

Nucleus Directs the Electronic Structure of the Atom

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Abstract

The present study supports the provocative idea that the nucleus directs the atom's electronic structure. With the progress of the atomic number the Atomic Molar Volume evolution of the chemical elements obeys the atom's electronic structure rules, fitting at the same time the concomitant specular evolution of the Neutron Excess addition to the nuclei. Details such as the Atomic Molar Volume contraction of the d blocks transition metals or of the Eu and Yb atomic volume anomaly of the lanthanoid metals respond to the nuclear in addition to the atom's electronic structure. Atom's nuclei are synthesized in the star interior and capture the electrons only after migration to the star's periphery, to become stable atoms: nuclei are prior to atoms. Nuclear structure elements, like the 50 and 82 neutron and proton magic numbers, are geared to the noble gases, the central elements of the electronic structure.

Keywords

Atom's Structure, Nuclear Structure, Electronic Structure, Neutron Excess

1. Introduction

The correlations existing between the atom's nuclear and electronic structure, whereby the nuclear structure directs the electronic one, were proposed in two different studies by the present author [1] [2]. In addition, starting from completely independent considerations, identical suggestions were advanced by two other authors [3] [4]. The aim of the present paper is to provide further support to the title statement, considering the evolution of the Atomic Molar Volume (AMV) with the progress of the chemical elements atomic number (**Figure 1**). The AMV outline and periodicity are beautifully explained by the atom's electronic structure, with the aid of the s, p, d and f orbital structure, multiplicity, spatial orientation and order of filling by the electrons [5]. It will be shown here that the

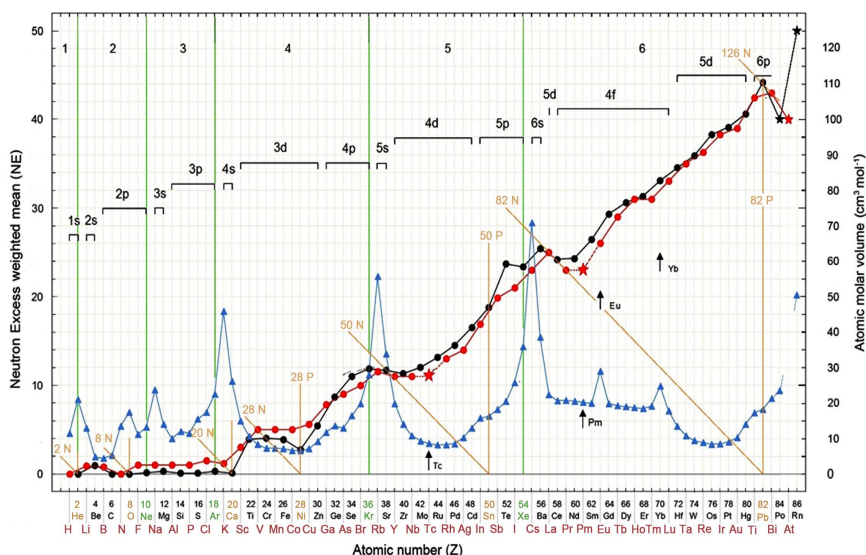


Figure 1. The representation of the Elements NE weighted means and of the Elements Atomic Molar Volumes. The noble gases limiting the periods of the periodic table, indicated at the top of the figure, are green; s, p, d, f, indicate the electron's angular momentum quantum numbers. Highlighted are the proton-neutron couples of the nuclear magic numbers. The NE means are black or red for even or odd Elements respectively. (▲) indicate the Atomic molar Volume. (★) indicate the most stable isotope of the artificial elements.

evolution mode of the Neutron Excess (NE) addition to the nuclei can faithfully explain the AMV outline in the periods 4, 5 and 6 of the periodic table as can be readily perceived from **Figure 1**. See discussion for periods 2 and 3. Even details such as the U shaped AMV contraction of the d blocks transition metals or the sudden AMV expansion of Eu and Yb, inside the lanthanoid metals of the 4f block, can find a convincing interpretation by the NE addition mode to the nucleus. To deal with the electronic structure of the atom it is mandatory to enter the world of chemistry.

A problem of semantics must be stressed here. The definition of the atom's electronic structure as the atomic structure is a misdefinition. It is at the origin of the nuclear and atomic definition of the two branches of physics. Atomic physics should be reserved to the physics of the whole atom in spite of the historical definitions originated at the time of the Bhor atom.

