Periodic table of elements revisited for accommodating elements of future years

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The periodic table of elements shows only three columns and two separate rows for lanthanides and actinides called lanthanide and actinide series respectively. The newly discovered elements have already occupied the last row and last column of the table, which has the electronic orbital configuration, $7s^2$ $5f^{14}$ $6d^{10}$ $7p^6$. After the discovery of two more new elements with atomic numbers 119 and 120, the third new element with atomic number 121, will have to be entered in the g-block series, according to the electronic orbital configuration theory, $7s^2$ $5f^{14}$ $6d^{10}$ $7p^6$ $8s^2$ $5g^1$. Thus, in the present periodic table, such new g-series has to be written separately below the actinide series. Such a representation of elements would be quite confusing. Therefore, to avoid this and also to ensure the visibility of the 'concept of inner orbitals like d, f, g, etc.', a new and expanded form of the periodic table has been designed. This table is expected to accommodate all the new elements of higher atomic numbers and also give instant information on the electronic orbital structure of an element.

Keywords: Atomic numbers, atomic structure, inner orbitals, periodic table.

THE discovery of periodic table goes back to nineteenth century. Several models were designed to accommodate the elements in a sequence based on their atomic weight, name, etc. Mendeleev's design of periodic table based on atomic number became the most popular and accepted by the scientific community. This periodic table is still being used today. The concept of atomic number, i.e. the number of electrons or protons in an atom is fundamental and is the basis of its structure and properties. The newly discovered elements are well accommodated in this table according to their atomic number. An atom consists of various shells in the order: K, L, M, N, etc., which consists of various orbitals like, s, p, d, f, etc. Therefore, the periodic table is also designed as the s-block, p-block, d-block, f-block, etc.

Until now, elements up to the last p-block have been discovered. The last element with atomic number 118 has the orbital structure, $7s^2$ $5f^{14}$ $6d^{10}$ $7p^6$. A new element with atomic number higher than 118, will enter a new row, i.e. 8th row, with an orbital 8s. However, new elements with atomic number more than 120 will not enter either f-block or d-block series. In the present periodic table there are seven periods or rows, ending with atomic number 118. If elements with atomic number higher than 118 are discovered, then there should be an additional period or row which will be the 8th period/row. Further, any element with atomic number ≥121 discovered, will be called the g-block element, which will be placed in this 8th period. In this regard, a periodic table with eight periods/rows containing this g-block was suggested by Glenn T. Seaborg in 1969 (ref. 1). Fricke *et al.*[2] also predicted an extended periodic table up to an atomic number 172. However, a detailed discussion on the extended periodic table in order to accommodate future higher elements is yet to be made. In this context, based on the atomic structure model, the periodic table has been revisited, designed and discussed in this article. It is expected that this newly designed periodic table will be helpful for researchers as well as students.

Discussion

The present periodic table is filled up with elements with atomic number up to 118. Any newly discovered element with atomic number 119 and 120 will occupy the s-block of the table without any difficulties. However, elements with atomic numbers ≥121 up to 138 if discovered, will have to be accommodated in separate series called as g-block and elements with atomic numbers ≥129 up to 152 will have to be put in an another f-block series. These have to be entered separately below the main table. In such a case, the table will appear congested and complicated.

The basic principle in the construction of a periodic table is the atomic number of the elements and orbital structures. The orbital structure of elements follows the

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formula, $4\ell + 2$, and hence can be written as: 1s 2s 2p 3s 3p 3d 4s 4p 4d 4f 5s 5p 5d 5f 5g 6s 6p 6d 6f 6g 6h 7s 7p 7d 7f 7g 7h 7i 8s 8p 8d 8f 8g 8h 8i 8j, etc. The azimuthal (orbital) quantum number, $\ell = 0$ stands for the orbital, s, and similarly 1 for p, 2 for d, 3 for f, 4 for g, etc. This can also be presented as shown in Figure 1.

The marked lines in the figure indicate the rows of the periodic table. Hypothetically this table can be extended up to infinity. In the left side, K, L, M, N, O, P, Q, R are the shells of atomic structures and in the right side, 1, 2, 3, 4, 5, etc., represent the row number of the periodic table. Besides s- and p-blocks, the d, f, g, etc., are heavier in nature and lie within s- and p-blocks as shown in Figure 2.

This means, d is nearer to p than f and similarly f will be nearer compared to g and so on. The figure shows that the 5th shell has g orbitals corresponding with the 8th row of the periodic table. It is also seen from Figure 2 that after every two rows a new column (block) is added into the table, which is further interior in the atomic structure.

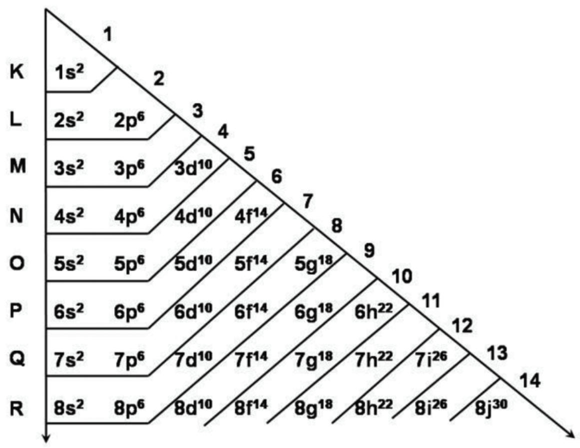

Figure 1. Atomic orbital structures-I.

