

In memory of Alexander Didyk

MULTINUCLEAR REACTIONS IN CONDENSED HELIUM

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Abstract. Helium high-pressure chambers filled with gaseous helium at pressures of about 1.1 and 3 kbar were irradiated by bremsstrahlung gamma rays with a maximum energy of 10 MeV during $\sim 10^5$ s. Inside the reaction chambers “extraneous” chemical elements are found which were absent prior to the onset of irradiation. To explain the appearance of synthesized elements, a new mechanism is proposed: multinuclear reactions. These reactions are due to the creation of nuclear molecules which consist of several helium nuclei. Nuclear molecules are formed by the fusion of several orthohelium atoms. It is proposed to execute experiments aimed at recording multinuclear reactions by passing electric discharges through helium or through a mixture of helium and hydrogen at a pressure of several bars.

Keywords: condensed matter nuclear science, low energy transmutation, multinuclear reactions, nuclear molecules, Bose–Einstein condensate

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1. INTRODUCTION

The phenomenological model of low energy nuclear reactions implies fusion of multiple atomic nuclei into one single formation with its subsequent decay into multiple nuclei [1-3]. This model assumes that such reactions take place due to the appearance in the excited condensed matter of local regions or capsules containing a large number of atoms [4]. Inside of such capsules, conditions for physical processes and the structures of atoms and nuclei may change. Herein it is not important how exactly the matter is excited and the capsules are formed, whether

it occurs under explosion-induced compression or electric discharge, through cavitation or electrolysis, a chemical or biochemical reaction, or due to radiation.

In a series of studies carried out by A.Yu. Didyk et al. at the Flerov Laboratory Nuclear Reactions of JINR [5-7, over 40 papers], metallic specimen in gaseous deuterium, hydrogen or helium under pressures of hundreds and thousands of bars were irradiated by braking gamma rays with E_{\max} of 10 MeV and 23 MeV. Under such pressures, the density of atoms in the gas is comparable with the density of atoms in solids or liquids. Therefore, from here on we shall use such a term as *condensed gas*. Similar investigations were done using chambers filled with pure condensed gases as hydrogen, helium [8-11] and xenon [12] under irradiation by gamma rays with E_{\max} of 10 MeV. In all of these experiments, extraneous chemical elements which had not been present prior to irradiating were found in the reaction chambers upon completion of irradiation. Such foreign elements range from hydrogen up to bismuth. This paper presents results of experiments on the synthesis of chemical elements under the action of braking radiation with E_{\max} of 10 MeV in condensed ^4He (99,999) under pressures of 1.1 kbar

and 3.05 kbar. In order to explain the appearance of extraneous chemical elements in these experiments, a new mechanism of multinuclear reactions is introduced.

2. EXPERIMENTS ON THE SYNTHESIS OF CHEMICAL ELEMENTS IN HELIUM

The helium high-pressure chamber (HeHPC) is shown in Fig. 1. The chamber body (3) and entrance-window plug (2) are made of beryllium bronze. A liner (6) and a sleeve (7) made of copper with 99.9% purity are placed inside the chamber. The chamber filled with helium (5) has the following inner dimensions: the length is 15mm; the diameter is 8 mm; and the volume is 0.754 cm³. Upon filling of the HeHPC and prior to its irradiation, the helium pressure was monitored using a strain gauge pressure sensor (8) during several weeks.

Irradiation of the HeHPC was carried out by braking gamma rays (1) with a maximal energy of 10 MeV at the MT-25 electron accelerator at the FLNR JINR. The electron current at the tungsten convector shaped as a disk of 40 mm diameter and 2.5 mm thickness and used to transform the electron flux into gamma rays was (1-1.5)·10¹⁴ s⁻¹. The electron beam was 6-7 mm in diameter. The beam spread of gamma quanta at the intensity half-height amounted to 10°±1° in horizontal and 8°±1° in vertical direction. Right behind the convector, an electron absorber of 25 mm thickness made from D16T duralumin was placed. Irradiation was performed during 7-8 hours a day. The irradiation parameters [8-11] are given in Table 1: № - experiment number; P – helium pressure at the start of irradiation; ΔP

Table 1

Parameters of the radiation					
№	P, kbar	ΔP, bar	ρ, atm/sm ³	T, s · 10 ⁻⁵	I, s ⁻¹ · 10 ⁻¹⁴
1	1.1	666	1.5·10 ²²	1.02	1.2-1.5
2	3.05	63	2.6·10 ²²	1.0	1-1.2

– helium pressure difference between the start and end of irradiation; T – irradiation duration; I – electron current.

Upon completion of irradiation, helium was released from the HeHPC to the surrounding environment and the chamber was opened. The most impressive result in the first experiment under 1.1 kbar pressure was the observation of thin black foils of cylindrical shape and considerable size (4) inside the HeHPC. The foils (Fig. 2) were composed predominantly of carbon and left oily stains on paper. The latter fact points to the presence of liquid oils on the foils such as hydrocarbons and to the synthesis of hydrogen.

In the second experiment under 3.05 kbar no carbon foils were observed. This is suggestively due to a small drop of pressure in the chamber during the irradiation: in the second experiment, it amounted to 63 bar, and in the first one was 666 bar (Table 1). Using scanning electron microscopy (SEM) and x-ray microprobe analysis (MPRA) studies were made of the element compositions of the “window plug” from beryllium bronze, anomalous structures and microparticles (objects) formed on the inner surfaces of the

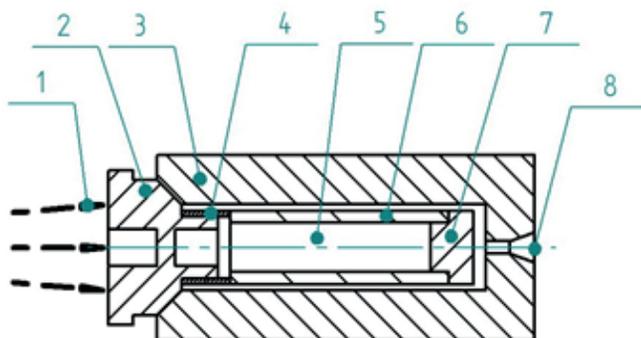


Fig. 1. The high-pressure chamber HeHPC.

