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On the periodic system's last element and its probable electronic configuration

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ABSTRACT. A formula for the quantization of the mean-statistical speed of K-electron in a multi-electron atom is obtained by analyzing Dirac's formula for the energy of an electron in an H-like atom and taking into account the screening effect.

The fine-structure constant is shown to underlie the quantization of the K-electron speed and to determine the last element of the periodic system.

For the first time a conclusion is made that, with the screening constant of K-electron taken into account, an electron shell is likely to be formed around nucleus with the charge $Z \leq 137$. A most probable electronic configuration of the last (137) element of the periodic table is provided on the basis of the Klechkovsky rule complement and the Thomas-Fermi theory.

A complete periodic table is supplied.

RESUME. Une formule pour la quantification de la valeur statistique moyenne de la vitesse d'un électron K dans un atome à plusieurs électrons est obtenue par analyse de la formule de Dirac de l'énergie d'un électron dans un atome hydrogénoïde en tenant compte de l'effet écran.

On montre que la constante de structure fine est à la base de la quantification de la vitesse de l'électron K et de la détermination du dernier élément de la table périodique.

Pour la première fois, on montre qu'en tenant compte de la constante d'écran de l'électron K, une couche électronique peut être formée autour d'un noyau de charge $Z \leq 137$. La configuration électronique du dernier élément (137) de la table périodique est donnée en se basant sur la règle de Klechkovsky complétée et sur la théorie de Thomas-Fermi.

Une table périodique complète est donnée.

The problem of the ordinal number of the last element in the periodic system is of great theoretical and, possibly, practical significance. Quite recently, by using reactions $^{232}Th + ^{44}Ca$, $^{236}U + ^{40}Ar$ experiments were carried out on the synthesis of the 110 th element [1]. Numerous experiments are also conducted in an effort of discovering or synthesizing heavier elements.

The problem of the last element (Z) is repeatedly discussed in scientific papers. Thus, A.I. Achiezer and V.V. Berestetsky [2] believe in the possibility of the existence of nuclei with $Z = 185 - 200$, though no assumptions are made concerning the existence of atoms with such nuclei.

V.I. Goldansky [3], while assuming the possibility of limiting the charge of the last element by the number 137, does not reject a possible existence of elements with $Z > 137$. S.A. Schukarev [4], considering the laws of populating the 8th period, left the question of the last element's ordinal number open.

According to Seaborg [5] the 7th period of the system should comprise 32 elements, the $8th - 50$, while the total number of elements should be 168.

E. Fermi [6], when calculating the cross-section of the e-capture by a nucleus, estimates the maximum value of the atomic system's nuclear charge as being equal to 140. Basing on the quantization of K-electron's mean-statistical velocity, paper [7] shows that the last H-like atom in the periodic table should be the one with the number 136. In the case of $Z = 137$, the calculated radius of K-electron's orbit turns out to be smaller than that of the nucleus. At $Z > 137$, the existence of K-orbit requires the speed of K-electron to be greater than that of light.

Paper [8], using the idea of K-electron speed quantization and the effect of its screening in a multi-electron atom states that the atom with $Z = 137$ must be the last one of the multi-electron atoms in the table. It also concludes that the fine-structure constant (α) underlies K-electron's speed quantization and determines the last element in the periodic system.

Proceeding from Bohr's H-atom model, the author comes to the conclusion in paper [9] that the $1s$-electron speed at $Z > 137$ must necessarily exceed the speed of light, which is believed to be impossible.

Let us generalize and develop the conclusions of papers [7,8]. It can be easily shown that the stability of an atom is determined not only by that of its nucleus but by the stability of the electron system as well. The instability of an electron system may be due to a decrease of the K-shell radius with the increase of Z and the simultaneous growth of K-electron's speed as well as the probability of its capture by the nucleus. However, an increase of the electron speed (v) is restricted by the finiteness of the speed of light (c) while a decrease of the orbital radius is limited by that of the nucleus.

The law of the electron speed quantization in an H-like atom can be deduced from Dirac's formula for the energy of the electron [10].

$$E_{n,j} = m_e c^2 \left\{ \left[1 + \frac{Z^2\alpha^2}{\left(n - j - \frac{1}{2} + \sqrt{(j+\frac{1}{2})^2 - Z^2\alpha^2}\right)^2} \right]^{-\frac{1}{2}} - 1 \right\}$$

where $j = l \pm s$ is the inner quantum number. Transforming the expression for the maximum value $j = n - \frac{1}{2}$, we obtain

$$E_n = m_e c^2 \left(\sqrt{1 - \frac{Z^2\alpha^2}{n^2}} - 1\right) \quad \text{or} \quad E_n = m_e c^2 \left(\sqrt{1 - \frac{v^2}{c^2}} - 1\right)$$

where

$$v = \alpha c \frac{Z}{n} \tag{1}$$

In expression (1) n takes on the values $1, 2, 3, \ldots$ etc., whereas Z can take on only integral values but not more than 137, since the electron speed (v) cannot possibly exceed c. Using (1) and the relations

$$\frac{mv^2}{r} = \frac{Ze^2}{r^2} \quad , \quad m = \frac{m_e}{\sqrt{1 - v^2/c^2}}$$

makes it possible to find an expression for the K-orbit radius

$$r_k = r_b \sqrt{1/Z^2 - \alpha^2} \tag{2}$$

where r_b is the Bohr radius.

