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A HYPOTHESIS ON THE SYNERGISM OF RADIATION AND WATER FILTERS IN THE FORMATION OF BIOOBJECTS

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Мақола тирик моддаларда Менделеев системасидаги бошланғич кимёвий элементлари нисбатан кўпроқ бўлиши ҳақидаги янги фаразни ўз ичига олади. Учунчи ва ундан кейинги таблица элементлари биринчи икки таблица элементларидан фарқли равишда кўп миқдорда субвалент электрон қобиқларга эга. Шу сабабли оғир элемент атомларида k-электрон қобиқ (космик ва ердаги нурланиш таъсирида) ионизацияси молекуляр занжирлар узилишига сабабчи Оже-каскадга олиб келади. Ушбу механизм ва Г.Р.Иваницкийнинг механизми тирик моддаларда енгил кимёвий элементлар танланганда радиацион фильтр ва гидролитик фильтр вазифасини ифодалайди.

Статья содержит гипотезу о доминировании химических элементов начальных периодов таблицы Менделеева в живом веществе. Идея состоит в том, что элементы третьего и последующих периодов таблицы, в отличие от первых двух периодов, имеют большее количество субвалентных электронных оболочек. Вследствие этого ионизация излучением (космическим и земным) k-электронной оболочки тяжелых атомов всегда приводит к оже-каскаду, что вызывает разрушение молекулярных цепей. Этот механизм, наряду с гидролитическим фильтром Г.Р. Иваницкого, может играть роль радиационного фильтра при выборе легких химических элементов в живом веществе.

The article contains a hypothesis on the dominance of chemical elements of top periods of the Periodic Table in living matter. The idea is that the elements of the third and next periods of the table, in contrast to the first two periods, have larger number of subvalent electron shells. Because of this, ionization of the k-electron shell by radiation (kosmic and terrestrial) in the heavy atoms always leads to the Auger cascade, which causes the destruction of molecular chains. This mechanism can play a role of the radiation filter in the selection of light chemical elements in living matter in addition to the mechanism of hydrolytic filter (G.R. Ivanitskii).

I. INTRODUCTION

It well known that carbon (not Si) lies in the basic structure of biological polymer (DNA, RNA, etc.), although the total concentration of Si in nature is 900 times greater than C, and from chemical point of view they are very similar [1-4].

A remarkable solution to this paradox was proposed by G. Ivanitskii [3, 5]. He believed that all processes of competitive growth of chains during the evolution took place in the liquid phase, and were synthesized in the womb of the planet or brought by

ice meteorites from the Cosmos. On this basis, the idea of Ivanitskii says that the hydrolysis for C- and Si-chains to be such a cause, which leads to crushing of Si-chains. At the same time, significant assymmetry is also observed for the remaining elements of the I and II periods in relation to the III period, which cannot be explained by hydrolysis (see Table). Apparently, the role of the water filter cannot be applied to all of them in full, as for the elements C and Si.

It should be noted that from chemistry point of view, carbon and silicon differ by the numbers of electronic shells around the nuclears. This means that the silicon atom has a larger number of subshells than carbon (3 and 2 respectively). Let us check our assumption on the role of a number of subshells considering other pairs of elements that are similar in properties due to valence shells, but different in the number of subshells. The results of such analysis, carried out for a large number of publications, are summarized in Table [4-7]. Thus, it becomes obvious that in addition to the "water filter" of G.R. Ivanitskii [2-3], there should be a different factor in the selection of chemical elements in living matter, sensitive to the number of their electronic subshells.

Table. The content of "leading" elements (mass fraction, %) in Nature [4-7].

Element	Symbol	Expansion %		Number of subshells
		In the living matter	In non-living nature	
Carbon	C	10.5	0.2	1
Silicon	Si	0.15	30.0	2
Hydrogen	H	10.0	1.0	0
Sodium	Na	0.1	2.6	2
Nitrogen	N	2.5	0.1	1
Phosphorous	P	0.95	0.08	2
Oxygen	O	70.0	50.0	1
Sulfur	S	0.16	0.04	2

II. THE RADIATION FILTER FOR THE SELECTION OF ELEMENTS

Among the possible candidate factors for the screening filter of elements for living matter, first of all, it is necessary to highlight the role of radiation, which has both the cosmic and terrestrial origin and presented long before the onset of life on Earth. The modern fundamental knowledge of the radiation impact on objects [8, 9] allows us to identify the most important mechanisms of radiation destruction of matter:

1) Elastic scattering of fast particles (radiation) on atoms. Some of these collisions lead to a direct knockout (elastic knockout) of atoms from their regular sites in chains;

2) Ionization of electrons of atoms and molecules, after which a series of electron-ion processes occur, leading to the destruction of covalent bonds between atoms in the chains (ionization mechanism).