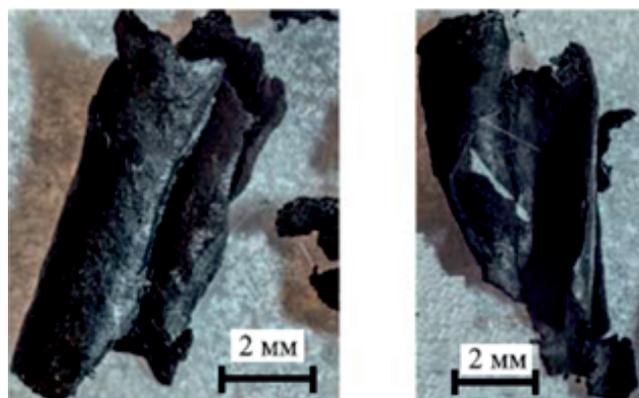


Fig. 2. Pictures of black foils

liners and sleeves under irradiation. All of the SEM and MPRA studies were organized at two independent certified laboratories: at the analytical centre of the Skobeltsyn Laboratory of Lomonosov Moscow State University and at the Research Institute for Perspective Materials and Technologies in Moscow. MPRA of the obtained structures and microparticles was done with the electron beam excitation area $\sim 1-4 \mu^2$. In some cases the investigated object was scanned with a microscope electron beam along the band where several x-ray spectra were obtained.

Figs. 3 and 4 display averaged element concentrations of K in atomic %, obtained in the experiments under helium pressures of 1.1 kbar and 3 kbar, as a function of the nucleus charge Z. In the case with 1.1 kbar averaging was done over 11 measurements of various objects, and in the case with 3 kbar, over 17 measurements. When comparing the images, one can see that the set of elements in the first experiment under 1.1 kbar is more diverse than in the second experiment under 3 kbar pressure. Both element distributions are characterized by presence of the group of light elements from ${}_6\text{C}$ to ${}_{30}\text{Zn}$. In the first experiment, along with light chemical elements such elements as ${}_{33}\text{As}$ (arsenic), ${}_{50}\text{Sn}$ (tin), ${}_{52}\text{Te}$ (tellurium), ${}_{56}\text{Ba}$ (barium), ${}_{73}\text{Ta}$ (thantalum) and ${}_{82}\text{Pb}$ (lead) were obtained. However, these chemical elements were not found in the second experiment. Only one element with the nucleus charge $Z > 30$

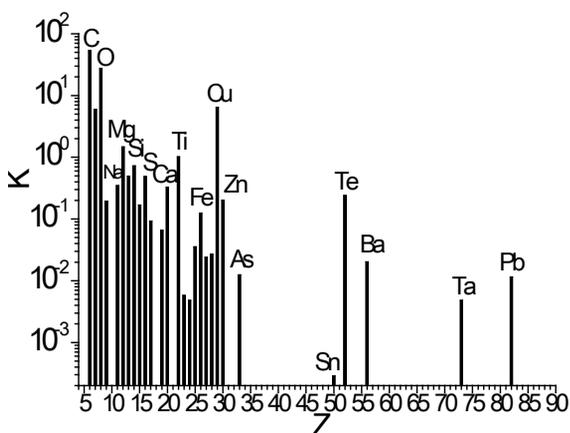


Fig. 3. Concentrations of elements on P = 1.1 kbar.

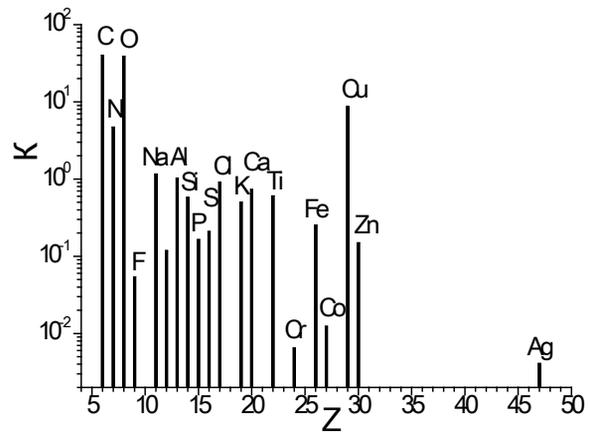


Fig. 4. Concentrations of elements on P = 3 kbar.

as ${}_{47}\text{Ag}$ (silver) was present. This distinction is apparently also due to the small drop of pressure in the chamber during the irradiation in the second experiment under 3 kbar.

On the basis of the facts that carbon foils and chemical elements with $Z > 30$ were obtained in the experiment under 1.1 kbar pressure while they were almost not observed in the experiment under 3 kbar, it can be assumed that the synthesis rate for the chemical elements depends on the helium pressure. Synthesis reactions proceed at 1.1 kbar more intensively than at 3 kbar pressure. This apparently points to the existence of an optimal value of gas pressure under which the reaction rate becomes maximal, with all other conditions being equal.

