4, s=2 Z=11

E_{5s5} = - 129.317112824 eV with n=5, k=1, j=5, s=5/2 Z=11

E_{5s6} = - 129.31977929 eV with n=5, k=1, j=-1, s=1/2 Z=11

E_{5s7} = - 129.31527963 eV with n=5, k=1, j=-2, s=1 Z=11

E_{5s8} = - 129.307780194 eV with n=5, k=1, j=-3, s=3/2 Z=11

E_{5s9} = - 9.6188053528 eV with n=5, k=1, j=-4, s=2 Z=3

E_{5s10} = -9.6187306708 eV with n=5, k=1, j=-5, s=5/2 Z=3

sub-level 5p, k=2

E_{5p1} = - 9.03002267613 eV with n=5, k=2, j=1, s=1/2 Z=3

36. Energy levels of atomic electrons of hafnium atom Hf (Z=72)

For hafnium atom we calculate energies only of the last 2 electrons of the sub-level 5s and energies of the first 2 electrons of the sub-level 5p, that are similarly shielded by preceding 68 electrons. Hence

sub-level 5s, k=1

E_{5s9} = - 17.0999148246 eV with n=5, k=1, j=-4, s=2 Z=4

E_{5s10} = -17.0996787931 eV with n=5, k=1, j=-5, s=5/2 Z=4

sub-level 5p, k=2

E_{5p1} = - 16.0533724496 eV with n=5, k=2, j=1, s=1/2 Z=4

E_{5p2} = - 16.053364243 eV with n=5, k=2, j=2, s=1 Z=4

37. Energy levels of atomic electrons of tantalum atom Ta (Z=73)

Also for tantalum atom and for subsequent atoms we calculate energies of the last 2 electrons of the sub-level 5s and energies of the sub-level 5p.