Thus, K-electron speed and its energy in an H-like atom is determined by the formulæ

$$v = \alpha c Z \quad \text{and} \quad E_k = m_e c^2 \left(\sqrt{1 - \alpha^2 Z^2} - 1\right) \tag{3}$$

However, the existence of an H-like atom with $Z = 137$ is out of the question since the K-orbit radius calculated by using formula (2) proves to be smaller than that of the radius (R) of the nucleus ($Z = 137$) found from the formula $R = R_0 \cdot A^{\frac{1}{3}}$ [11], where $R_0 = 1,3 \cdot 10^{-13} sm$ and A is the mass number that can be calculated by using the condition of the maximum β-stability of nuclei $Z = A(1,98 + 0,015 A^{\frac{2}{3}})^{-1}$ [11]. From this follows that the last H-like atom in the table has the number $Z = 136$.

In a multi-electron atom, however, the interaction between door- and bent-electrons brings about the screening effect of the upper layers by the lower ones, which reduces the effective charge of the nucleus and formulæ(1), (2), and (3), therefore, will have the form

$$v = \alpha c(Z - \delta) \quad , \quad r_k = r_b \sqrt{1/(Z-\delta)^2 - \alpha^2}$$
$$E_k = m_e c^2 (\sqrt{1 - \alpha^2 (Z-\delta)^2} - 1)$$

where δ is the screening constant equal to 1 at large values of Z [4,5]. Hence, the ordinal number of the last multi-electron element will be 137. At $Z = 138$, the K-shell "sinks" into the nucleus, i.e., $r_k < R$, whereas $Z > 138$ r_k and E_k become complex numbers and K-electron's speed exceeds c.

Let us consider now the most probable completion of the Mendeleyev periodic table. The 103rd element completes the population of the 5f-sub-shell (actinoids). Beginning with the 104th element, the population of the 6d-sub-shell is continued, from which follows that the population of the 7th period will proceed in the same way as that of the 6th and will end up with the 118th element. Obviously, the periods in the Mendeleyev table are grouped in pairs (Fig.1) : the second period is grouped with the third, the fourth –with the fifth, and the sixth– with the seventh, the properties of each successive pair being different from those of the preceeding one. Hence, the eighth period must be principally different from the seventh. It will begin with populating the 8s-sub-shell. According to the Kletchcovsky rule [12], the population of the 5g-sub-shell cainosymmetrics must begin after a complete population of the 8s-sub-shell.

An analysis of the periodic system, however, shows that the Kletchcovsky empirical rule requires certain supplementary details : each of the cainosymmetric sub-shells in the initial stage of filling in"cuts off" from subsequent sub-shell a certain number of states (N) determined by the formula $N = n' - n"$, where n' and $n"$ are the main quantum numbers of the preceeding and the subsequent sub-shells. In agreement with this formula, $N = 0$ for the third and fourth periods ; $N = 1$ for the sixth and seventh periods, and it equals two for the eighth period. This being the case, the 5g-sub-shell population must begin with the 123d element. Elements 121 and 122 will belong to the 6f-sub-shell since, by the Kletchcovsky rule, it must follow the 5g-sub-shell.

The Thomas-Fermi statistical method [13] also states that the population of the 5g-sub-shell ($l = 4$) will begin only with $Z = 123$. Indeed, the result $Z = 123,2$ will be obtained if the empirically recommended value $\gamma = 0,169$ is introduced into the formula $Z = \gamma(21 + 1)^3$. Thus, element 137 may have the electronic configuration : $8s^2 6f^2 5g^{15}$. Taking into account the results of papers [14-18] a different configuration for the 137th element may be suggested, viz. $8s^2 7d^1 6f^3 5g^{13}$, though in this case the 5g-sub-shell will begin to fill in with element 125. In Fig.1, arrows connect chemically similar elements while the dotted line marks the domain of cainosymmetrics.

To conclude, we would like to specify some parameters of the last element ($Z = 137$) : $A = 379$; $R = 9,4 \cdot 10^{-13} sm$; $r_k = 4,775 \cdot 10^{-12} sm$; $E_k = -448292,4eV$; the Thomas-Fermi total electron energy $E^{T-F} = -20,94Z^{\frac{2}{3}} = -2026085,2eV$. The values r_b, α, and m_e are taken from paper [19].

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