3. MULTINUCLEAR REACTIONS

Fig. 5 shows averaged concentrations of chemical elements determined by 5 measurements (black dots). Two measurements were done at the carbon foil and the other three, at the microparticles [9, Tables 3, 4]. This figure was drawn and

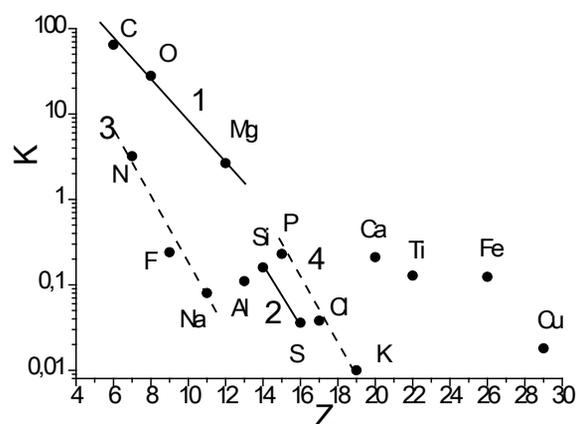
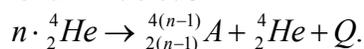


Fig. 5. The concentration of the elements in five dimensions.

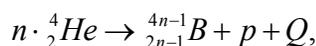
analyzed first, along with figures 3 and 4. Conspicuous here are the groups of elements. The first and second ones are the groups of chemical elements which are even by the nucleus charge. They are represented by the elements such as carbon-oxygen-magnesium and silicon-sulfur. The third and fourth are the groups of chemical elements which are odd by the nucleus charge. They include such elements as nitrogen-fluorine-sodium and phosphorus-chlorine-potassium. One can draw a straight line through the dots of every group. All lines of such groups are numbered in Fig. 5.

Since the elements in the groups fall behind each other by a charge that is a multiple of two, i.e. by ${}^4_2\text{He}$ nucleus, it can be assumed that under the action of gamma rays multinuclear reactions proceed in condensed helium.

The emergence of even chemical elements ${}^N_Z A$ can be presented as a result of fusion into a compound of $(n - 1)$ helium nuclei from a common formation comprised of “ n ” helium nuclei, with simultaneous emission of one helium nucleus:



Odd chemical elements ${}^N_Z B$ are then a result of fusion into a compound of “ n ” helium nuclei, but with the emission of a proton:



where Q is the energy released in the reaction. The common formation produced from individual helium nuclei is a nuclear molecule, or the so-called transmolecule [4]. It is believed that the existence of a transmolecule consisting of helium nuclei is due to nuclear and electromagnetic interactions. The reaction with emission of helium from a transmolecule will have a larger cross section than the reaction with emission of a proton because the outgoing helium nucleus is not involved in the fusion process. The possibility of formation of transmolecules decreases exponentially as the number of helium nuclei in the transmolecule increases

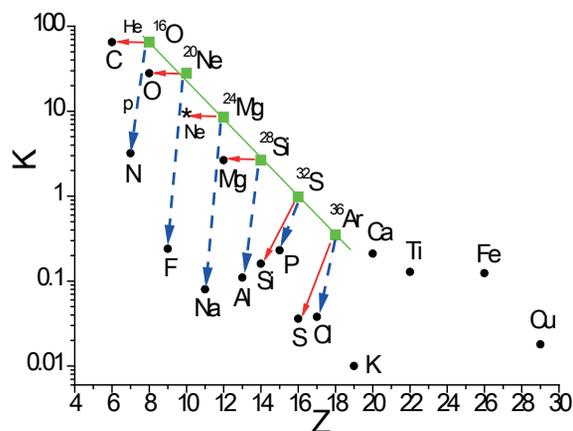


Fig. 6. Transformation of transmolecules ($n \cdot {}^4\text{He}$) emission of helium or proton.

(Fig. 6, shown by the green line). If during the fusion of helium nuclei into a compound the ratio of the cross section with helium emission to the cross section with proton emission is preserved, the yields of the respective products have to decrease exponentially as well. Such behavior in the product yields can be observed in Fig. 5, lines 1-4. In Fig. 6 the reactions of transformation of transmolecules from ${}^{16}_8\text{O}$ to ${}^{36}_{18}\text{Ar}$ (the green squares) with the emission of helium (solid arrow) or a proton (dotted arrow) are schematically shown by arrows. The ${}^{16}_8\text{O}$ transmolecule consisting of four helium nuclei transforms into ${}^{12}_6\text{C}$ with the emission of helium or into ${}^{15}_7\text{N}$ with the emission of a proton. The ${}^{20}_{10}\text{Ne}$ transmolecule composed of five helium nuclei transforms into ${}^{16}_8\text{O}$ with the emission of helium or into ${}^{19}_9\text{F}$ with the emission of a proton, etc. During the fusion of helium nuclei into a compound, it can evaporate neutrons. For the yields of final products, neutron evaporation and subsequent β^+ -decay of the compound are equivalent to the emission of a proton from this compound. Beginning with the ${}^{20}_{10}\text{Ne}$ transmolecule the reactions with the production of two or more fragments become possible, for example: $5 \cdot {}^4\text{He} \rightarrow {}^{12}\text{C} + 2 \cdot {}^4\text{He}$ and $6 \cdot {}^4\text{He} \rightarrow {}^{12}\text{C} + {}^{12}\text{C}$.

A nuclear transmolecule is formed due to the successive capture of orthohelium nuclei or other transmolecules. The average spacing between helium atoms at a temperature of

300 K under pressures of 1 kbar and 3 kbar is $4.1 \cdot 10^{-10}$ m and $3.4 \cdot 10^{-10}$ m, while the mean time between the collisions of helium atoms is $\sim 3 \cdot 10^{-13}$ s. Therefore, a transmolecule is a stable formation on a nuclear time scale of 10^{-20-22} s. It should be assumed that nuclear forces binding the nuclei together and Coulomb repulsive forces preventing the nuclei from instant fusion coexist in a nuclear transmolecule in balance.