sub-level 5s, k=1

E_{5s9} = - 26.7182481141 eV with n=5, k=1, j=-4, s=2 Z=5

E_{5s10} = -26.7176718653 eV with n=5, k=1, j=-5, s=5/2 Z=5

sub-level 5p, k=2

E_{5p1} = - 25.0833920487 eV with n=5, k=2, j=1, s=1/2 Z=5

E_{5p2} = - 25.0833720128 eV with n=5, k=2, j=2, s=1 Z=5

E_{5p3} = - 25.0833386194 eV with n=5, k=2, j=3, s=3/2 Z=5

38. Energy levels of atomic electrons of tungsten atom W (Z=74)

sub-level 5s, k=1

E_{5s9} = - 38.4736281977 eV with n=5, k=1, j=-4, s=2 Z=6

E_{5s10} = -38.4624757028 eV with n=5, k=1, j=-5, s=5/2 Z=6

sub-level 5p, k=2

E_{5p1} = - 36.1200803183 eV with n=5, k=2, j=1, s=1/2 Z=6

E_{5p2} = - 36.1200387721 eV with n=5, k=2, j=2, s=1 Z=6

E_{5p3} = - 36.119969528 eV with n=5, k=2, j=3, s=3/2 Z=6

E_{5p4} = - 36.1198725864 eV with n=5, k=2, j=4, s=2 Z=6

39. Energy levels of atomic electrons of rhenium atom Re (Z=75)

sub-level 5s, k=1

E_{5s9} = - 52.3658387125 eV with n=5, k=1, j=-4, s=2 Z=7

E_{5s10} = -52.363624994 eV with n=5, k=1, j=-5, s=5/2 Z=7

sub-level 5p, k=2

E_{5p1} = - 49.1634358485 eV with n=5, k=2, j=1, s=1/2 Z=7

E_{5p2} = - 49.1633588787 eV with n=5, k=2, j=2, s=1 Z=7

E_{5p3} = - 49.1632305962 eV with n=5, k=2, j=3, s=3/2 Z=7

E_{5p4} = - 49.1630509993 eV with n=5, k=2, j=4, s=2 Z=7

E_{5p5} = - 49.16282009 eV with n=5, k=2, j=5, s=5/2 Z=7

40. Energy levels of atomic electrons of osmium atom Os (Z=76)

sub-level 5s, k=1

E_{5s9} = - 68.3946238577 eV with n=5, k=1, j=-4, s=2 Z=8

E_{5s10} = -68.3908474514 eV with n=5, k=1, j=-5, s=5/2 Z=8

sub-level 5p, k=2

E_{5p1} = - 64.2134569727 eV with n=5, k=2, j=1, s=1/2 Z=8

E_{5p2} = - 64.2133256654 eV with n=5, k=2, j=2, s=1 Z=8

E_{5p3} = - 64.2131068204 eV with n=5, k=2, j=3, s=3/2 Z=8

E_{5p4} = - 64.2128004371 eV with n=5, k=2, j=4, s=2 Z=8

E_{5p5} = - 64.2124065154 eV with n=5, k=2, j=5, s=5/2 Z=8

E_{5p6} = - 64.2131068204 eV with n=5, k=2, j=-1, s=1/2 Z=8

41. Energy levels of atomic electrons of iridium atom Ir (Z=77)

sub-level 5s, k=1

E_{5s9} = - 86.5596888944 eV with n=5, k=1, j=-4, s=2 Z=9

E_{5s10} = -86.5536396609 eV with n=5, k=1, j=-5, s=5/2 Z=9

sub-level 5p, k=2

E_{5p1} = - 81.2701417663 eV with n=5, k=2, j=1, s=1/2 Z=9

E_{5p2} = - 81.2699314382 eV with n=5, k=2, j=2, s=1 Z=9

E_{5p3} = - 81.2695808906 eV with n=5, k=2, j=3, s=3/2 Z=9

E_{5p4} = - 81.2701980273 eV with n=5, k=2, j=4, s=2 Z=9

E_{5p5} = - 81.2684591381 eV with n=5, k=2, j=5, s=5/2 Z=9

E_{5p6} = - 81.2695808906 eV with n=5, k=2, j=-1, s=1/2 Z=9

E_{5p7} = - 81.2676879332 eV with n=5, k=2, j=-2, s=1 Z=9

42. Energy levels of atomic electrons of platinum atom Pt (Z=78)

sub-level 5s, k=1

E_{5s9} = - 106.860699143 eV with n=5, k=1, j=-4, s=2 Z=10

E_{5s10} = -106.851479157 eV with n=5, k=1, j=-5, s=5/2 Z=10

sub-level 5p, k=2

E_{5p1} = - 100.333488051 eV with n=5, k=2, j=1, s=1/2 Z=10

E_{5p2} = - 100.333167477 eV with n=5, k=2, j=2, s=1 Z=10

E_{5p3} = - 100.332633186 eV with n=5, k=2, j=3, s=3/2 Z=10

E_{5p4} = - 100.33188518 eV with n=5, k=2, j=4, s=2 Z=10

E_{5p5} = - 100.330923459 eV with n=5, k=2, j=5, s=5/2 Z=10

E_{5p6} = - 100.332633186 eV with n=5, k=2, j=-1, s=1/2 Z=10

E_{5p7} = - 100.329748021 eV with n=5, k=2, j=-2, s=1 Z=10

E_{5p8} = - 100.324939411 eV with n=5, k=2, j=-3, s=3/2 Z=10

43. Energy levels of atomic electrons of gold atom Au (Z=79)

In platinum atom external electrons, that are responsible for chemical bonds, are 10: 2 electrons belonging to the sub-level 5s and 8 belonging to the sub-level 5p. Hence because of the particular configuration of the sub-level 5p, that presents in platinum atom 8 electrons, the subsequent electron 5p9 of gold atom is shielded by preceding 78 electrons. We calculate now only energies of the sub-level p (k=2).