Let us discuss these two mechanisms in more details (see [8-12]).

Elastic mechanism. The efficiency of the elastic knockout mechanism F is defined by the ratio of masses, m_e/M_a, where m_e is the mass of incident fast electrons, and M_a is the mass of an atom. This efficiency F is proportional to the cross-section σ_d of the elastic displacement (knockout)

$$\sigma_d = \int_{E_d}^{E_{\max}} \frac{d\sigma}{dE} dE , \qquad (1)$$

giving as a result $F \sim m_e/M_a$. It is obvious that the elastic scattering will more efficiently destroy the chains with light atoms than with heavy ones. According to the mechanism, the light chemical elements should more effectively have been knocked out from their sites. This mechanism of destruction is not able to explain the predominance of light elements in nature.

Ionization mechanism. It is very interesting to consider the electron-ion processes initiated by the primary ionization of core electrons and leading to breaking of covalent bonds of light and heavy atoms. It turns out that the Auger effect should take place then [10]. Let us compare how this effect proceeds in the pair of atoms discussed above. Figure 2(*a*) corresponds to the case when ionization occurs in the deepest electron shell of the atom from the second period (for example, carbon presented in macromolecular chains). The hole formed in the K shell of the carbon atom as a result of ionization is unstable. This state relaxes by two possible ways: either by falling of a valence electron into the hole of the K shell with emission of a photon (radiative channel), or by transition of valence electrons into the hole of the K shell with energy transfer to the neighboring electron of the valence shell (Auger effect).

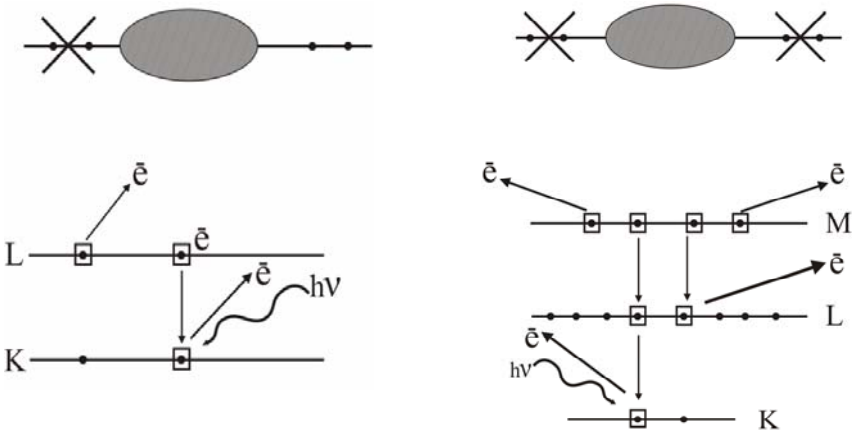


Figure. The destruction of a molecular chain by the Auger explosion mechanism as a function of the number of electron subshells of an atom with ionization of the *K* shell: the smaller number of subshells (left); the larger number of subshells (right).

This competition of the radiation and Auger transition is characteristic of all atoms (both light and heavy) [10]. An individual radiative transition that causes fluorescence is more likely for atoms with a large nuclear charge (*Z*):

$$\Omega_{fl} \sim Z^4 / (a + Z^4), \tag{2}$$

i.e. the radiative transition $L \rightarrow K$ is more probable for the elements of the 3-rd period of than for the 2-d period ($\Omega_{fl}^{C} < \Omega_{fl}^{Si}$).

For the entire atom as a whole, the process goes through the intermediate *L* level, and this introduces a significant change in the corresponding relaxation channels of the deep-level hole. Indeed, the relative probabilities of carrying of one hole to the valence shells are for C and Si the following:

$$\Omega_{fl}^{C} = W_r^{C} / (W_r^{C} + W_A^{C}) \tag{3}$$

and

$$\Omega_{fl}^{Si} = \left(W_r^{Si} / (W_r^{Si} + W_A^{Si})\right)_{L\to K} \left(W_r^{Si} / (W_r^{Si} + W_A^{Si})\right)_{M\to L} \approx \left(W_r^{Si} / (W_r^{Si} + W_A^{Si})\right)^2. \quad 4)$$

Then the expression

$$1 - \Omega_{fl}^{C} < 1 - \Omega_{fl}^{Si} \quad (5)$$

means that the carrying of the primary hole from the *K*-shell by the Auger process prevails in Si. It is interesting to note that this conclusion seems to be valid for all cases of *K*-hole relaxation if intermediate subshells participate in it.