The characteristics of multinuclear reactions are displayed in **Table 2**. № indicates the line number. The second column presents reaction products – the isotopes of elements produced

in the reactions. The content of the respective isotope in the natural mixture is shown in the brackets. The isotopes with the plus sign A^+ are β^+ -radioactive isotopes emanating e^+ (positrons). Their lifetime is also given here. In the third column multinuclear reactions with the formation of the $n\text{-}^4\text{He}$ transmolecule are displayed. The binding energy (\mathcal{E}) of the reaction products is given in the fourth column, and the calculated energy (Q) released in the reaction, in the fifth column. The sixth column presents recoil energy (q) for the helium, proton, and neutron.

Table 2

Multinuclear reactions in helium

№	Reaction product	Reaction $n\text{-}^4\text{He}$	\mathcal{E} , keV	Q , keV	q , keV
1	^7Li (92.5%)	$2\text{-}^4\text{He} - p$	39245	-17347	
2	^8Be	$2\text{-}^4\text{He} - e\gamma$	56500	-92	
3	^9Be	$3\text{-}^4\text{He} - ^3\text{He}$	58165	-19004	
4	^{11}B (80.0%)	$3\text{-}^4\text{He} - p$	76205	-8682	
5	$^{11}\text{C} + 20.4$ m	$3\text{-}^4\text{He} - n$	73440	-11447	
6	^{12}C (98.9%)	$3\text{-}^4\text{He} - e\gamma$	92162	7275	
7	^{12}C	$4\text{-}^4\text{He} - ^4\text{He}$	92162	7275	5 456
8	^{15}N (0.37%)	$4\text{-}^4\text{He} - p$	115492	2309	2 165
9	$^{15}\text{O} + 2$ m	$4\text{-}^4\text{He} - n$	111956	1227	1 150
10	^{16}O (99.8%)	$5\text{-}^4\text{He} - ^4\text{He}$	127619	14437	11 549
11	^{19}F	$5\text{-}^4\text{He} - p$	147801	6323	6 007
12	$^{19}\text{Ne} + 17$ s	$5\text{-}^4\text{He} - n$	143781	2302	2 187
13	^{20}Ne (90.5%)	$6\text{-}^4\text{He} - ^4\text{He}$	160645	19166	15 972
14	^{23}Na	$6\text{-}^4\text{He} - p$	186564	16790	16 090
15	$^{23}\text{Mg} + 11$ s	$6\text{-}^4\text{He} - n$	181725	11951	11 453
16	^{24}Mg (79.0%)	$7\text{-}^4\text{He} - ^4\text{He}$	198257	28483	24 922
17	^{27}Al	$7\text{-}^4\text{He} - p$	224952	26882	25 922
18	$^{27}\text{Si} + 4$ s	$7\text{-}^4\text{He} - n$	219357	21287	20 527
19	^{28}Si (92.23%)	$8\text{-}^4\text{He} - ^4\text{He}$	236537	38467	34 193
20	^{31}P	$8\text{-}^4\text{He} - p$	262917	36551	35 409
21	$^{31}\text{S} + 2.6$ s	$8\text{-}^4\text{He} - n$	256738	30373	29 424
22	^{32}S (95.02%)	$9\text{-}^4\text{He} - ^4\text{He}$	271781	45415	40 369
23	^{35}Cl (75.8%)	$9\text{-}^4\text{He} - p$	298290	43549	42 339
24	$^{35}\text{Ar} + 1.8$ s	$9\text{-}^4\text{He} - n$	291462	36801	35 779
25	^{36}Ar (0.34%)	$10\text{-}^4\text{He} - ^4\text{He}$	306716	52055	46 849
26	^{39}K (93.26%)	$10\text{-}^4\text{He} - p$	333724	50767	49 498
27	$^{39}\text{Ca} + 0.9$ s	$10\text{-}^4\text{He} - n$	326411	43454	42 367

It is seen from Table 2 that such chemical elements as lithium, beryllium and boron are not produced in simple reactions with the emission of helium-3 and a proton since $Q < 0$. These elements emerge paired with the radioactive isotopes of nitrogen, oxygen, fluorine and others in the reactions with participation of five or six helium nuclei. Such reactions require an essential reorganization of the compound formed through fusion of all helium nuclei in the transmolecule. That is why respective reaction cross sections are suppressed.

In Table 2 attention should be paid to the reactions presented in lines 2 and 6. Transmolecules consisting of two and three helium nuclei can be relatively stable. In the first case, stability of the ^8Be (beryllium) transmolecule results, first and foremost, from the impossibility of fusion of two helium nuclei due to the energy causes, with $Q < 0$. In the second case, notwithstanding that the bond energy of ^{12}C equal to 92161.7 keV is greater than the sum of bond energies of three helium nuclei, $3 \cdot ^4\text{He} = 84887$ keV, by the value ~ 7274.7 keV, the reaction $3 \cdot ^4\text{He} \rightarrow ^{12}\text{C} + 6e^-$ is suppressed. This is due to the retardation in the redistribution of the released energy resulting only from the electromagnetic interaction between carbon and six atomic electrons [13]. The six electrons are bound into the Bose condensate. Their bond energy is ~ 3 keV. Apart from this reaction, the following reaction

can take place as well: $3 \cdot ^4\text{He} \rightarrow ^{12}\text{C} + 6e^- + \gamma$. A gamma quantum with an energy of 4438keV is produced in this reaction through the decay of the ^{12}C excited state.

Now, let us have a look at line 16 in Table 2. The bond energy of the ^4He nucleus equal to 28295.6745 keV is lower than the energy released in the reaction $7 \cdot ^4\text{He}(^{28}\text{Si}) \rightarrow ^{24}\text{Mg} + ^4\text{He} + 28483$ keV; however, it is greater than the ^4He recoil energy of 24922 keV. Thus, the reaction energy is not enough to destroy the produced ^4He nucleus. Therefore, the Mg point in Fig. 5 remains at line 1. However, the cross section of the reaction with the emission of a proton $7 \cdot ^4\text{He}(^{28}\text{Si}) \rightarrow ^{27}\text{Al} + p + 26882$ keV increases, and the Al point shifts from line 3 upwards in Fig. 5.