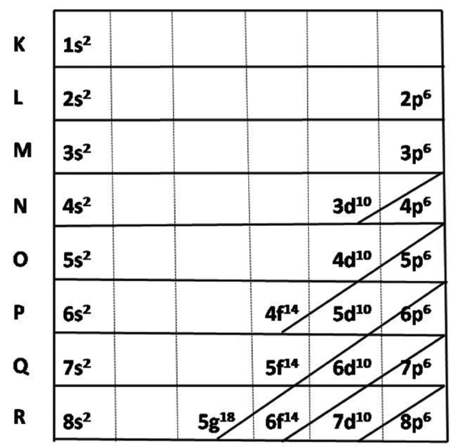

Figure 2. Atomic orbital structures-II.

It is clear from Figure 2 that all the atomic orbitals are mainly confined within s and p orbitals for a given quantum number. For the first principal quantum number, $n = 1$, it is only 1s; for $n = 2$, these are 2s 2p; for $n = 3$, these are 3s 3p. However, from $n = 4$ onwards the situation becomes different, i.e. 4s 3d 4p for $n = 4$; 5s 4d 5p for $n = 5$; 6s 4f 5d 6p for $n = 6$ and 7s 5f 6d 7p for $n = 7$. Therefore, proceeding in this manner it can be predicted that for $n = 8$, these would be 8s 5g 6f 7d 8p and this trend could be hypothetically extended up to infinity. However, because of energy constraints and overlapping, there might be a high probability of instability in those elements with $n = 8$. It is also seen from atomic orbital structure-II (Figure 2) that the overlapping of the shells starts from $n = 3$ and this increases with increase in the principal quantum number.

The shapes of the atomic orbitals from s to g orbitals are available in the literature. For example, Jim Holler's website contains the three-dimensional structure of these orbitals[3]. Based on these principles, a newly designed periodic table is shown in Figure 3. This periodic table is expected to accommodate both the existing and future elements with higher atomic numbers. In the table, the numbers written in each location in the 8th row represent only the serial number of those places (Figure 3). It is also clearly seen that the gap between s and p orbitals have increased with increase in the row numbers of the new periodic table.

One should note here that certain anomalies exist in the exact orbital structures of lanthanides (La) and actinides (Ac) and their positions in the present periodic table. For example, La and Ac are supposed to be in the d-block because of their orbital structures, [Xe]$5d^1$ $6s^2$ and [Rn] $6d^1$ $7s^2$ respectively. On the contrary, these two elements are often called as f-block elements, despite their position in the first group in d-block series. Yb and No should not have f^{14} orbital configuration, but their configurations are [Xe] $4f^{14}$ $6s^2$ and [Rn] $5f^{14}$ $7s^2$ respectively, which indicate that they should be the last f-block elements. However, Lu and Lr are considered as the last f-block elements, i.e. La and Ac elements, as their orbital configurations are [Xe] $6s^2$ $4f^{14}$ $5d^1$ and [Rn] $7s^2$ $5f^{14}$ $6d^1$ respectively. Hence these two elements should have been the first d-block elements – which is not the case. This is mainly because of the exchange of orbitals due to lower energy gap between f and d orbitals. Therefore, the position of La and Ac right below Sc, Y in the same group in case of the earlier periodic table is now not seen. Rather Lu and Lr have occupied their places. Consider two other examples, Nd and U which belong to the same f-group, having the orbital configurations [Xe] $4f^4$ $6s^2$ and [Rn] $5f^3$ $6d^1$ $7s^2$ respectively. This indicates that Nd is the fourth lanthanide element and U is the third actinide element, which does not support them to be in the same f-group elements. In the present periodic table, the elements are mainly arranged on the basis of their atomic