2. Methods

The isotopes of any chemical element can be defined in equivalent ways by couples of two numbers added to the element symbol: ${}_Z X^A$; ${}_Z X^N$; ${}_Z X_{NE}$. Z, A, N, NE, indicate the proton number, Mass, the Neutron and the Neutron Excess numbers respectively of an isotope. In the present paper the third way is chosen, with $NE = A - 2Z$, allowing the isotope representation in the Z, NE plane. The mass numbers A were obtained from Tuli, as well as the mass excess values for the nuclear reactions, expressed in MeV [6]. The result is a new method for the representation of the chemical elements isotopes [7].

3. Results

In **Figure 1** the by far large AMV expansion corresponds to the electron filling of the s orbital couples marking the table periods opening and their closing by the noble gases. Inside the s orbital couples the NE addition to nuclei is similar. It is practically null for the 1 to 3 s orbital couples, see discussion, but strongly increases with the nuclear mass and size increase of the 4, 5 and 6 s orbital couples.

The electron filling of the 4, 5 and 6 p orbitals, marked by a sharp expansion of the AMV, is accompanied by a corresponding specular increase of the NE addition to nuclei. See the discussion for the very low or null NE addition to the nuclei for the 2p and 3p orbitals, nevertheless associated with a sharp AMV expansion.

A net AMV contraction accompanies the electron filling of the 3, 4 and 5 d orbitals in spite of the progressive NE addition to the nuclei. The AMV contraction of the d blocks metals shows in all instances a characteristic U shaped outline. A general AMV contraction accompanies again the electron filling of the 4f orbitals, in spite of a sustained NE addition to nuclei. However, in the Eu and Yb instance a sudden AMV expansion replaces the contraction. The electron filling of the d and f orbitals always anticipates that of the p orbitals of the same period.

The 50 and 82 neutron magic numbers cross the ^{86}Kr and ^{136}Xe isotopes at the upper border of the beta stability valley (**Figure 2**), thus extending the partial gearing of the 50 and 82 proton magic numbers with the Xe and Rn noble gases [2].

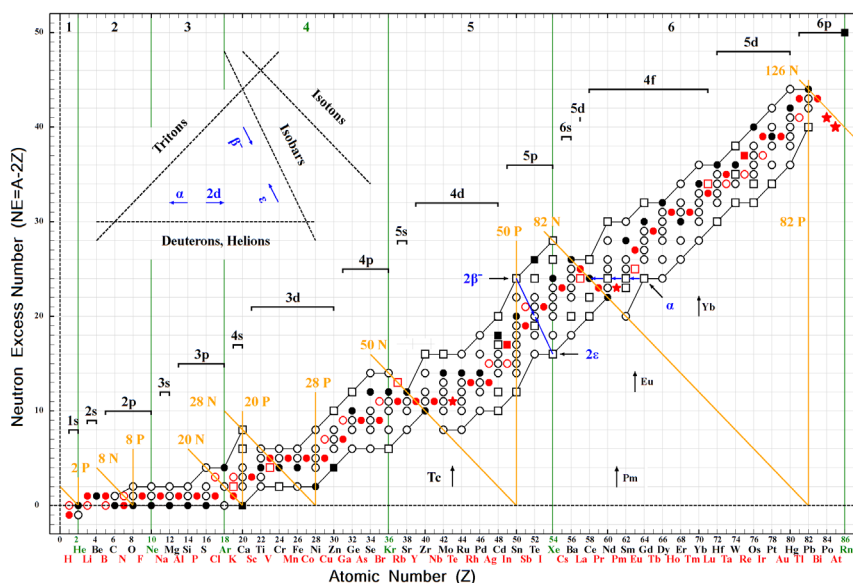


Figure 2. Representation of the Elements isotopes by the Neutron Excess number, $NE = A - 2Z$, in the Z - NE plane and the respective electronic structure. Other indication as in **Figure 1**. Even and odd Element's symbols are black and red respectively; (○) (□) represent stable and radioactive isotopes respectively, with the full symbol indicating the most abundant isotope of each Element; (★) represents the most stable isotope of the artificial Elements. The inset shows basic relationships between the isotopes along with radioactive decay paths.

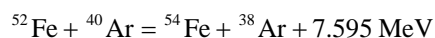
4. Discussion

The salient features of the Atomic Molar Volume (AMV) expansion outline will be first considered from the atom's electronic structure and, subsequently from the accompanying nuclear events point of view.

The table periods opening, behind their closure by the noble gases, entails the progress of the electronic principal quantum number. The ensuing electron filling of the s spherical orbitals causes, as accepted [5], the largest increase of the atom's radius and volume: the AMV expansion is essentially of electronic origin. The increasingly large NE addition to the nuclei in the 5, 6 and 7 s orbitals indicates a concerted action of the electronic and nuclear structures in the related AMV expansion. See below for the lack of NE addition in the 1 to 3 s orbitals.