In line 19 from Table 2, in the reaction $8 \cdot ^4\text{He}(^{32}\text{S}) \rightarrow ^{28}\text{Si} + ^4\text{He} + 38467.2\text{keV}$, the released energy and recoil energy of ^4He is already larger than the bond energy of the ^4He nucleus. Consequently, it is the reaction with the emission of a proton and production of P (phosphorus) that chiefly takes place here. The reaction with the escape of helium and formation of Si (silicon) is suppressed, with the Si point in Fig. 5 shifting from line 1 downward. The same happens in the event of the reaction with nine helium nuclei, $9 \cdot ^4\text{He}(^{36}\text{Ar})$, with the production of S (sulphur) and Cl (chlorine). Under changed conditions, when reactions with helium emission are suppressed, we can observe a new systematics in the reaction cross sections. This is reflected in the fact that the values of chemical element yields in the reactions shift to other lines, 2 (Si-S) and 4 (P-Cl-K) (Fig. 5).

The production of chemical elements starting from chlorine with $Z > 19$ (Fig. 5) is apparently governed by secondary processes. Under such processes, multinuclear interactions take place with the participation of transformed atoms (transatoms [15]) of chemical elements obtained in the preceding reactions. The 100-percent production of ^{15}N and ^{36}Ar in multinuclear reactions, lines 8 and 25 in Table 2, should be given special attention. In the natural mixture their presence amounts to 0.37%

and 0.34%. Therefore, in mass analyses predominant registration of ^{15}N and ^{36}Ar isotopes provides evidence of the multinuclear reactions proceeding in condensed helium.

4. FORMATION OF TRANSMOLECULES. ELECTRON BOSE-CONDENSATE

For the formation of a transmolecule from helium nuclei, helium atoms have to transform into helium transatoms (Fig. 7). Helium atoms are unique for such transformation. As is known, helium atoms have two stable basic states: parahelium 1^1S_0 and orthohelium 2^3S_1 . The existence of orthohelium [14] and transhelium [15] is due to the exchange interaction associated with the indistinguishability of the electrons (identity principle). The exchange interaction is characterized by the exchange energy (“A”). As opposed to the electrostatic energy “C”, the contribution of exchange energy into the total energy of the system may be of different signs depending on whether the spin part of the wave function is symmetric or antisymmetric. The correction ΔE to the total energy of system (1) connected with the electron interaction is determined in frames of the perturbation theory:

$$\Delta E = C \pm A, \tag{1}$$

where the sign “+” refers to the antisymmetric $\uparrow\downarrow$ spin state $S = 0$; and the sign “-” indicates the symmetric $\uparrow\uparrow$ spin state $S = 1$. In an atom, the energy of Coulomb repulsion between the electrons “C” and the exchange energy “A” (exchange integral) are positive. This is why due to the exchange energy attractive forces between the electrons (orthohelium) and repulsive forces (1) are present in a helium atom concurrently. The spins of electrons in parahelium are antiparallel $\uparrow\downarrow$, while in

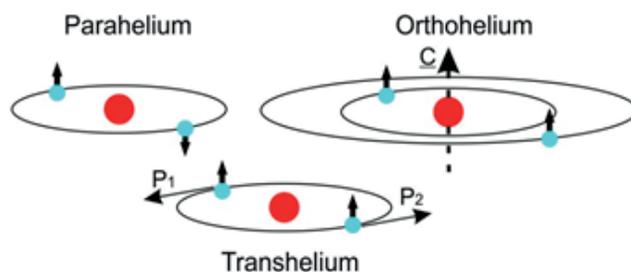


Fig. 7. Main states of a helium atom.

orthohelium they are parallel $\uparrow\uparrow$ (Fig. 7). As distinct from parahelium, the electrons in orthohelium cannot be present in the same state according to the Pauli principle. Therefore, in orthohelium the electrons are found in different states, at different energy levels (Fig. 7). The main states of parahelium and orthohelium differ by 19.77 eV. The parahelium lines are singlets ($S = 0$), and orthohelium lines are triplets ($S = 1$). The characteristic lines in the optical spectrum have a wavelength of 501.6 μm in parahelium, and of 587.6 μm in orthohelium. The transition with two-photon emission $2^3S_1 \rightarrow 1^1S_0 + 2\gamma$ between ortho- and parahelium is strongly suppressed and has a lifetime of $2.5 \cdot 10^8$ s. The one-photon, magnetic-dipole decay of the 2^3S_1 -state has a lifetime of $8 \cdot 10^3$ s. However, radiationless transitions during an interaction with an incident electron or another atom are also possible.

Orthohelium, unlike parahelium, has a strong magnetic field since magnetic moments of its electrons are always parallel. The radius R_1 of the first electron in orthohelium (or in a parahelium atom) is $3.1 \cdot 10^{-11}$ m; and the radius R_2 of the second orthohelium electron is $8.76 \cdot 10^{-11}$ m. The magnetic moment of the electron μ_e produces a magnetic field with the magnetic induction vector \mathbf{B}_μ equal to [16]:

$$\mathbf{B}_\mu = \mu_0 \frac{3\mathbf{n}(\mu_e \cdot \mathbf{n}) - \mu_e}{r^3}, \quad (2)$$

where $\mu_0 = 1.26 \cdot 10^{-6}$ H/m is the magnetic constant; $\mu_e = 9.29 \cdot 10^{-24}$ J/T = $5.79 \cdot 10^{-5}$ eV/T; r is the distance from the electron up to the point where the field is calculated; \mathbf{n} is a unitary vector in the direction r . At the centre of an orthohelium atom, the magnetic field near the nucleus \mathbf{B}_0 is calculated using the formula (2): $\mathbf{B}_0 = -\mu_0 \mu_e / R_1^3 - \mu_0 \mu_e / R_2^3 = -393 - 17 = -410$ T. The negative sign indicates that magnetic field at the atom's centre is directed in the opposite direction to the magnetic moments of the electrons. The magnetic field B_{R_2} at the point located on the C axis (Fig. 7) at the distance R_2