sub-level 5p, k=2

E_{5p1} = - 121.403493387 eV with n=5, k=2, j=1, s=1/2 Z=11

E_{5p2} = - 121.403024036 eV with n=5, k=2, j=2, s=1 Z=11

E_{5p3} = - 121.402241782 eV with n=5, k=2, j=3, s=3/2 Z=11

E_{5p4} = - 121.401146627 eV with n=5, k=2, j=4, s=2 Z=11

E_{5p5} = - 121.39973857 eV with n=5, k=2, j=5, s=5/2 Z=11

E_{5p6} = - 121.402241782 eV with n=5, k=2, j=-1, s=1/2 Z=11

E_{5p7} = - 121.398017611 eV with n=5, k=2, j=-2, s=1 Z=11

E_{5p8} = - 121.390977327 eV with n=5, k=2, j=-3, s=3/2 Z=11

E_{5p9} = - 1.00333441027 eV with n=5, k=2, j=-4, s=2 Z=1

44. Energy levels of atomic electrons of mercury atom Hg (Z=80)

In mercury atom the tenth electron 5p10 completes the sub-level 5p.

sub-level 5p, k=2

E_{5p1} = - 144.480155088 eV with n=5, k=2, j=1, s=1/2 Z=12

E_{5p2} = - 144.479490346 eV with n=5, k=2, j=2, s=1 Z=12

E_{5p3} = - 144.478382442 eV with n=5, k=2, j=3, s=3/2 Z=12

E_{5p4} = - 144.476831376 eV with n=5, k=2, j=4, s=2 Z=12

E_{5p5} = - 144.47483715 eV with n=5, k=2, j=5, s=5/2 Z=12

E_{5p6} = - 144.478382442 eV with n=5, k=2, j=-1, s=1/2 Z=12

E_{5p7} = - 144.472399763 eV with n=5, k=2, j=-2, s=1 Z=12

E_{5p8} = - 144.46242863 eV with n=5, k=2, j=-3, s=3/2 Z=12

E_{5p9} = - 4.01331917617 eV with n=5, k=2, j=-4, s=2 Z=2

E_{5p10} = - 4.01330532741 eV with n=5, k=2, j=-5, s=5/2 Z=2

45. Energy levels of atomic electrons of thallium atom Tl (Z=81)

We calculate for thallium atom only energies of the last two electrons of the sub-level 5p.

Sub-level 5p

E_{5p9} = - 9.02989890265 eV with n=5, k=2, j=-4, s=2 Z=3

E_{5p10} = - 9.02982879291 eV with n=5, k=2, j=-5, s=5/2 Z=3

The sub-level 5p is complete for which the last electron occupies the first quantum state of the sub-level 5d.

Sub-level 5d (k=3)

E_{5d1} = - 8.04849847218 eV with n=5, k=3, j=1, s=1/2 Z=3

46. Energy levels of atomic electrons of lead atom Pb (Z=82)

Sub-level 5p

E_{5p9} = - 16.0529812639 eV with n=5, k=2, j=-4, s=2 Z=4

E_{5p10} = - 16.0527596832 eV with n=5, k=2, j=-5, s=5/2 Z=4

The subsequent 2 electrons occupy the first 2 quantum states of the sub-level 5d.

Sub-level 5d (k=3)

E_{5d1} = - 14.3084406617 eV with n=5, k=3, j=1, s=1/2 Z=4

E_{5d2} = - 14.3084333469 eV with n=5, k=3, j=2, s=1 Z=4

47. Energy levels of atomic electrons of bismuth atom Bi (Z=83)

Sub-level 5p

E_{5p9} = - 25.0824370051 eV with n=5, k=2, j=-4, s=2 Z=5

E_{5p10} = - 25.0818960369 eV with n=5, k=2, j=-5, s=5/2 Z=5

The subsequent 3 electrons occupy the first 3 quantum states of the sub-level 5d.