Thus, there is a significant difference in the relaxation of deep-level holes (for example, in the *K*-shell) for the elements with different number of subshells: Auger relaxation (cascade) prevails for heavier atoms, as a result of which a larger charge carry to the valence shell, and the chemical bonds are destroyed (Fig. 2).

The detailed analysis shows [10] that for silicon, the Auger-cascade is not only competitive with radiative transitions, but also in some cases prevails over them. Thus, after the first act of relaxation, two "holes" appear on the *L*-shell. Now each of these holes will be filled by the drop of electrons from the *M*-shell, and mainly, by Auger transitions (because the atom is heavy). As a result, four "holes" are formed in the *M*-shell, which corresponds to two broken chemical bonds. This is the way the of breaks of chains occur in the localization of heavy atoms, and this becomes important for the elements, beginning from the third period, for which three electron shells (*K*, *L*, *M*) and later are realized. Moreover, this process increases so called shaking [10].

Here, however, there is one more important point, namely the destruction of Coulomb-unstable structures after the carrying of the large charge into the valence shell. Indeed, after a very rapid phase of the breaking of chemical bonds, this Coulomb-unstable complex can relax by two ways: either by displacing of the ionized atom from its position in the chain, or by neutralizing of the defective region (its "flooding" by surrounding electrons), i.e. there is competition between these two processes (the Dexter-Varley paradox) [8, 10-12]. It was found [8, 11] that this paradox is quantum, and the probability of destruction of the quantum system is regulated by the expression

$$P \sim \exp\left(-\Delta E_V / \hbar\omega_D\right), \quad (6)$$

where ΔE_V is the width of the valence band, and ω_D is the Debye frequency. It is necessary to note that macromolecules (for example DNA) in cells are not always in linear but rolled conformation. It results in the change of ΔE_V and affects the probability of chain destruction. We note that the value of this probability *P* depends very strongly on ΔE_V and is contained in a wide range of values from 10^{-1} to 10^{-4} for molecular chains of organic nature and classical semiconductors, respectively. In the case of polymeric objects, these probabilities are very large [13], which is important for the problem discussed in the article.

The mechanism of destruction of molecular systems by Auger cascades has been known for a long time. In particular, so-called subthreshold defect formation occurs in silicon due to this effect [10-12]. We assume that Auger cascades in relatively heavy atoms from the third and lower periods play an important role as filters for light elements to be selected as constituents to form stable structures of biological objects. Moreover, there was a synergy between those two filters in the cases when the Auger mechanism discussed above was supplemented by the hydrolysis filter.

It is necessary to note that the universal character of the radiation filter (Auger filter) makes it more preferable, at least from the points of view of E.Mach and W.Occam's razor principles [14]. All mathematical calculating part on sub-threshold defect formation in semiconductors due to Auger effect has been performed in [8, 11].

IV. CONCLUSION

The obtained results can be formulated as the following.

It is evident that a prominent asymmetry of the abundance of light atoms and heavy ones is observed in Nature. In living matter, light atoms dominate, while heavy atoms in non-living mater.

This disparity is most obvious for C and Si: only carbon atoms composed the most important biopolymers, organize the living matter.

The basic concept that explains the disproportion with respect to C and Si is the "water filter", which leads to the destruction of the length of Si-molecules, in contrast to the C-molecules.

Since this disproportion in the distribution is also valid for the elements that are more inert to water, the concept of "light" and "heavy" atoms can be used for the atoms with smaller and larger number of subvalent shells.

On this ground, we propose a hypothesis on the role of ionizing radiation, which leads to completely different results for atoms with the small and large number of shells: in the former case, a single Auger transition occurs, and in the latter case Auger cascades take place.

As a result of the Auger processes, complete breaking of chemical bonds can occur in heavy atoms with multi-shells included into the bioobjects. Efficiency of ionization mechanism of selection depends on the type of conformation.

In general, it can be assumed that both water and ionizing radiation are two effective filters giving a preference of light atoms in living matter.

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