from the nucleus is ~ 70 T and directed parallel to the magnetic moments of the electrons μ_e . The C axis is restored perpendicularly to the electron orbitals and passes through the atom's centre. At the distance $c^2 \gg R_2^2$, on the C axis the magnetic induction vector for orthohelium from expression (2) is $\mathbf{B}_c = \frac{4\mu_0 \mu_e}{c^3}$ and parallel to μ_e . Consequently, two orthohelium atoms are attracted to each other with magnetic self-focusing along the axis C. The energy of their magnetic interaction along the axis C is: $E_\mu = 4\mu_e \cdot B_c$. At a distance R_2 , the magnetic interaction energy is equal to ~ 0.016 eV. As two orthohelium atoms approach each other, the energy of their interaction enhances.

With a decreased distance between the orthohelium atoms, the motion of the electrons in one orthohelium will synchronize owing to the electromagnetic interaction with the motion of the electrons in the second orthohelium. As a consequence of such synchronization, both inner- and outer-shell electrons of the orthohelium atoms will be located at the orbitals in diametrically opposite positions (Fig. 8). Due to this, the sums of momenta of the outer- and inner-shell electrons separately are equal zero, $\mathbf{P}_1 = -\mathbf{P}_2$ (Fig. 7), which is one of the conditions for the electron pairing. Moreover, due to the additionally arising attractive exchange interaction between the electrons of different orthohelium atoms and to strong magnetic field, such electrons form Cooper pairs with $S = 1$ (Fig. 8) bound into a boson. These electron bosons are common for the two helium nuclei. So, an excited nuclear transmolecule of ^8Be has one Cooper electron pair at the outer orbital and another Cooper pair at the inner orbital (Fig. 8). Because the outer pair represents a boson, it

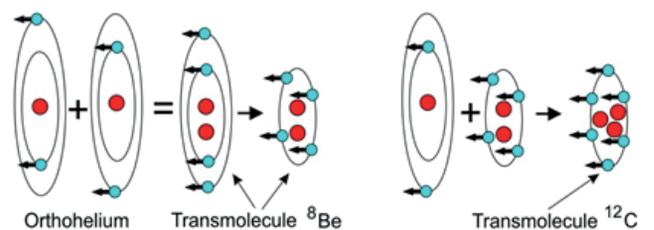


Fig. 8. The formation of transmoecules ^8Be and ^{12}C .

immediately passes into the ground state with the emission of two photons. Consequently, this leads to electron Bose condensate around the transmolecule. The radius of a ${}^8\text{Be}$ transmolecule is $R_{\text{Be}} = 1.32 \cdot 10^{-11} \text{m}$. The magnetic field B_0 at the centre is $2 \cdot 10^4 \text{ T}$ and at the distance $1.2 \cdot R_{\text{Be}}$ from the centre the magnetic field B_R equals $4 \cdot 10^3 \text{ T}$.

The magnetic interaction of an orthohelium atom and a ${}^8\text{Be}$ transmolecule, as well as exchange interaction between their electrons result in the transformation of the orthohelium atom into a transhelium atom (Fig. 8). The radius R_{He} of transhelium is $2.64 \cdot 10^{-11} \text{ m}$, $B_0 = 1.3 \cdot 10^3 \text{ T}$. Further interaction of transhelium with the ${}^8\text{Be}$ transmolecule leads to the formation of a ${}^{12}\text{C}$ (carbon) transmolecule. The radius of the ${}^{12}\text{C}$ transmolecule is as follows: $R_{\text{C}} = 0.89 \cdot 10^{-11} \text{m}$. The magnetic field B_0 at the centre is 10^5 T and at the distance $1.2 \cdot R_{\text{C}}$ from the centre the magnetic field B_{Rc} equals $2 \cdot 10^4 \text{ T}$. The possibility of existence of transmolecules is due to nuclear forces and ultrastrong inhomogeneous magnetic fields of $10^4 - 3 \cdot 10^8 \text{ T}$ at their centres [15].

As was noted in section 3, ${}^8\text{Be}$ and ${}^{12}\text{C}$ transmolecules can be stable. Therefore, they can interact both with orthohelium, transforming it into transhelium, and with each other. These interactions result in the formation of other, heavier nuclear transmolecules. **Fig. 9** displays a few combinations composed of orthohelium atoms, ${}^8\text{Be}$ and ${}^{12}\text{C}$ transmolecules, which lead to the production of: A – an ${}^{16}\text{O}$ (oxygen) transmolecule; B – a ${}^{20}\text{Ne}$ (neon) transmolecule; C – a ${}^{24}\text{Mg}$ (magnesium) transmolecule; and D – a ${}^{28}\text{Si}$ (silicon) transmolecule. For example, an ${}^{16}\text{O}$ transmolecule can be obtained by combining a ${}^{12}\text{C}$ transmolecule with orthohelium or by combining two ${}^8\text{Be}$ transmolecules. The arrows on the right (Fig. 9) show the isotopes of chemical elements produced in multinuclear reactions with the emission of a helium (${}^4\text{He}$) nucleus, a proton (p) and a neutron (n) (Table 2).