Sub-level 5d (k=3)

E_{5d1} = - 22.3569363912 eV with n=5, k=3, j=1, s=1/2 Z=5

E_{5d2} = - 22.3569185331 eV with n=5, k=3, j=2, s=1 Z=5

E_{5d3} = - 22.3568887694 eV with n=5, k=3, j=3, s=3/2 Z=5

48. Energy levels of atomic electrons of polonium atom Po (Z=84)

Sub-level 5p

E_{5p9} = - 36.1180999407 eV with n=5, k=2, j=-4, s=2 Z=6

E_{5p10} = - 36.1169781882 eV with n=5, k=2, j=-5, s=5/2 Z=6

Sub-level 5d (k=3)

E_{5d1} = - 32.1939846318 eV with n=5, k=3, j=1, s=1/2 Z=6

E_{5d2} = - 32.1939956033 eV with n=5, k=3, j=2, s=1 Z=6

E_{5d3} = - 32.1938858836 eV with n=5, k=3, j=3, s=3/2 Z=6

E_{5d4} = - 32.1937994792 eV with n=5, k=3, j=4, s=2 Z=6

49. Energy levels of atomic electrons of astatine atom At (Z=85)

Sub-level 5p

E_{5p9} = - 49.1597669545 eV with n=5, k=2, j=-4, s=2 Z=7

E_{5p10} = - 49.1576887696 eV with n=5, k=2, j=-5, s=5/2 Z=7

Sub-level 5d (k=3)

E_{5d1} = - 43.8195841259 eV with n=5, k=3, j=1, s=1/2 Z=7

E_{5d2} = - 43.8195155223 eV with n=5, k=3, j=2, s=1 Z=7

E_{5d3} = - 43.8194011834 eV with n=5, k=3, j=3, s=3/2 Z=7

E_{5d4} = - 43.819241108 eV with n=5, k=3, j=4, s=2 Z=7

E_{5d5} = - 43.8190352973 eV with n=5, k=3, j=5, s=5/2 Z=7

50. Energy levels of atomic electrons of radon atom Rn (Z=86)

Sub-level 5p

E_{5p9} = - 64.2071980011 eV with n=5, k=2, j=-4, s=2 Z=8

E_{5p10} = - 64.2036527097 eV with n=5, k=2, j=-5, s=5/2 Z=8

Sub-level 5d (k=3)

E_{5d1} = - 57.2337333883 eV with n=5, k=3, j=1, s=1/2 Z=8

E_{5d2} = - 57.2336163541 eV with n=5, k=3, j=2, s=1 Z=8

E_{5d3} = - 57.2334212963 eV with n=5, k=3, j=3, s=3/2 Z=8

E_{5d4} = - 57.2331482155 eV with n=5, k=3, j=4, s=2 Z=8

E_{5d5} = - 57.2327971117 eV with n=5, k=3, j=5, s=5/2 Z=8

E_{5d6} = - 57.2334212963 eV with n=5, k=3, j=-1, s=1/2 Z=8

Radon has in the two sublevels 5p and 5d an electronic configuration 8,2+6 that gives to atom a high degree of stability that explains its classification inside the group 0 of inert elements.

51. Energy levels of atomic electrons of francium atom Fr (Z=87)

The peculiarity of radon, characterized by stability and chemical inertia due to the existence of the two configurations 8, 2+6 in the two external sub-levels involves the last electron of francium is shielded by preceding 86 electrons. It is valid also for subsequent chemical elements.

Sub-level 5p

E_{5p9} = - 81.2601161047 eV with n=5, k=2, j=-4, s=2 Z=9

E_{5p10} = - 81.2544372325 eV with n=5, k=2, j=-5, s=5/2 Z=9

Sub-level 5d (k=3)

E_{5d1} = - 72.4364307046 eV with n=5, k=3, j=1, s=1/2 Z=9

E_{5d2} = - 72.4362432383 eV with n=5, k=3, j=2, s=1 Z=9

E_{5d3} = - 72.4359307935 eV with n=5, k=3, j=3, s=3/2 Z=9

E_{5d4} = - 72.4354933712 eV with n=5, k=3, j=4, s=2 Z=9

E_{5d5} = - 72.4349309709 eV with n=5, k=3, j=5, s=5/2 Z=9

E_{5d6} = - 72.4359307935 eV with n=5, k=3, j=-1, s=1/2 Z=9

E_{5d7} = - 0.89427735076 eV with n=5, k=3, j=-2, s=1 Z=1

52. Energy levels of atomic electrons of radium atom Ra (Z=88)

For radium atom we calculate only energies of the sub-level 5d.