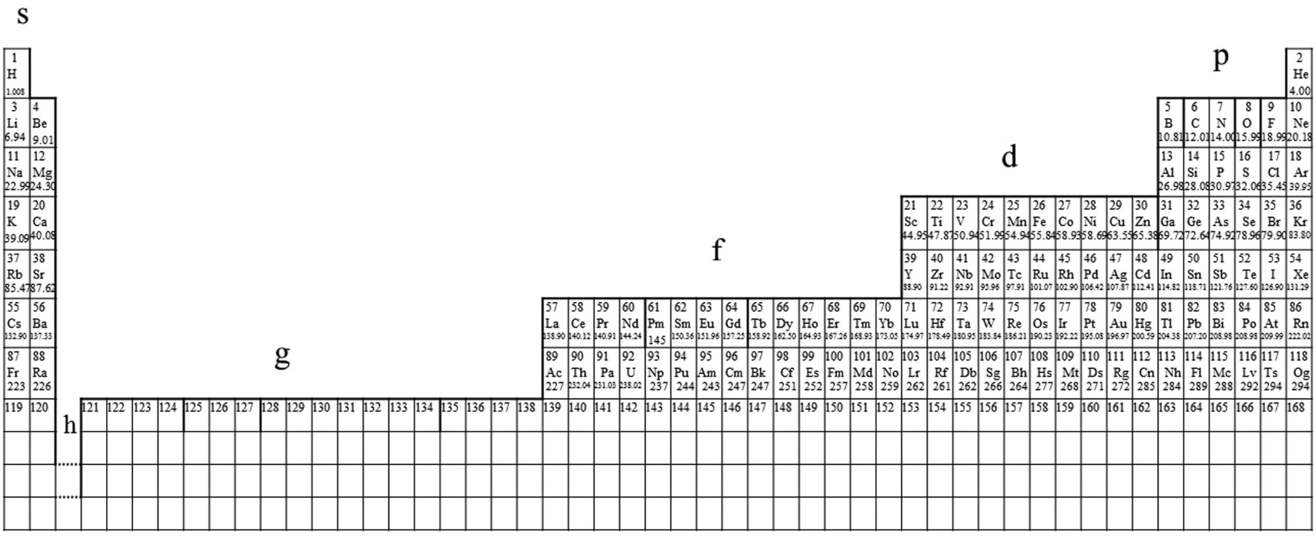

Figure 3. The newly designed periodic table.

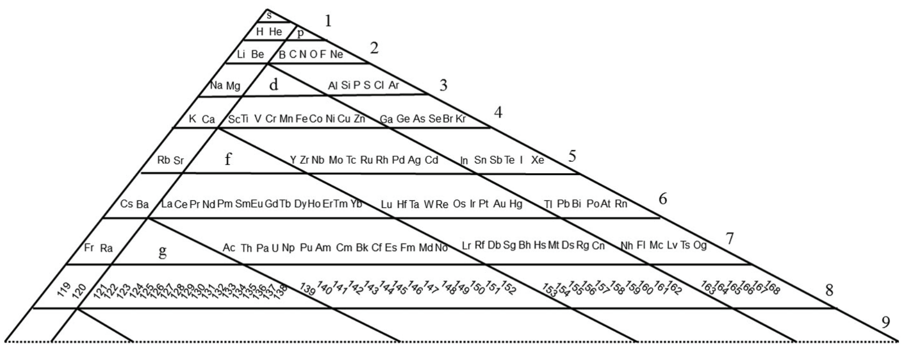

Figure 4. Periodic table in the triangular form.

number and the way the orbitals are filled as shown in Figures 1 and 2. Similar anomalies may also exist in case of future g-block elements as the energy gap between g and f orbitals would still be lower compared to that between f and d orbitals. However, for a better understanding of the periodic table, it has been designed in the manner as shown in Figure 3.

It is seen from this new table that after two rows a new column has appeared and this pattern continues. The same is also envisaged from the orbital patterns shown in Figures 1 and 2. The g-block elements will be expected to be further inner block elements compared to the f-block elements. The orbitals of g-block elements would be buried inside the already buried f-orbitals. This table shows that d orbitals are buried within s and p orbitals from 4th to 5th row, f orbitals are buried within s and d orbitals from 6th to 7th row. Hence, it is expected that g orbitals would be buried within s and f orbitals from 8th to 9th row. This pattern might be hypothetically continued till infinity. It is also understood that the s orbitals form the outermost layer, p orbitals are below s orbitals, d orbitals are below p orbitals and so on. However, the new periodic table contains all the existing elements and can accommodate future elements without putting them in separate rows unlike the present periodic table.

The newly designed periodic table can also be written in a triangular form as shown in Figure 4. Figure 4 shows that there is a space between s- and p-blocks for every alternate rows, for e.g., it is seen in the rows – 1, 3, 5, 7. Apart from this, an additional column starts in every alternate rows, for e.g., in rows – 4, 6, 8. This looks like an expanding periodic table which starts from first row containing only two elements H and He. This resembles the constituents of Sun which are responsible for the generation of all other elements in the solar system. Several other forms of periodic table have been reported earlier[4,5]. However, the concept behind the triangular form of periodic table here is different from that reported earlier by Zmaczynski[6].

It is observed that the total number of shells would be 8 if the g-block elements are actually discovered in future. The last shell would be R shell, which will contain the orbitals 8s 5g 6f 7d 8p. This means, the orbitals (g orbitals) from the 5th shell, i.e. O shell will contribute in this shell, and are called as sub-innermost orbitals; orbitals (f orbitals) from 6th shell, i.e. P shell will also contribute, called as innermost orbitals and the other contributing orbitals (d orbitals) from 7th shell, i.e. Q shell, are called as inner orbitals. This type of new form of periodic table (i.e. Figures 3 and 4) can be extended easily to incorporate many more new elements of future years. However, at present it is difficult to predict such new elements, nevertheless perhaps future generations could discover them and which might have certain role to play in their life.

Conclusion

The newly designed periodic table presented in this article is aimed to make it easily understandable and to contain the basic principles of atomic orbital structure without any additional/separate rows/columns. It is certainly expanded compared to the existing periodic table. The concept of different block elements with respect to their orbital structure is clear in this newly designed periodic table.

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