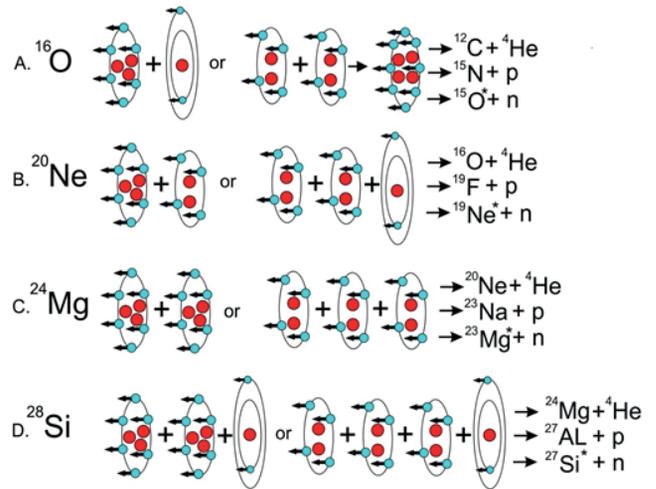


Fig. 9. The formation and collapse of transmolecules.

Thus, production of transmolecules depends on the orthohelium formation cross section and its spatial density. Upon formation of transmolecules multinuclear reactions proceed automatically. Consequently, the cross sections of multinuclear reactions are comparable with the cross sections of atomic processes!

5. NUCLEAR PROCESSES IN IONIZED HELIUM

It is evident from the earlier sections that gamma quanta are not involved in multinuclear reactions. They only ionize helium atoms. The ionization potential of a helium atom is equal to 24.59 eV. During the recombination – capture of free electrons by helium ions – a mixture of two “gases” of parahelium and orthohelium is formed. Since the level densities for orthohelium are thrice greater than with parahelium, the probability for orthohelium formation in the course of ion recombination ought to be also three times greater. The orthohelium density should be such that the magnetic attraction forces between them can lead to the formation of transmolecules. This is attained, firstly, due to the small interatomic spacing in condensed helium, and, secondly, as Compton electrons of large recoil energy produced by intensive fluxes of gamma rays generate in helium “plasma tracks” with a high density of ions and electrons.

The greater the ion density, the greater is the density of orthohelium. With increasing density of the electrons, the radiationless

transitions of orthohelium into parahelium grow more intensive. So, there are two contrary processes. Thus, with the given electron density of specific ionization, there exists apparently an optimal density, condensed helium pressure, with which the orthohelium density is maximal.

In condensed gases, a “plasma track” represents a “capsule” inside which the conditions for physical processes and the atomic and nuclear structures are subject to change. The use of intensive fluxes of gamma quanta proves to be the most suitable method for ionization of condensed helium owing to their high penetrability through the thick walls of the reaction chamber. Other radiations, coupled with high ionization, do not have such a penetrating power. It should be noted that the products of multinuclear reactions such as fragments, alpha particles and protons have a higher density of specific ionization than the electrons. Therefore, they, in their turn, produce along their tracks plasma of higher density than the one generated by the electrons. So, it is likely that the conditions for a chain reaction are thereby created!

Since the multinuclear reactions are connected with ionization of helium, attempts should be made to register nuclear radiations, for example, gamma quanta, by passing electric discharge through helium under pressure up to several bar.

As stated in section 3, the following reaction may proceed in the ^{12}C transmolecule during the fusion of three helium nuclei: $3\cdot^4\text{He} \rightarrow ^{12}\text{C} + 6e^- + \gamma$. A gamma ray with an energy of 4438 keV is emitted in this reaction due to the decay of the excited state of ^{12}C . A gamma ray of the same energy may be produced in the reaction: $4\cdot^4\text{He} \rightarrow ^{12}\text{C} + ^4\text{He} + \gamma$. In multinuclear reactions with evaporation of a neutron (Table 2), β^+ -radioactive isotopes emitting e^+ positrons are produced. A positron-electron annihilation results in the emission of two gamma rays, each of energy 511 keV.

An attempt should be made to register the above gamma quanta during the irradiation of helium by a powerful alpha or beta source placed inside a gas chamber under a pressure of ~ 1 kbar.

It must not be ruled out that in experiments [17] conducted in the fifties of the previous century under the leadership of Igor Kurchatov with the aim of exploring the possibility of thermonuclear reactions in gaseous atmosphere of hydrogen, deuterium, helium and their mixture, the emergence of neutrons and powerful x-radiation in the energy range 300-400 keV is due to multinuclear processes. – Plasma must not be heated, and it is very bad to do so!

Clearly, the synthesized chemical elements during their excitation by electric discharge will produce characteristic radiation in the optical region. For this reason, considerable interest is attracted to experiments aiming to register characteristic optical radiation produced by nuclear reaction products and, what is more interesting, by transmolecules.

All the electrons in the even-charge, light transmolecules are bound into bosons and have a binding energy in the transmolecule and an energy of transitions between the excited levels of hundreds electron-volt [15]. That is why it would be of interest to study odd-charge transmolecules which have one electron not bound into the boson. Supposedly, such a transmolecule can be obtained from a mixture of hydrogen and helium. Indeed, ^8Be and ^{12}C transmolecules produced under the action of electric discharges may merge with a protium atom and its nucleus (proton) due to magnetic attraction and strong central magnetic fields, thereby forming an odd transmolecule. The magnetic field B_0 of the protium atom (hydrogen) at the centre is equal to 79 T; and at the distance $1.2\cdot R_{\text{H}}$ from the centre, $B_{\text{RH}} = 16$ T. In the case when the proton adds to the ^8Be transmolecule, a ^9B (boron) transmolecule is formed. When the proton adds to the ^{12}C transmolecule, this

results in the formation of a ^{13}N (nitrogen) transmolecule. The ^{13}N transmolecule is less stable than the ^{12}C one. It decays according to the reaction $^{13}\text{N} \rightarrow ^{12}\text{C} + \text{p}$, possibly with the emission of a gamma ray with the energy 4438 keV.