Sub-level 5d (k=3)

E_{5d1} = - 89.4276741324 eV with n=5, k=3, j=1, s=1/2 Z=10

E_{5d2} = - 89.4273884036 eV with n=5, k=3, j=2, s=1 Z=10

E_{5d3} = - 89.4269121882 eV with n=5, k=3, j=3, s=3/2 Z=10

E_{5d4} = - 89.4262454872 eV with n=5, k=3, j=4, s=2 Z=10

E_{5d5} = - 89.4253883008 eV with n=5, k=3, j=5, s=5/2 Z=10

E_{5d6} = - 89.4269121882 eV with n=5, k=3, j=-1, s=1/2 Z=10

The subsequent two electrons are shielded by preceding 86 electrons:

E_{5d7} = - 3.57710528883 eV with n=5, k=3, j=-2, s=1 Z=2

E_{5d8} = - 3.57709843152 eV with n=5, k=3, j=-3, s=3/2 Z=2

53. Energy levels of atomic electrons of actinium atom Ac (Z=89)

Sub-level 5d (k=3)

E_{5d1} = - 108.207461498 eV with n=5, k=3, j=1, s=1/2 Z=11

E_{5d2} = - 108.207043162 eV with n=5, k=3, j=2, s=1 Z=11

E_{5d3} = - 108.206345936 eV with n=5, k=3, j=3, s=3/2 Z=11

E_{5d4} = - 108.205369819 eV with n=5, k=3, j=4, s=2 Z=11

E_{5d5} = - 108.204114812 eV with n=5, k=3, j=5, s=5/2 Z=11

E_{5d6} = - 108.206345936 eV with n=5, k=3, j=-1, s=1/2 Z=11

E_{5d7} = - 8.04847147071 eV with n=5, k=3, j=-2, s=1 Z=3

E_{5d8} = - 8.04843675475 eV with n=5, k=3, j=-3, s=3/2 Z=3

E_{5d9} = - 8.04838815239 eV with n=5, k=3, j=-4, s=2 Z=3

54. Energy levels of atomic electrons of thorium atom Th (Z=90)

Sub-level 5d (k=3)

E_{5d1} = - 128.775790405 eV with n=5, k=3, j=1, s=1/2 Z=12

E_{5d2} = - 128.775197917 eV with n=5, k=3, j=2, s=1 Z=12

E_{5d3} = - 128.774210438 eV with n=5, k=3, j=3, s=3/2 Z=12

E_{5d4} = - 128.772827966 eV with n=5, k=3, j=4, s=2 Z=12

E_{5d5} = - 128.771050503 eV with n=5, k=3, j=5, s=5/2 Z=12

E_{5d6} = - 128.774210438 eV with n=5, k=3, j=-1, s=1/2 Z=12

E_{5d7} = - 14.3083553239 eV with n=5, k=3, j=-2, s=1 Z=4

E_{5d8} = - 14.3082456042 eV with n=5, k=3, j=-3, s=3/2 Z=4

E_{5d9} = - 14.3080919959 eV with n=5, k=3, j=-4, s=2 Z=4

E_{5d10} = - 14.3078945001 eV with n=5, k=3, j=-5, s=5/2 Z=4

55. Energy levels of atomic electrons of protactinium atom Pa (Z=91)

In thorium atom the sub-level 5d is full and consequently the electron 5f1 of protactinium is shielded by preceding 90 electrons. For protactium we will calculate only energies of the last 4 electrons of the sublevel 5d and energy of the electron of the sub-level 5f.

Sub-level 5d

E_{5d7} = - 22.356728047 eV with n=5, k=3, j=-2, s=1 Z=5

E_{5d8} = - 22.3568887694 eV with n=5, k=3, j=-3, s=3/2 Z=5

E_{5d9} = - 22.3560851568 eV with n=5, k=3, j=-4, s=2 Z=5

E_{5d10} = - 22.3556029892 eV with n=5, k=3, j=-5, s=5/2 Z=5

Sub-level 5f (k=3)

E_{5f1} = - 0.74159612837 eV with n=5, k=4, j=1, s=1/2 Z=1

56. Energy levels of atomic electrons of uranium atom U (Z=92)

For uranium atom and for subsequent atoms we will calculate only energies of the sub-level 5f.