The most important news of **Figure 1** concerns the sequence of the electron filling of the p, s and d or f orbitals. Not only that sequence parallels the NE addition to nuclei but it is also related to the nucleus by the 50 and 82 neutron magic isotons. That is the noble gases and the alkaline and alkaline earth metals, at the heart of the atom's electronic structures, are patently related to the nuclear structure.

Inside the periods the AMV expansion may be still important but always at a lower rate compared to the effects of the increase of the electron principal quantum number. An AMV expansion occurs accompanying the electron filling of the three p orbitals by six electrons. Since the p electrons distribute only radially along the x, y and z atom's Cartesian coordinates they will cause a considerable radius and AMV expansion of the atom. To that AMV expansion corresponds a sustained increase of the NE addition to the nuclei in the 4, 5 and 6 periods: again a concerted action of the nuclear and electronic structures. Yet this is not true for the periods 2 and 3 where to the AMV expansion the NE addition to nuclei is practically null. As already suggested [2] this may be the result of the different mechanisms of nucleosynthesis: nuclear fusion for the elements up to Fe then followed by the neutron capture mechanism [8]. A very different suggestion may be advanced. High levels of the ^{40}Ar neutron rich isotope, 1% only of the solar system Ar abundance, may be synthesized in the star's interior to be subsequently depleted as neutron sources for nucleosynthesis, always in the star's interior, as in the reaction below:



An event very difficult to ascertain since totally confined in the star's interior.

At variance with the p, the electron filling of the d orbitals is accompanied by a sharp AMV contraction, the characteristic of the d metals blocks transitions in chemistry. The five d orbitals hosting ten electrons, compared to the p orbitals, distribute more evenly around the nucleus with a better spatial utilization of the atom's volume. This is likely the most important reason of the AMV contraction of the d transition metals. In addition, the d are spatially internal to the p orbitals and border the huge AMV expansion of the s orbitals elements. This last situation, together with the volume expansion caused by the half and complete filling

of the d blocks, confer the typical U shaped outline of the AMV contraction of the d metal blocks (**Figure 1**). Interestingly Sc, Y, La and Zn, Cd, Hg, the elements opening and closing respectively the d blocks, show chemical properties very different compared to the properties of the internal d blocks metals [5]. From the nuclear structure point of view the NE level appears more elevated at the borders, see in particular Zn, compared to the central elements of the d blocks, (**Figure 1** and **Figure 2**). The nuclear works in concert with the atom electronic structure.

The AMV contraction, following the electron filling of the 4f orbitals again ascribes to geometric reasons. The 4f seven orbitals distribute spatially around the nucleus even more evenly compared to the d orbitals [5], thus granting the allocation of fourteen electrons without a major expansion of the atomic radius and of the AMV. From the electronic structure side, the AMV anomalous expansion of Eu and Yb is caused by the sudden increase of their atomic radius, in his turn caused by the half and complete filling of the f block orbitals [5]. In chemistry, these metals appear therefore as Eu^{++} and Yb^{++} ions, at variance with the oxidation numbers X^{+++} of the bulk lanthanoid metals [9]. The rather sudden EN addition to nuclei indicate that in Eu and Yb anomaly the nuclear and the electronic structures of the atom work in concert (**Figure 1** and **Figure 2**).

A partial gearing of elements of the nuclear and electronic structures may be found in the four proton identical gap between the 50 and 82 proton magic numbers and the noble gases Xe and Rn respectively. The same applies to the seven proton identical gap from Kr and Xe to the unstable nuclei of Tc and Pm respectively [2]. The 50 and 82 neutron magic isotons, crossing the upper border of the beta stability valley at the noble gases ^{86}Kr and ^{136}Xe isotopes, considerably extends the above gearing (**Figure 2**). An important share of the periodic table, from Kr to Rn, appears somehow geared to nuclear structure.

5. Conclusion

The AMV expansion, when electrons increase the atom's radius and volume as in the case of the s and p orbitals or in the case of the Eu and Yb 4f orbitals, is patently clear. The same is true in the case of the AMV contraction when electrons dwell in spaces internal to the p orbitals. What, at present, is obscure is how the NE addition to the nuclear structure, concomitant with the above events, can affect the atomic radius and volume, typical properties of electronic structure. The answer may likely be in the electrostatic and electromagnetic interactions between the two main atom's compartments [10].

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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