Such nuclear transmolecules are hydrogen-like atoms with heavy multinuclear formations at the centre. The outer-shell electron in such transmolecules moves around in its orbital in the strong magnetic field produced by paired electrons. In the approximation when the radii of orbitals of the outer-shell electron in ^9B and ^{13}N transmolecules are equal to the hydrogen atom radius $R_{\text{H}} = 5.29 \cdot 10^{-11}$ m, the magnetic induction vector B_{RH} of the ^9B transmolecule at R_{H} is equal to 316 T, whereas for the ^{13}N transmolecule B_{RH} equals 474 T ($B_r = \frac{P_e \mu_0 \mu_e}{r^3}$, where P_e is the number of paired electrons [15]). For these reasons the outer-shell electron orbitals at the ^9B and ^{13}N transmolecules are displaced relative to the hydrogen atom orbitals in accordance with the corrections for the given masses to the Rydberg constant (3) and split into two sublevels by formula (4):

$$R_A = R / (1 + m_e / M_A), \tag{3}$$

$$\Delta E = \pm \mu_e \cdot B_{\text{RH}}, \tag{4}$$

where R_A is the Rydberg constant for an atom with the nucleus of mass M_A ; R is the Rydberg constant; m_e is the electron mass. In our case, M_A equals: 2 or $3 \cdot ^4\text{He}$ nuclei plus a proton. In **Table 3**, the main Balmer lines ($n \rightarrow 2$, n is the principal quantum number) in the visible range are given in nanometers for the hydrogen atom

(λH), displaced (λ_{MA}) for the ^9B ($\lambda^9\text{B}$) and ^{13}N ($\lambda^{13}\text{N}$) transmolecules and split for the ^9B ($\lambda n^9\text{B}$) and ^{13}N ($\lambda n^{13}\text{N}$) transmolecules. Displacement of transitions, according to (3), is calculated by the formula: $\lambda_{\text{MA}} = \lambda_{\text{H}} M_{\text{H}} (M_{\text{A}} + m_e) / M_{\text{A}} (M_{\text{H}} + m_e)$, where M_{H} is the proton mass. All of the levels of the outer-shell electrons of ^9B and ^{13}N transmolecules are not only displaced but split, according to (4), into two states. For a ^9B transmolecule the ground state splitting ($n = 1$) by energy is $\Delta E = \pm 1.83 \cdot 10^{-2}$ eV and for a ^{13}N transmolecule the ground-state splitting is $\Delta E = \pm 2.74 \cdot 10^{-2}$ eV (4).

Since the radii of hydrogen electron orbitals: $r_n = \hbar \cdot n^2 / 2 \cdot m_e \cdot v$, then $r_2 = 2.1 \cdot 10^{-10}$ m, $r_3 = 4.8 \cdot 10^{-10}$ m. The magnetic fields of the ^9B transmolecule at r_2 and r_3 are $B_{r_2} = 4.91$ T and $B_{r_3} = 0.43$ T, and for the ^{13}N transmolecule, $B_{r_2} = 7.37$ T and $B_{r_3} = 0.65$ T. Correspondingly, r_2 and r_3 level splitting for the ^9B transmolecule is $\Delta E_{r_2} = \pm 2.85 \cdot 10^{-4}$ eV and $\Delta E_{r_3} = \pm 2.51 \cdot 10^{-5}$ eV; and for the ^{13}N transmolecule level splitting at r_2 and r_3 is $\Delta E_{r_2} = \pm 4.26 \cdot 10^{-4}$ eV and $\Delta E_{r_3} = \pm 3.6 \cdot 10^{-5}$ eV. Consequently, one can observe four lines in the spectrum which are doublets $H\alpha$ of the split levels r_2 and r_3 . Because at the orbitals with $n \geq 4$ the magnetic fields produced by the paired electrons are small, two lines will be observed in the spectrum for H_β , H_γ and other transitions. It is seen from Table 3 that the distances between the split states are considerable and must be well registered by spectroscopic instrumentation.

Thus, there is a relatively simple nuclear and spectral methods by which you can try to register in electric discharges flow multinuclear reactions in helium or mixtures of helium with hydrogen when the pressure up to several bar.

6. CONCLUSION

When irradiation of condensed helium at pressures of 1.1 and 3.05 kbar braking gamma quanta with a maximum energy of 10 MeV, the volume of the reaction chamber discovered the chemical elements missing before the start of the exposures.

Table 3

Balmer's lines of transmolecules ^9B , ^{13}N

	H_α 3→2	H_β 4→2	H_γ 5→2	H_δ 6→2	H_ϵ 7→2	H_ζ 8→2
λH	656.279	486.133	434.047	410.174	397.007	388.9
$\lambda^9\text{B}$	655.961	485.898	433.837	409.976	396.815	388.7
$\lambda n^9\text{B}$	655.853 655.870 656.052 655.069	485.844 485.952	433.794 433.880	409.937 410.015	396.779 396.851	388.67 388.73
$\lambda^{13}\text{N}$	655.952	485.890	433.830	409.969	396.809	388.7
$\lambda n^{13}\text{N}$	655.759 655.816 656.088 656.114	485.809 485.971	433.765 433.895	409.911 410.027	396.755 396.863	388.65 388.75

The emergence of extraneous chemical elements can be explained by multinuclear reactions. Multinuclear reactions take place due to the formation of nuclear transmolecules composed of several helium nuclei. Primary nuclear transmolecules of ${}^8\text{Be}$ with electrons that are pairwise bound into bosons with $S = 1$ are produced through fusion of two orthohelium atoms. Heavier transmolecules are formed via fusion of orthohelium and lighter transmolecules with each other.

The atoms of orthohelium are produced in helium during its ionization by gamma radiation with subsequent recombination of the emerged ions. So, the cross sections of low-energy multinuclear reactions directly depend on the special density of orthohelium, i.e. on the cross sections of the atomic processes.

Further experiments should be conducted to register multinuclear reactions by passing electric discharges through helium or a mixture of helium and hydrogen under pressure up to several bar. In the case of their registration, it is proposed to revert to the idea of power production using electric discharges in condensed light gases such as hydrogen, deuterium, helium and their mixtures [17].

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