Sub-level 5f (k=3)

E_{5f1} = - 2.96638441862 eV with n=5, k=4, j=1, s=1/2 Z=2

E_{5f2} = - 2.96638403964 eV with n=5, k=4, j=2, s=1 Z=2

57. Energy levels of atomic electrons of neptunium atom Np (Z=93)

Sub-level 5f (k=3)

E_{5f1} = - 6.67436458663 eV with n=5, k=4, j=1, s=1/2 Z=3

E_{5f2} = - 6.67436266748 eV with n=5, k=4, j=2, s=1 Z=3

E_{5f3} = - 6.67435946853 eV with n=5, k=4, j=3, s=3/2 Z=3

58. Energy levels of atomic electrons of plutonium atom Pu (Z=94)

Sub-level 5f (k=3)

E_{5f1} = - 11.8655361585 eV with n=5, k=4, j=1, s=1/2 Z=4

E_{5f2} = - 11.8655300927 eV with n=5, k=4, j=2, s=1 Z=4

E_{5f3} = - 11.865519983 eV with n=5, k=4, j=3, s=3/2 Z=4

E_{5f4} = - 11.8655058294 eV with n=5, k=4, j=4, s=2 Z=4

59. Energy levels of atomic electrons of americium atom Am (Z=95)

Sub-level 5f (k=3)

E_{5f1} = - 18.5398984705 eV with n=5, k=4, j=1, s=1/2 Z=5

E_{5f2} = - 18.5398836615 eV with n=5, k=4, j=2, s=1 Z=5

E_{5f3} = - 18.5398589794 eV with n=5, k=4, j=3, s=3/2 Z=5

E_{5f4} = - 18.5398244251 eV with n=5, k=4, j=4, s=2 Z=5

E_{5f5} = - 18.5397799978 eV with n=5, k=4, j=5, s=5/2 Z=5

60. Energy levels of atomic electrons of curium atom Cm (Z=96)

Sub-level 5f (k=3)

E_{5f1} = - 26.6974506699 eV with n=5, k=4, j=1, s=1/2 Z=6

E_{5f2} = - 26.6974199618 eV with n=5, k=4, j=2, s=1 Z=6

E_{5f3} = - 26.6973687813 eV with n=5, k=4, j=3, s=3/2 Z=6

E_{5f4} = - 26.697297129 eV with n=5, k=4, j=4, s=2 Z=6

E_{5f5} = - 26.6972050042 eV with n=5, k=4, j=5, s=5/2 Z=6

E_{5f6} = - 26.6973687813 eV with n=5, k=4, j=-1, s=1/2 Z=6

61. Energy levels of atomic electrons of berkelium atom Bk (Z=97)

Sub-level 5f (k=3)

E_{5f1} = - 36.3381917139 eV with n=5, k=4, j=1, s=1/2 Z=7

E_{5f2} = - 36.3381348234 eV with n=5, k=4, j=2, s=1 Z=7

E_{5f3} = - 36.3380400057 eV with n=5, k=4, j=3, s=3/2 Z=7

E_{5f4} = - 36.3379072603 eV with n=5, k=4, j=4, s=2 Z=7

E_{5f5} = - 36.3377365882 eV with n=5, k=4, j=5, s=5/2 Z=7

E_{5f6} = - 36.3380400057 eV with n=5, k=4, j=-1, s=1/2 Z=7

E_{5f7} = - 36.3375279889 eV with n=5, k=4, j=-2, s=1 Z=7

62. Energy levels of atomic electrons of californium atom Cf (Z=98)

Sub-level 5f (k=3)

E_{5f1} = - 47.462120371 eV with n=5, k=4, j=1, s=1/2 Z=8

E_{5f2} = - 47.4620233178 eV with n=5, k=4, j=2, s=1 Z=8

E_{5f3} = - 47.4618615626 eV with n=5, k=4, j=3, s=3/2 Z=8

E_{5f4} = - 47.4616351056 eV with n=5, k=4, j=4, s=2 Z=8

E_{5f5} = - 47.4613439463 eV with n=5, k=4, j=5, s=5/2 Z=8

E_{5f6} = - 47.4618615626 eV with n=5, k=4, j=-1, s=1/2 Z=8

E_{5f7} = - 47.4609880851 eV with n=5, k=4, j=-2, s=1 Z=8

E_{5f8} = - 47.4595322893 eV with n=5, k=4, j=-3, s=3/2 Z=8

63. Energy levels of atomic electrons of einstenium atom Es (Z=99)

Sub-level 5f (k=3)

E_{5f1} = - 60.0692352187 eV with n=5, k=4, j=1, s=1/2 Z=9

E_{5f2} = - 60.0690797583 eV with n=5, k=4, j=2, s=1 Z=9

E_{5f3} = - 60.0688206583 eV with n=5, k=4, j=3, s=3/2 Z=9

E_{5f4} = - 60.068457918 eV with n=5, k=4, j=4, s=2 Z=9

E_{5f5} = - 60.0679915369 eV with n=5, k=4, j=5, s=5/2 Z=9

E_{5f6} = - 60.0688206583 eV with n=5, k=4, j=-1, s=1/2 Z=9

E_{5f7} = - 60.0674215155 eV with n=5, k=4, j=-2, s=1 Z=9

E_{5f8} = - 60.0650896118 eV with n=5, k=4, j=-3, s=3/2 Z=9

E_{5f9} = - 60.0618249469 eV with n=5, k=4, j=-4, s=2 Z=9

64. Energy levels of atomic electrons of fermium atom Fm (Z=100)

Sub-level 5f (k=3)

E_{5f1} = - 74.1595346465 eV with n=5, k=4, j=1, s=1/2 Z=10

E_{5f2} = - 74.1592977006 eV with n=5, k=4, j=2, s=1 Z=10

E_{5f3} = - 74.1589027903 eV with n=5, k=4, j=3, s=3/2 Z=10

E_{5f4} = - 74.1583499162 eV with n=5, k=4, j=4, s=2 Z=10

E_{5f5} = - 74.1576390783 eV with n=5, k=4, j=5, s=5/2 Z=10

E_{5f6} = - 74.1589027903 eV with n=5, k=4, j=-1, s=1/2 Z=10

E_{5f7} = - 74.1567702766 eV with n=5, k=4, j=-2, s=1 Z=10

E_{5f8} = - 74.1532160871 eV with n=5, k=4, j=-3, s=3/2 Z=10

E_{5f9} = - 74.1482402219 eV with n=5, k=4, j=-4, s=2 Z=10

E_{5f10} = - 74.1418426803 eV with n=5, k=4, j=-5, s=5/2 Z=10

In fermium atom the sub-level 5f of the level n=5 is full. Starting from the subsequent atom with Z=101, mendelevium Md, the sub-level q (k=5) of the level n=5 will begin to be filled.

65. Conclusions

The calculation of actual energies of electrons inside atoms of different chemical elements allows to do some considerations:

- Firstly the reversal of potential levels of energy that happens in hydrogen atom (for instance the reversal of the sub-level 4s with the sub-level 3d and the reversal of sub-levels 5s, 5p, 5d with the sub-level 4f) doesn't happen for actual levels of energy of electrons inside of other atoms;
- this reversal instead has been wrongly assumed in electronic configurations that are normally accepted at present;
- this wrong hypothesis involves the best part of weaknesses that are into current periodic tables of chemical elements;
- these waknesses then emerge from the existence of wide regroupments of chemical elements that are really out of a periodic classification and consequently out of the table itself;
- It is valid for transition elements that includes 10 sub-groups, rare earths and actinides.

Calculations in the order of the Deterministic Quantum Model of atom allow to understand these transition elements are the effect of a wrong hypothesis and hence a periodic table that includes really all chemical elements is possible.
The subsequent step consists in the identification of physico-chemical properties of elements in order to understand the availability of single atoms to make complex molecules and chemical compounds.

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